A Study on ECG-based Biometrics using Open Source Hardware

Jin Su Kim, Gyu Ho Choi, and Sung Bum Pan*
Chosun University, Dong-gu, Gwangju, 61452, Korea
{babotn5, choiguho}@gmail.com, sbpan@chosun.ac.kr

Abstract

Biometric technology uses unique physical features as bioinformation. Electrocardiogram(ECG) is a signal recording potential changes related to heartbeats in the form of voltage, and each individual has unique ECG signals in terms of heart location and size thereof. Therefore, they are used to diagnose diseases and examine personal identity. The ECG device can be made compact in comparison with other biosignal measurement instruments and the signals measured in locations easily accessible. This paper aims to implement a personal identification system based on ECG signals. Noise removal and signal split is conducted as a pre-processing process by using the Band Pass Filter(BPF), Median Filter(MF) and R-Peak. Features are extracted by using the morphological method from the time domain. Euclidean Distance(ED) is used to analyze the verification data and registration data. In the experiment result, For 18 verification data with the lowest EER 1.67%, driving was 113.4 seconds.

Keywords: Biometrics, Electrocardiogram, Personal Authentication

1 Introduction

In the modern society, it is sometimes necessary to prove personal identity in daily life. The conventional method for proving personal identity is to present an identity card based on possession and use knowledge-based ID/PW. However, because the method is inconvenient and involves risks, there is an increasing need for biometric technology. Biometric technology uses unique physical properties of a person different from other people as bioinformation. The type of biometric technology currently popular is facial, fingerprint and iris recognition which can be altered and forged. Therefore, they are used in various crimes [9].

To address this issue, biometric of Electromyogram(EMG) and Electroencephalograms(EEG) and ECG signals has been studied. An EMG is a signal recording micro current occurring when muscles move in the form of voltage, and can be used for activity recognition and disease diagnosis. An EEG is a signal recording electrical flow occurring by brain activities, and can be used for identification of intention and situation analysis. An ECG is a signal recording potential changes related to heartbeats in the form of voltage and can be used for disease diagnosis and personal identification. Each person has unique characteristics depending on heart location and size, and physical conditions [6].

Fig. 1 shows locations for measuring the EMG, EEG and ECG signals. The EMG sensor is attached on each muscle to be measured as shown in Fig. 1 (a) to measure muscular movement. For EEG signals, patients wear the measuring instrument on any desired location of their head as shown in Fig. 1 (b) to attach sensors, and hair disturbs acquisition of signals. On the other hand, ECG signals can be acquired from both wrists as shown in Fig. 1 (c) and can be replaced by small accessories, for example, watches and bracelets to acquire the signals.

The conventional biometric system uses USB or Bluetooth to send signals acquired from the measuring instrument through communication with the computer and then processes the signals in the computer.

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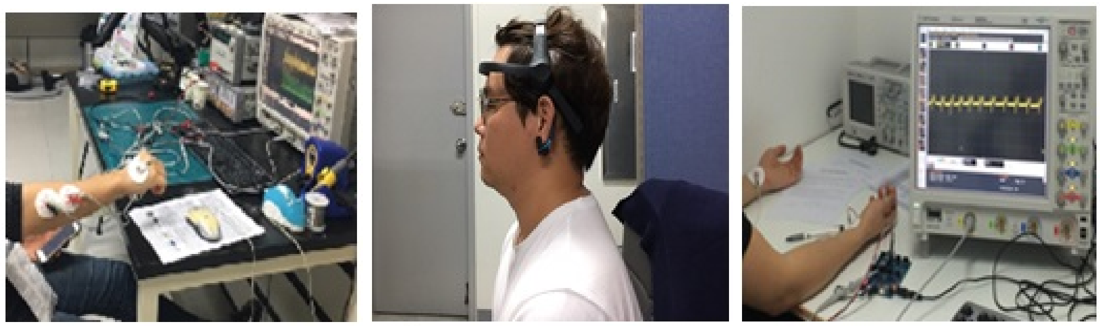
*Corresponding author: Dept. of Electronics Engineering, Chosun University, Dong-Gu, Gwanghu, 61452, Korea, Tel: +82-62-230-6897



(a) EMG Measurement (b) EEG Measurement (c) ECG Measurement

Figure 1: Location for acquiring signals for biometric

However, it is hard to implement application to actual situation[7][2][11]. Researchers have studied how to process the signals in a compact device, for example, communication between the measuring instrument and mobile phones, the measuring instrument and the embedded system, not communication between the measuring instrument and the computer, for higher usability of the biometric system in real life[1][5][10].

