Photoplethysmogram Based Biometric Identification for Twins Incorporating Gender Variability

Nur Izzati Mohammed Nadzri and Khairul Azami Sidek
Department of Electrical and Computer Engineering, Faculty of Engineering,
International Islamic University Malaysia,
P.O. Box 10, Jalan Gombak, 50728 Kuala Lumpur.
izzatinadzri91@gmail.com

***Abstract*—This study focuses on a Photoplethysmogram (PPG) based biometric identification for twins incorporating gender variability. To the best of our knowledge, little has been said pertaining to this research which identifies twins using PPG signals. PPG device has been widely used due to its advantages such as non-invasive, low cost and small in size which makes it a convenient analytical tool. PPG signals has the capability to ensure the person to be present during the acquisition process which suggest that PPG can provide liveness detection suitable for a biometric system which is not available in other biometric modalities such as fingerprint. A total of four couple of twins which consists of four female and four male subjects in age range between twenty two to thirty years old were used to assess the feasibility of the proposed system. The acquired PPG signals were then processed to remove unwanted noise using low pass filter. After that, multiple cycles of PPG waveforms were extracted and later classified using Radial Basis Function (RBF) and Bayes Network (BN) to categorize the subjects using the discriminant features to calculate and analyze the performance of this system. The outcome also provides a complimentary mechanism to detect twins besides using the current existing methods.**

***Index Terms*—Bayes Network (BN); Identical; Photoplethysmogram (PPG); Radial Basis Function Network (RBF).**

I. INTRODUCTION

With the rapid growth of new technology, identity theft and fraud are becoming a serious issue to most countries. In Australia, according to the survey conducted by the Australian Bureau of Statistics Personal Fraud Survey in 2010-2011, Australians lost $1.4 billion due to personal frauds [1]. In another survey which was led by the Australian Institute of Criminology for the Attorney- General report in May 2013 [2] mentioned that 1 in 10 Australians have reported misused of their personal information in the previous 12 months, with 1 in 5 people reporting misused of their personal information at some time during their life. Therefore, in order to mitigate this problem, we need a system to recognize a person based on their behavioural and physical characteristics such as physical appearance and biological signals. The system that fulfils these criteria is called as a biometric identification system.

Biometric can verify that a person is who he claims to be. It solves the problem faced by traditional methods which are categorized as token based and password based that needs people to memorize certain combination of alphanumeric representation and carry along identification (ID) cards. However, identifying an individual's especially twins is an under research area. Twins are unique human being which shares same genetics. Some of the twins are hard to differentiate from each other particularly if the twins are have the same gender and look alike as shown in Figure 1. In some crime cases, which identical twins with same gender are involved, the investigator might be confused to determine and differentiate which individual committed the crime since they have similar physical appearance.

Figure 1: Example of twin [3]

Furthermore, some twins may swap their identity for their own advantage, satisfaction and pleasure that will cause misperception to other people. Crime cases involving twins cannot be taken casually since it will give a bad influence and impression to the other twin which is innocent. Some of the examples of the crime cases involving twin are credit card fraud, homicide cases such as committing murder using the twin's identity and other cases that manipulate their twin's identity for their own benefit. There are other methods that can be applied to distinguish twins such as DNA and face recognition. For DNA test, the processing time to get the result is longer than others while for face recognition, since the twins looks alike it is hard to differentiate one another. Thus, alternative biometric modalities need to be applied to determine the identity of individuals that mostly relates to the true characteristic of a person which is our biological signals such as Electrocardiogram (ECG), Electroencephalogram (EEG), and PPG signals.

PPG is used to estimate 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 is attached to the fingertip or earlobe [4]. It has a main components which are diastolic points, systolic points, dicrotic notch and dicrotic wave. These components will have a different value and shape for each person even though the person is a twin. Example of a PPG waveform are shown in Figure 2.

