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Heart Electrical Signal Pattern Analysis in Electrocardiogram Using Principle Component Analysis Method

Gil Gaspar M. Lobo Pinto[1], Nur Aji Wibowo[2], Surya Satriya Trihandaru[3]

[1, 2, 3] Satya Wacana Christian University, Faculty of Science and Mathematics,
52-60Diponegoro, Salatiga 50711, Jawa Tengah, Indonesia

Abstract: ***Had been done research about heart electrical signal pattern analysis on electrocardiogram to know and to identify the characteristics of each recorded signal wave which was recorded by using Principle Component Analysis. Some steps that are needed to achieve the result of electrocardiogram consist of signal processing, smoothing (filter), features extraction, normalization, three dimensional graphics and data reduction or principle Component Analysis. In this research, the information about heart beats is detected from peak QRS complex and RR interval in the electrocardiogram signal. It is obtained that the plotted results of the both of principal component from the Principle Component Analysis projection show that there are several dissemination. It happens because of the result of the movement of electrocardiogram signal wave toward time and its amplitude. The result received from Principle Component Analysis Method shows that the character of each of the electrocardiogram signal wave has different patterns which are represented by spots' distribution on the graphics. Those spots show the differences and the similarities of time taken through by each of electrocardiogram signal wave and its amplitude show that Principle Component Analysis can be used to distinguish the characters of each signal and to show the existing movement.***

Keywords: Electrocardiogram, Principle Component Analysis, heart, smoothing, features extraction, and normalization.

1. Introduction

Human's heart is one of the most important organs in human's body. The function of heart is very vital, which is to pump and also to regularly manage the blood circulation to over all of human's body. The works of heart to create electrical impulses are disseminated out from the heart to the skin. These electrical impulses can be detected through electrode which is patched to the skin [1-2].

Electrocardiogram (ECG) is a graphic made by an electrocardiograph which records heart's electrical activities in certain times [3]. ECG signal is marked by crests and trough graph which is consecutively labeled with letters P, Q, R, S, and T [4], as shown by the Figure 1. The first heart's cycle wave is P wave signal. This wave is caused by electrical impulse which happens when atrium is in depolarization process before atrium is actually started. The second wave in the QRS complex is caused by electrical impulse which happens when ventricle is in depolarization process spreading through ventricle. While, T wave is happened caused by the returning of the ventricle muscles to their places and it is called ventricle repolarization [5-6].

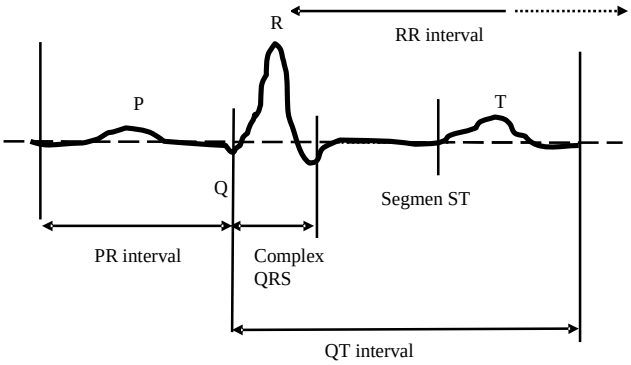


Figure 1: Signal ECG model [4].

The way of working of ECG is relatively easy. However, to understand the information from the recording result needs some experiences and knowledge about any indication that related with human's heart. Manual extraction toward the important information of ECG signal is inefficient since there are too many data that have to be observed [7].

Another method to know the characteristics of ECG signal is by using the help of computer [7]. Using this way, some existing methods such as Feature Extraction and Principle Component Analysis (PCA) can be done automatically by computer so that the detection of any forms of signal, duration, amplitudes, and fluctuation will be done more thoroughly.

This research is done to enable us to identify the heart's pattern signal characteristics through ECG signal which has been extracted and analyzed using PCA method.

2. Methodology

The needed tools and materials are ECG censor, Vernier Lab Quest (interface), electrode censor and personal computer (PC). The used ECG censor has 3 alligator cables which are: red cable which is used as positive cable, green cable as negative cable, and black cable as the reference. Vernier Lab Quest is used to connect between PC and ECG censor.

To record ECG signal needed by time during 3 minutes. ECG signal is recorded by PC using logger pro software. The data resulted from the recording through the software is then copied and saved in "txt" form. The data is actually a statistical data resulted from the signal process which is based on the ECG signal parameter which then is analyzed using MATLAB R2009a software.