This paper suggests a personal identification system which uses a compact measuring instrument and a signal processor. In the initial stage of experiment, personal identification is examined by using ECG signals. The signals are split in the method for detecting R-Peak which is a reference point, and noise in the signals is removed by using the BPF and MF. The characteristics are extracted by using the morphological ECG properties and extract characteristics effective for personal identification[2]. ED is used to classify the registration data and the verification data when they arrives. EER is calculated to show the performance of personal identification system.

This paper is composed of the following chapters. Chapter 2 describes the suggested personal identification system using a compact measuring instrument and a signal processor, and also the personal identification experiment in the initial stage of experiment. Chapter 3 analyzes the result of using the acquired ECG data. Chapter 4 draws a conclusion.

2 Personal Identification System

The signal measuring instrument in the conventional identification system using biosignals is big as shown in Fig. 1, processes the biosignals in a computer, and is not highly portable or mobile, and thus not ideal to be used in daily living. To address this issue, it is studied to make a small measuring instrument and a signal processor by making a compact measuring instrument using an ECG measuring sensor to be attached to the rear side of mobile phone case, and processing acquired signals in an embedded system to make a small processor[1][5][10].

2.1 System with Small Device

This paper suggests a personal identification system with a compact measuring instrument and a signal processor. As shown in Fig. 3, ECG signals for initial registration and used in personal identification are acquired after attaching a sensor to a wearable device. The acquired ECG signals are split on the basis of the information of waves P, Q, R, S and T by using the CPU in the wearable device. Pre-processing is conducted to remove noise in the split signals. The morphological method of ECG waveform which is

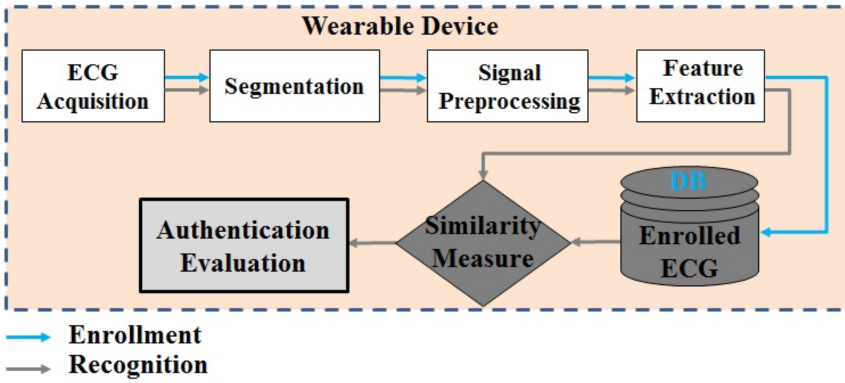


Figure 2: Personal identification experiment flow using a compact device

Figure 3: Personal identification system using a compact device

a time domain feature extraction method appropriate for real-time processing is used to extract features and build a registration database.

For the request of personal identification, the sensor attached to the wearable device is used to acquire signals and conduct signal splitting, pre-processing and feature extraction described above. They are then compared with the registered data in the DB to progress identification and assessment. As shown in Fig. 3, the wrist-wearable compact personal identification system features that its user is sometimes unaware of the wearing thereof and does not intervene therein. It can be used for many fields, for example, banking, computer security, communication, medical service, border entry management.

2.2 System Using Separate Driving of Compact Device and Computer

In the initial experiment stage of the system with the compact device suggested in this paper, the personal identification experiment is conducted using ECG signals as shown in Fig. 4. The signals are detects R-Peak, and noise is removed by means of the BPF and MF. In the time domain, features are extracted by using information of amplitude, gradient and duration which is a morphological method. Verification data and the registration data to analyze ED.