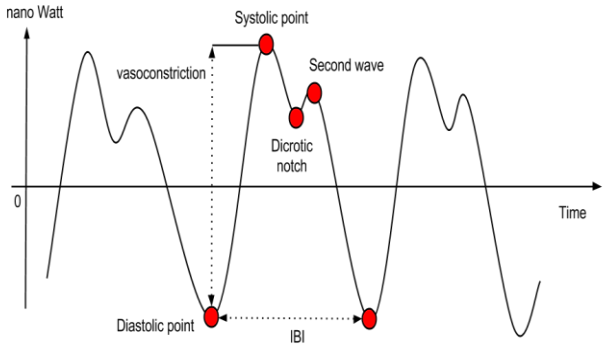

Figure 2: Main component of PPG signal [5]

Recently, PPG has gained the attention of researchers due to it's a superior trifold criteria which are non-invasive, low cost and small in size that makes it a convenient analytical tool. Since, biometric uses characteristic which are available from our body, the PPG signal representation would strongly correlate to a person's identity. Previous studies on PPG based biometric recognition methods to support its performance in security applications have been suggested. However, in this study, the fundamental objective in order to increase user acceptability of PPG based biometric recognition incorporates twins with gender variability. Past studies have mainly focused on subjects recognition techniques is in normal conditions neglecting twin's inconsideration with gender variability. Therefore, this study proposed a PPG based biometric identification for twins incorporating in gender variability.

The flow of this report is divided into 4 parts. Section 2 describes the related works of the study. Next, section 3 elaborates on the methodology of the study, whereas section 4 focuses on the experimentation and results. Finally, section 5 lays out the conclusion of the research.

II. Related Works

In the past, studies on the twin identification using various techniques have been performed. This section briefly elucidate the related works of the studies which consist of related literatures on biometric identification for twins and PPG based identification system.

A. Related Works on Biometric Identification for Twins

Li et al. in [6] focused on techniques identifying twins by collecting associated data such the photo, facial motion video and audio recording. An audio-visual twin database was acquired for identification system in the Sixth Mojiang International Twins Festival. For the photography technique, 2D face was captured which consist of one frontal image and another two profile images for each subject. During the motion video recording session, at least six expressions were recorded three time which consists of emotion when smiling, anger, surprise, sadness, fear and disgust. In the audio recording session, four free style talking were recorded and repeated three times with an interval of three seconds which lasted for thirty seconds in average. These collected data were processed and identity of a twins were recognized based on three conditions which are twin verification, twin identification and pairwise twin similarity. However, these methods takes longer time to be process, too much procedures and this behavioural biometric is not consistent over time and changes as an individual grows older.

Nisha et al. in [7] investigated the features in facial marks to differentiate twin. The face images data of 295 individuals with their twins were collected at the Twins Days Festival at Twinsburg, Ohio, in 2009. This study began with image collection. Then, proceed with the manual annotation of the subject's face which is followed by feature extraction and normalization of the data. Later, the process of graph matching to differentiate between the twins and last but not least, the performance evaluation were performed to assess the reliability of the proposed technique. The study suggest that there are similarities in facial marks between twins. However, it is found out that the similarity of the individual with their twin is quite identical with high percentage of similarities which suggests that facial marks is not a good modality to differentiate between twins and the facial marks can be changed over time.

As a summary, biometric recognition such as facial, audio-visual and facial marks can be a medium to identifying twins. However, these aforementioned techniques are not recommended because some behavioural biometric are not consistent over time, for example, facial recognition changes as an individual grows older or if they perform facial surgery which alters the original structure of their face.

B. Related Works on PPG Based Biometric Identification

Lee et al. in [8] studied the performance of PPG based biometric identification system. The raw data of PPG signals were collected from 10 individuals with 708 datasets followed by preprocessing using Butterworth bandpass filter. Then, this datasets undergoes the feature extraction stage and classification is performed using neural network algorithm. From the study, the results show the false acceptance rate of 4.2% and a false rejection rate of 3.7% which suggest the capability of the proposed system. However, this study did not focus on the PPG based biometric identification system for twins with gender variability conditions since the data only deals with the normal individuals without considering any condition.