In this research, there are two steps done. The first step is signal processing, data smoothing, graphic normalization, and features extraction. While, the second step is arranging three dimensional graphic, reducing ECG signal data, and identifying ECG signal pattern graphic as shown on Figure 2:

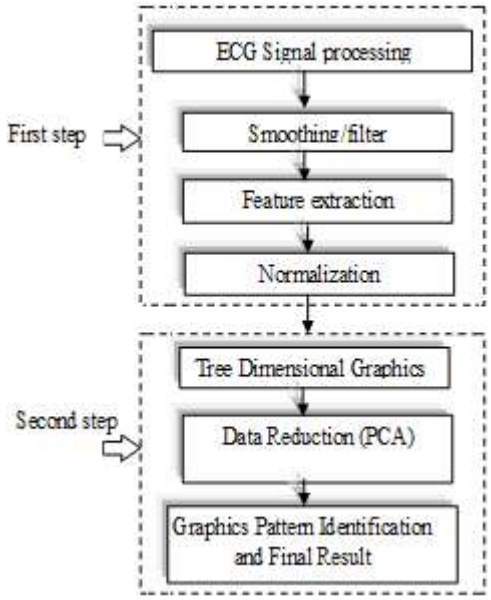


Figure 2: ECG Signal Result Procession Table

2.1 Signal Processing

Signal processing is explained as analysis, interpretation, and manipulation of a signal. Signal represents space and time alteration from a source containing information [8]. The signal discussed here is ECG signal.

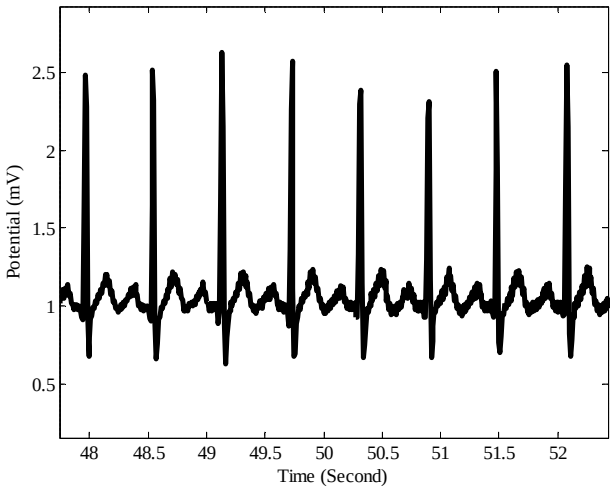


Figure 3: ECG Output Signal

2.2 Smoothing

ECG signal pre-processing can help to vanish the contamination from ECG signal. Generally, ECG contamination can be classified into some categories [4].

- Power Line Interference
- Electrode Pop or Contact Noise
- Patient-Electrode Motion Artifacts
- Electromyographic (EMG) Noise
- Baseline Wandering

Among the above noises there might be another disturbance that is a noise which has wideband characteristic, processes a stochastic complex, and is able to distort ECG signal. For instance, electrical line distribution which has narrow band characteristic is centering at 50 Hz frequency and with bandwidth less than 1 Hz. Usually, ECG signal hardware tool can solve the disturbance caused by electrical channel. However, for baseline wondering and noises that has wide band characteristic, it is not easy to be pressured by any hardware. On the other hand, the offline software scheme is able to process ECG signal [4]. The step for smoothing noises from some ECG output signal graphics by using filter method using MATLAB R2009a Software.

2.3 Features Extraction

This model is important to read ECG signals since it can differ each characteristic of ECG signal such as P peak wave, QRS complex peak wave, and T wave peak. By identifying QRS complex peak and RR interval in ECG signal, we can give information about heart beat, heart's tissues condition, and other forms of heart deviation.

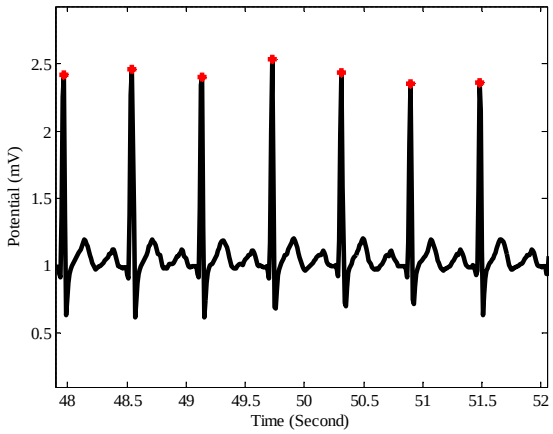


Figure 4: QRS Complex Detection Result (peak R)

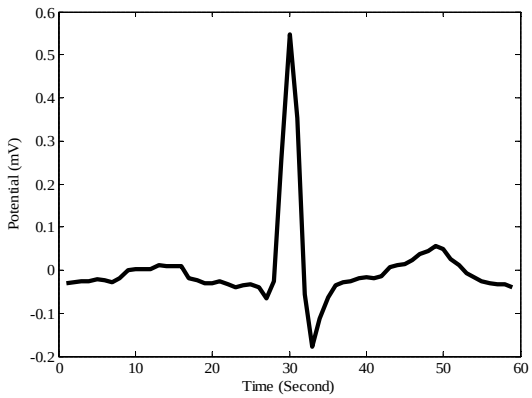


Figure 5: Extraction Result of the ECG signal

2.4 Graphic Normalization

Normalization is used to remove baseline in order to manage the signal to keep staying on zero line. This method will not change the characteristics of a graphic and still keep the main characteristic of ECG signal.