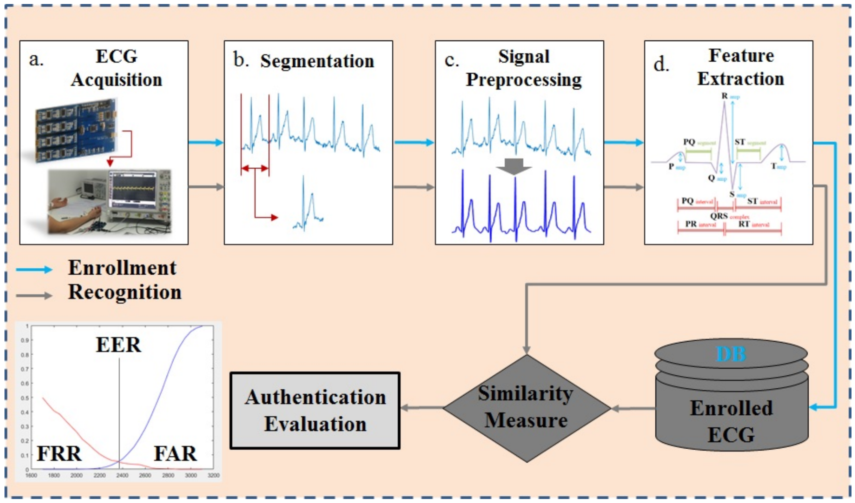


Figure 4: Personal identification experiment flow

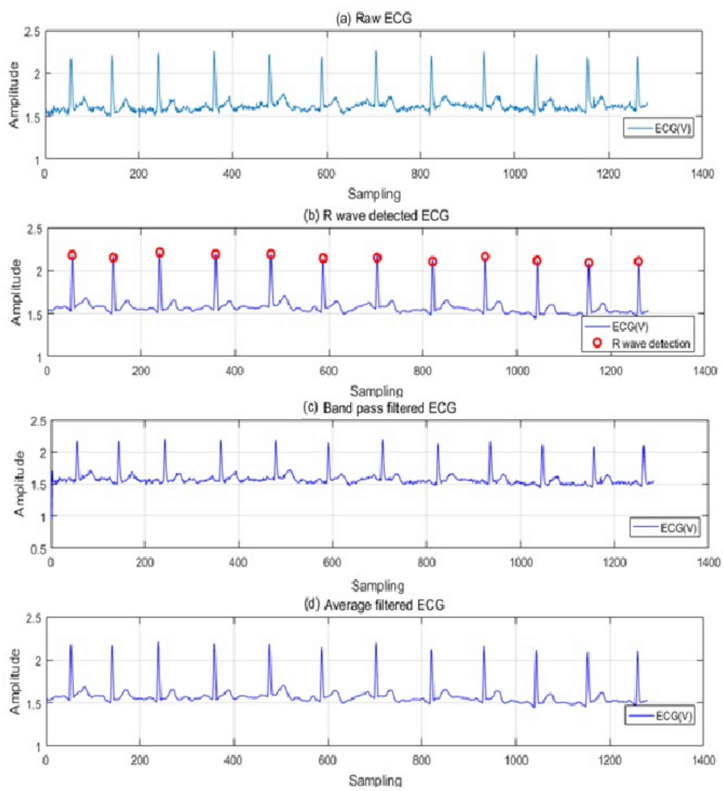


Figure 5: ECG waveform

The developed Cypress cortex-M3 and oscilloscope MSO9104A are used to acquire the ECG lead 1 signal obtained from user's wrist while the user is not aware of the process going on as shown in Fig. 1 (c). This process minimizes the number of required electrodes. Twenty adult males and females participated in the experiment for measuring the signal that continued for 10 seconds at 128Hz 60 times. The participants felt comfortable during the measuring process, sitting down on the chair.

The ECG data continuously acquired are split to identify users. Because the ECG signals are acquired periodically, the split method is divided into using and not using a reference point. This paper uses the split method for using the reference point R-Peak. The Pan & Tompkins algorithm is used to detect the R-Peak as shown in Fig. 5 (b)[8]. With R-Peak as a reference, the domains P, Q, S and T are detected to split the ECG signal with waves P to T as one cycle.

An ECG signal is measured in the form of voltage related to heartbeats, and has various noises, for example, line interference (60Hz), muscle constriction noise (higher than 40Hz) and baseline wandering (lower than 0.5Hz) that need to be pre-processed[4][3]. The aforementioned noises are removed by using a BPF at 0.5 to 40Hz in this paper, and Fig. 5 (c) shows the signals passing through the BPF. Because ECG signals have unique physical property information of a person in the QRS sections, an MF is used for other sections than the QRS sections to remove the noises as shown in Fig. 5 (d).