Bonissi et al. in [9] elaborated on another study of subject recognition based on PPG signals. The study stars with data collection which are from 14 individual's subject for 20 seconds. Then, followed by preprocessing technique using highpass Butterworth filter. The process continues with feature extraction and finally matching technique using cross correlation used to evaluate the performance of proposed

system. However, based on the result of the study, PPG signals were not tested on any specific conditions.

However, based on these literatures 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.

III. METHODOLOGY

In this study, four proposed stages were involved to develop the proposed system. These stages include data acquisition, preprocessing, feature extraction and classification which can be summarized as in Figure 3 which will be explained in the next subsection.

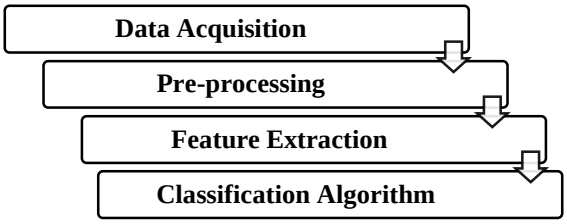

Figure 3: The proposed stages of PPG Based Biometric Identification System for Twins incorporating Gender Variability

A. Data Acquisition

Raw PPG signals were collected acquired eight individuals consisting of four couple of twins which involves four female and four male subjects in a resting condition at the age between 22-30 years old by using Easy Pulse sensor as shown in Figure 4.

Figure 4: Easy Pulse sensor [10]

B. Preprocessing

Then, the raw data will go through the pre-processing stages which ensures that there is minimal external noise, outliers or artifacts in the data. As a result, the signal will be smoothen and clearer from noise after the preprocessing stage.

C. Feature Extraction

Later, feature extraction will be implemented to discriminate unique features of the data since PPG signals of individuals are distinct because every trait that a person has differs from others. In this study, a total of 16 fiducial points are used consisting diastolic, systolic and dictoric point as shown in Figure 5.

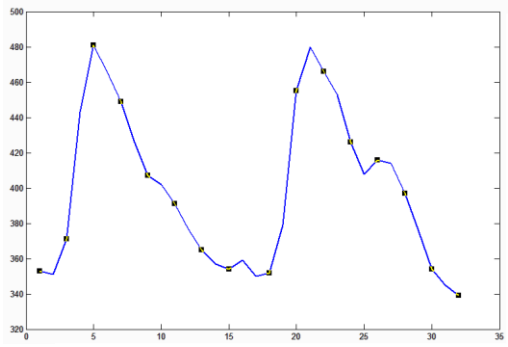

Figure 5: Example of fiducial points of PPG signals

D. Classification Algorithm

Last but not least for the final stage, classification will be perform using selected algorithm to classify the data and to assess the performance of the proposed system.

For this study, the accuracy of the proposed techniques were calculated by using the Radial Basis Function Network (RBF) and Bayes Network (BN) algorithms that will be explain further in the next subtopic.

a. Radial Basis Function

RBF networks fundamentally have three layers which are an input layer at the beginning, a hidden layer at middle with a non-linear RBF activation function and finally an output layer with linear activation functions as shown in Figure 6.

The hidden layer implements a set of radial basis functions while the output layer implements linear summation functions as in a Multilayer Perceptron. RBF also consist of network training datasets. This training network is divided into two stages which are the weights from the input hidden layer and the weights from the hidden to output layer. Mathematically, this can be written as in Equation 1.