The time domain of ECG signals allows extraction of properties effective for personal identification and verification[2]. This paper uses ECG lead 1 signal to extract morphological waveform features in the time domain shown in Fig. 6. Used 15 features include 5 amplitude features (waves P, Q, R, S and T), 2 gradient features (domains P-Q and S-T), and 8 duration features (domains P-Q, Q-R-S, S-T, P-R, R-T, P-S, Q-T and P-T). Use ED to classify the registration data and the verification data and examine personal identification performance with EER when the feature information of verification data arrive.

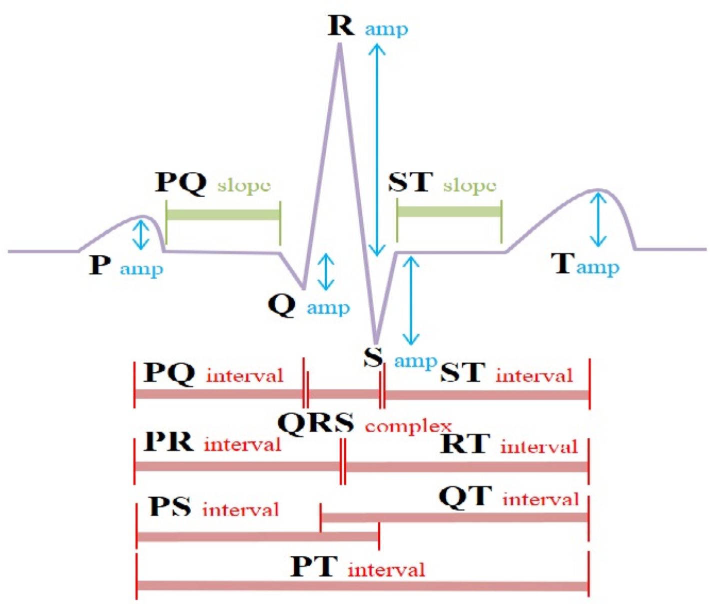
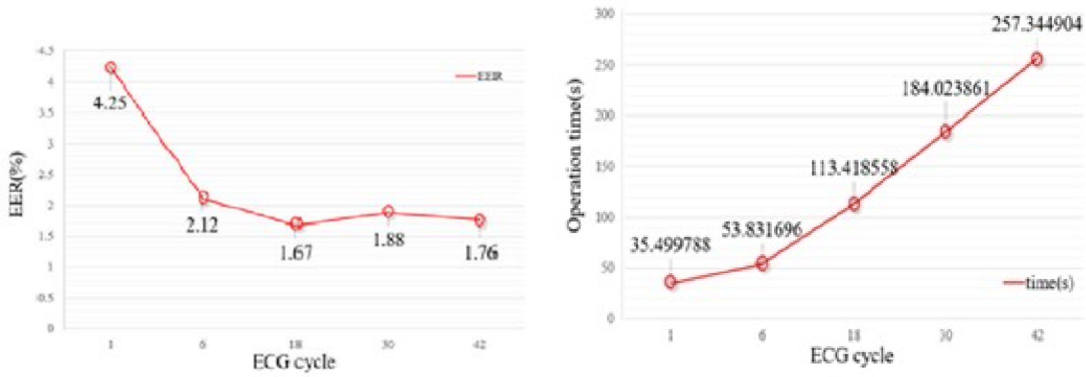


Figure 6: Morphological feature information

3 Experiment Result

In the experiment, EER changes and operation time were analyzed with 18 random registration data and 1 to 42 verification data from the individual data. Fig. 7 (a), as the number of verification data increased from 1 to 6, EER showed a sharp decrease, and was the lowest 1.67% for 18 verification data. Fig. 7 (b) shows operation time. As the number of verification data increased from 1 to 42, the entire operation time of increased as the number of data increased. For 18 verification data with the lowest EER 1.67%, driving was 113.4 seconds.



(a) Experiment Result (b) Operation time

Figure 7: Experiment Result and Operation Time

4 Conclusion

Conventional methods for personal identification have some disadvantages and used for many criminal purposes. To address this issue, biometric has been studied. ECG signals can be implemented with a compact device and used easily in disease diagnosis and personal identification. Therefore, the ECG lead 1 signal is used in personal identification experiment. For pre-processing the signal, it is split and noise is removed by using the BPF, MF and R-Peak and morphological ECG waveform features are extracted. ED is used to analyze the registration data and the verification data.