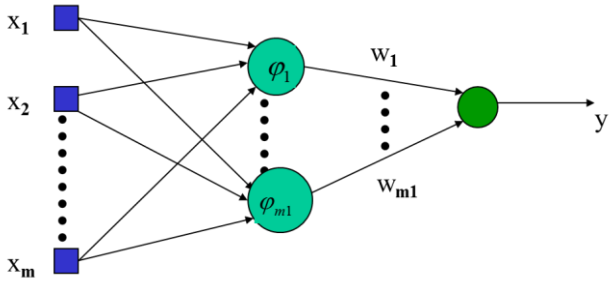

Figure 6: RBF Network architecture

$$y(x) = \sum i=1\ w_i h_i\ (x) \quad (1)$$

where y(x) is the output, wi is the vector of weights, and hi is the vector of hidden units [11]. The benefit of RBF network is due to its having shorter learning time and the probability of determining appropriate hidden basis function parameters without having to perform a full non-linear optimization of the whole network.

b. Bayes Network

BN is an effective representation of the joint probability distribution of a set of random variables and are based on statistical induction. BN is efficient since it is based on the local

models and independent d-separation. . Besides that, BN also has a major advantage since the algorithm uses the benefit of structure to compute posterior probability, compute most probable instruction and used decision making technique [12]. Mathematically, this can be written as in Equation 2.

$$P(V_1,V_2,.....V_n) = \Pi\ P\ _{ni=1}\ (V_i \mid par(V_i)) \qquad (2)$$

where V is a node in graph, and par(V) be set of the immediate parent of V.

IV. EXPERIMENTATION AND RESULTS

Based on the proposed methodology in Section three, eight PPG signals were taken from a twin. Next, these raw PPG signals are processed using a low pass filter to remove the unwanted signals. The results of this step is shown in Figures 7 to 14 that shows filtered PPG signals for all the subjects.

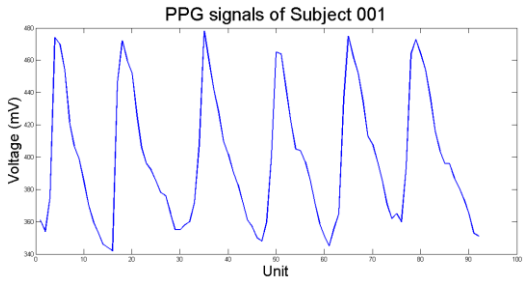

Figure 7: PPG signal for Subject 001

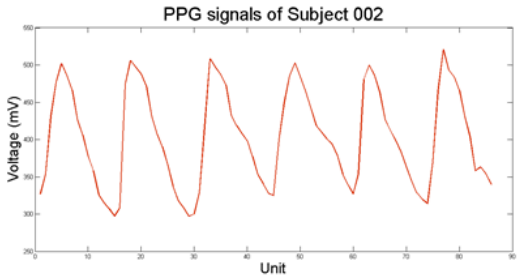

Figure 8: PPG signal for Subject 002

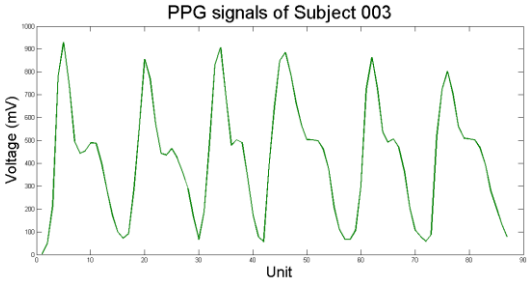

Figure 9: PPG signal for Subject 003

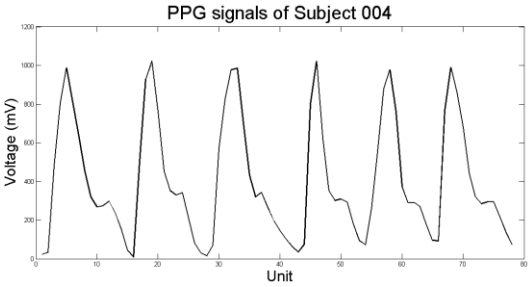

Figure 10: PPG signal for Subject 004

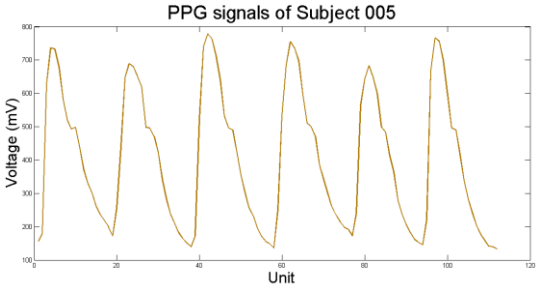

Figure 11: PPG signal for Subject 005

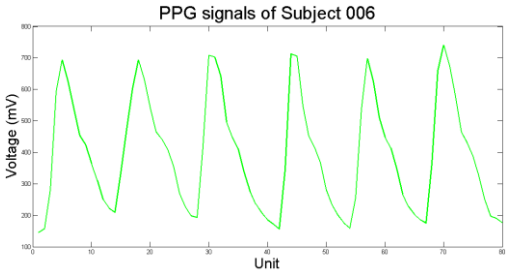

Figure 12: PPG signal for Subject 006

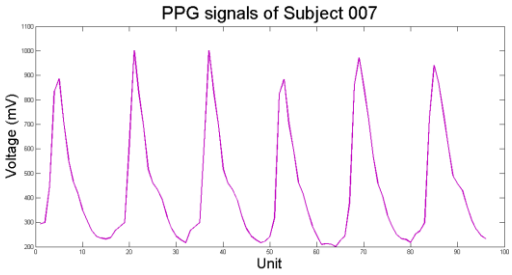

Figure 13: PPG signal for Subject 007

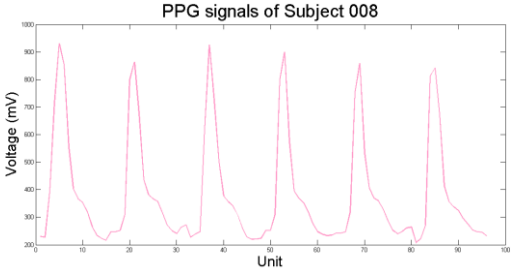

Figure 14: PPG signal for Subject 008

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 15 to 22 shows the PPG segmentation for each subject.