In the personal identification experiment, For 18 verification data with the lowest EER 1.67%, driving was 113.4 seconds. It is a plan to make a single-driving system for Raspberry Pi, and make a personal identification system by connecting the ECG measuring instrument to Raspberry PI to acquire data in real time.

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References

[1] Administrator. AliveCor. `https://www.alivecor.com/` [Online; Accessed on October 3, 2017].

[2] S. Ergin, A. K. Uysal, E. S. Gunal, S. Gunal, and M. B. Gulmezoglu. Ecg based biometric authentication using ensemble of features. In *Proc. of the 9th Iberian Conference on Information Systems and Technologies (CISTI'14), Barcelona, Spain*, pages 1–6. IEEE, June 2014.

[3] S. B. P. Gyu Ho Choi, Hae Min Moon. Biometrics system technology trends based on biosignal. *Journal of Digital Convergence*, 15(1):381–391, January 2017.

[4] M. Haris, P. Chakraborty, and B. V. Rao. Emg signal based finger movement recognition for prosthetic hand control. In *Proc. of the Communication, Control and Intelligent Systems (CCIS'15), Mathura, India*, pages 194–198. IEEE, November 2015.

[5] S. J. Kang, S. Y. Lee, H. I. Cho, and H. Park. Ecg authentication system design based on signal analysis in mobile and wearable devices. *IEEE Signal Processing Letters*, 23(6):805–808, June 2016.

[6] J. S. Kim and S. B. Pan. A study on emg-based biometrics. *Journal of Internet Services and Information Security (JISIS)*, 7(2):19–31, May 2017.

[7] K. Muthuvel and L. P. Suresh. Adaptive neuro-fuzzy inference system for classification of ecg signal. In *Proc. of the 2013 International Conference on Circuits, Power and Computing Technologies (ICCPCT'13), Nagercoil, India*, pages 1162–1166. IEEE, March 2013.

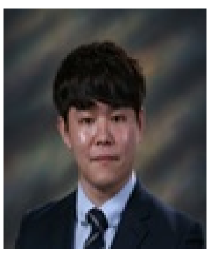
[8] J. Pan and W. J. Tompkins. A real-time qrs detection algorithm. *IEEE transactions on biomedical engineering*, (3):230–236, 1985.

[9] S. B. Pan, Y.-W. Chung, K.-I. Chung, and J. H. Kim. Biometrics technology trends. *The Institute of Electronics and Information Engineers*, 29(5):529–537, May 2002.

[10] D. Prindle. Myo gesture control armband review, June 2015. `https://www.digitaltrends.com/pc-accessory-reviews/myo-gesture-control-armband-review/` [Online; Accessed on October 3, 2017].

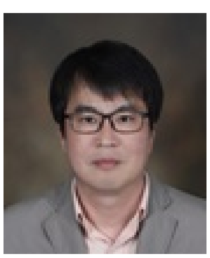
[11] S. Wahabi, S. Pouryayevali, and D. Hatzinakos. Posture-invariant ecg recognition with posture detection. In *Proc. of the 2015 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP'15), Brisbane, Australia*, pages 1812–1816. IEEE, April 2015.

Author Biography



Jin Su Kim received B.S degree in the Department of Control, Instrumentation and Robot Engineering from Chosun University, Gwangju, Korea in 2016. He is currently a M.S. candidate in the Department of Control and Instrumentation Engineering at Chosun University. His current research interests include Image Processing, Embedded System, and Biometrics.

Gyu Ho Choi received B.S degree in the Department of Control, Instrumentation and Robot Engineering from Chosun University, Gwangju, Korea in 2016. He is currently a M.S. candidate in the Department of Control and Instrumentation Engineering at Chosun University. His current research interests include Image Processing, Embedded System, and Biometrics.



Sung Bum Pan received the B.S., M.S., and Ph.D. degrees in Electronics Engineering from Sogang University, Korea, in 1991, 1995, and 1999, respectively. He was a team leader at Biometric Technology Research Team of ETRI from 1999 to 2005. He is now professor at Chosun University. His current research interests are biometrics, security, and VLSI architectures for real-time image processing.