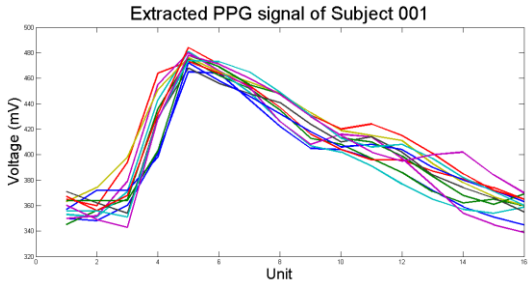

Figure 15: PPG segmentation for Subject 001

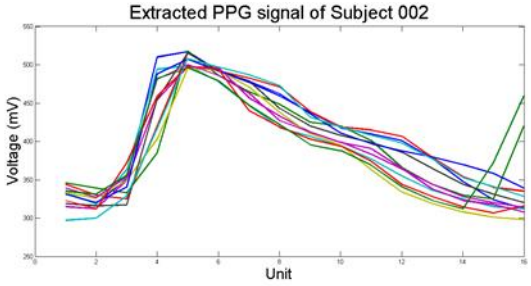

Figure 16: PPG segmentation for Subject 002

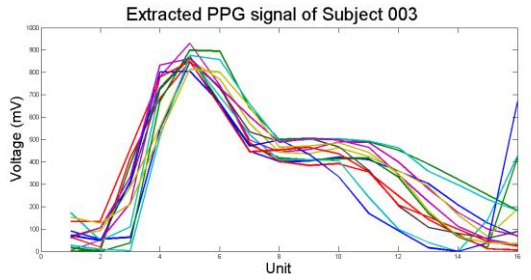

Figure 17: PPG segmentation for Subject 003

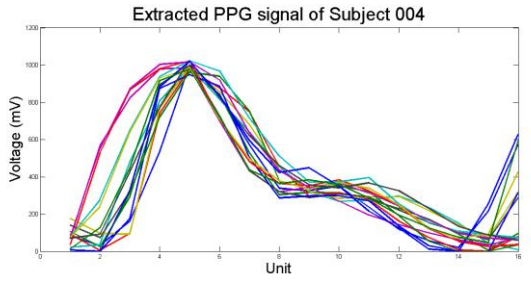

Figure 18: PPG segmentation for Subject 004

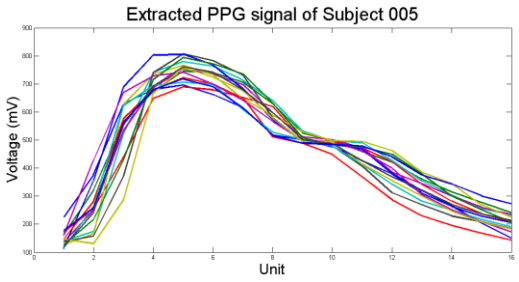

Figure 19: PPG segmentation for Subject 005

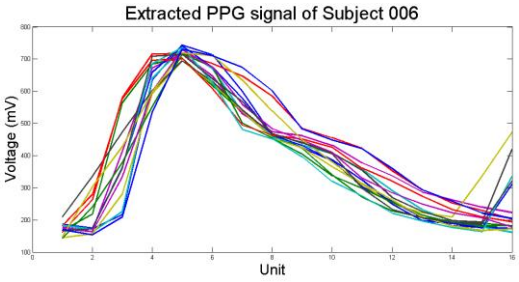

Figure 20: PPG segmentation for Subject 006

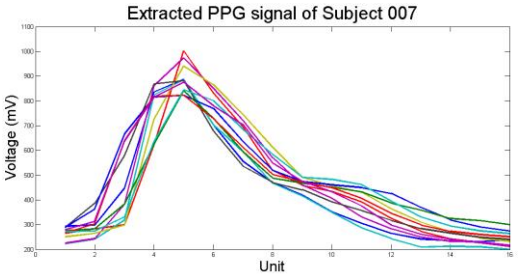

Figure 21: PPG segmentation for Subject 007

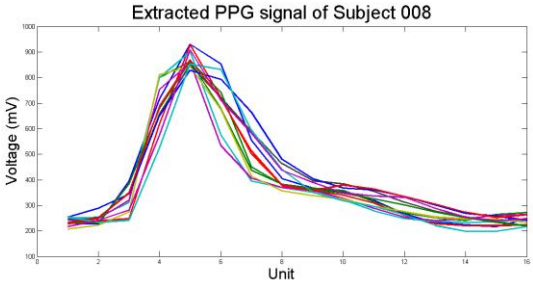

Figure 22: PPG segmentation for Subject 008

Lastly, the final stage of PPG based biometric identification is classification. This step uses data mining software called Weka. It is an application that consists of a group of classifiers. As stated in the previous section, RBF and BN are implemented in the study. The result of the classification techniques is shown in Table 1.

Table 1.
The Classification accuracies of RBFN and BN

Classifier	Accuracy (%)
RBF	94
BN	89

From the results, classification accuracy of 94% and 89% were achieved when using RBF and BN respectively. The outcome using RBF gives better output because it has these advantages [11]:

- Having shorter learning time, and
- The probability of determining appropriate hidden basis function parameters without having to perform a full non-linear optimization of the whole network.

In addition, the result suggest that PPG based biometric identification for twins incorporating gender variability is robust across a neural network classifier and a non-neural network classifier attaining high accuracy rates. Therefore, as a proof of concept, it is verified that PPG based biometric identification for twins incorporating gender variability is feasible to be used and acts as a compliment for traditional subject recognition method which suggest high identification rate.

V. CONCLUSION

As a conclusion, based on results, the research objectives was successfully achieved. In general, PPG based biometric recognition for twin is proven and is possible to recognize the identity of twins. 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 94% and 89% were achieved using RBF and BN respectively that suggest the capability of our proposed system to identify individuals even for a twin. The outcome provides an alternative mechanism to detect a person for security purposes. Besides that, PPG signal provides the proof of life of a subject which is not available in other biometrics modalities because the person need to be present during the time of recognition. Therefore, the outcome will be reliable since PPG signal of an individuals cannot be duplicated.

ACKNOWLEDGMENT

This study was funded by the Research Acculturation Grant Scheme (RAGS-14-034-0097) under the Ministry of Education Malaysia.

REFERENCES

[1] Australia's National Information and Referral Service, The Australian Bureau of Statistics (ABS) Personal Fraud Survey, Personal Fraud. (Access on March 2016) http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/4528.0Main%20Features220102011?opendocument&tabname=Summary&prodno=4528.0&issue=2010-2011&num=&view=

[2] R.G. Smith, H. Alice, "Identity crime and misuse in Australia: Results of the 2013 online survey." (Access on March 2016) http://www.aic.gov.au/publications/current%20series/rpp/121140/rpp128.html

[3] W. Tuohy H. Sun" Twins tell about their special relationship." (2012) (Accessed on March 2016) http://www.heraldsun.com.au/lifestyle/twins-tell-our-specialrelationship/story-e6frfhix-1226295487506

[4] Elgendi. M, "On the Analysis of Fingertip Photoplethysmogram Signals," Current Cardiology Reviews, Vol. 8, No. 1, pp 14-25 (2012)

[5] (Accessed on February 2016) https://support.empatica.com/hc/en-us/articles /204954639-Utilizing-the-PPG-BVP-signal

[6] J. Li, L. Zhang, D. Guo; S. Zhuo, and T. Sim, "Audio-Visual Twins Database", Biometrics (ICB), pp. 493-500, (2015).

[7] N. Srinivas, G. Aggarwal, and P. J Flyn, "Facial Marks as Biometric Signatures to Distinguish between Identical Twins." Ieee Transactions on Information Forensics and Security, Vol.7, No.5, (October 2012).

[8] A. Lee and Y. Kim, "Photoplethysmography as a Form of Biometric Authentication.", Samsung Electronics, Digital Media & Communications R&D Center, IEEE, (2015).

[9] A. Bonissi, R. D. Labati, L. Perico, R. Sassi, F. Scotti and L. Sparagino, "A preliminary study on continuous authentication methods for photoplethysmographic biometrics," Biometric Measurements and Systems for Security and Medical Applications (BIOMS), 2013 IEEE Workshop on, Napoli, pp. 28-33. (2013)

[10] Introducing Easy Pulse: A DIY photoplethysmographic sensor for measuring heart rate – (Access on February 2016) http://embedded-lab.com/blog/introducing-easy-pulse-a-diyphotoplethysmographic-sensor-for-measuring-heartrate/#sthash.6ExdRHgj.dpuf

[11] J. A. Bullinaria, "Radial Basis Function Networks: Algorithms.", University of Birmingham, UK, (2015).

[12] G. Castillo, "Bayesian Network Classifiers.", (2011). (Accessed on March 2016) http://www.slideshare.net/gladysCJ/lesson-71-bayesiannetwork-classifiers

[13] Y. Wan, X. Sun and J. Yao, "Design of a photoplethysmographic sensor for biometric identification," Control, Automation and Systems, 2007. ICCAS '07. International Conference on, Seoul, pp. 1897-1900 (2007)

[14] P. Spachos, Jiexin Gao and D. Hatzinakos, "Feasibility study of photoplethysmographic signals for biometric identification," 2011 17th International Conference on Digital Signal Processing