2.5 Three Dimensional Graphic

This method is used to arrange ECG signal in a form of three dimensional figures whose tension is functioned as time and

periodical number. Data from the graphic is then arranged in a vector column and line element of the graphic is declared as *N*. There is a big number of *p* column and variable X_1, X_2, ..., X_p in matrix $(N \times p)$ [9]. It is shown as below Figure:

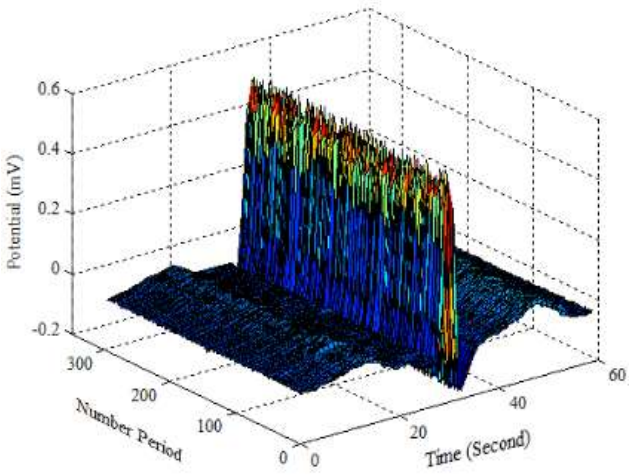


Figure 6: Three Dimensional ECG Output Signal Result

2.6 PCA/ Data Reduction

PCA is a statistical analysis technique to transform variables which are still correlating to each other forming a new set of variable. In other word, this method is reducing the number from the dimension to make the number to be lesser compared to the original variable without losing many information. The new variable is called Principle Component [9-12].

PCA is also a way to recognize the data patterns. By showing the numbers, it is aimed to underline their similarities and differences [9-12]. To sum up, the process of using PCA is as follows:

1. Collecting data in this case variable and sample.
2. Assuming the data is saved in random vector $X = [X_1\ X_2\ X_P]$ where lined elements declare *N* and the number on *p* variable column as $X_1, X_2, ..., X_p$ on matrix $(N \times p)$ [8].
3. Searching relevant data. It is done by calculating the average value and reducing the sample value with the average value as below figure:

$$M = \frac{1}{p} = \left(X_1 + ... + X_p\right) \quad (1)$$

M = Average Value.

Will be looking for $\hat{X}_k$ for $k = 1, 2, ..., p$ where:

$$\hat{X} = X_k - M \quad (2)$$

X_k = data adjustment.

So that matrix column $(N \times p)$ can be written as:

$$B = \left[\hat{X}_1\ \hat{X}_2 ... \hat{X}_P\right] \quad (3)$$

4. Looking for covariance matrix $(p \times p)$ from the achieved data by using equation as the following formula.

$$S = \frac{1}{p-1} = BB^T \quad (4)$$

Basic Covariance formula is expressed as:

$$\text{cov}(x, y) = \frac{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)\left(Y_i - \bar{Y}\right)}{n-1} \quad (5)$$

Where *X* and *Y* represent two dimensions which are *X* and *Y*.

5. Looking for Eigen value namely λ must be obtained $A\vec{x} = \lambda\vec{x}$ with $\vec{x}$ is not zero vector ($\vec{x}$ is called as eigenvector) that has to be chased.

$$\begin{aligned} S\vec{x} &= \lambda\vec{x}, \vec{x} \neq 0 \\ S\vec{x} - \lambda\vec{x} &= 0 \\ \left(\lambda I - S\right)\vec{x} &= 0 \\ \vec{x} &\rightarrow \left|S - \lambda I\right| = 0 \end{aligned} \quad (6)$$

I = Identity Matrix $(p \times p)$.

λ = Eigen values.

The above equation is called characteristic equation.

6. Looking for Eigen vector $\vec{x}$. Utilizing equation.

$$\left|S - \lambda_i I\right|\vec{x} = 0 \quad (7)$$
$$i = 1, 2, ..., n.$$

n = a number of sample.

$\vec{x}_i$ = eigenvector for the used Eigen value [9-12].

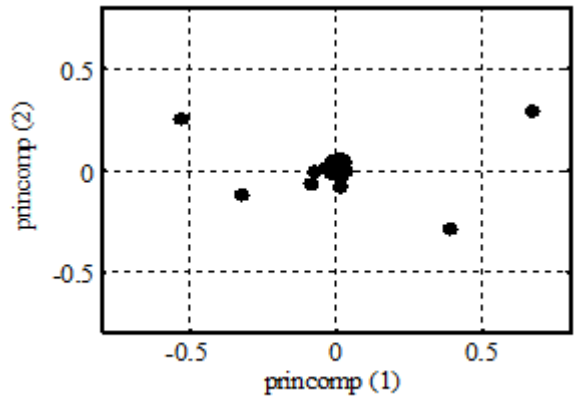
The above equation is fixed for each achieved Eigen value. Eigenvector with the biggest Eigen value is called the First Principal Component, etc. In this research, PCA is done automatically by using MATLAB R2009a software. Position of each variable will produce a PCA graphic. In this graphic, *X* axis is the first principal component and *Y* axis is the second principal component. This graphic will show the relationship between those variables

2.7 Graphic Pattern Identification / Final Result

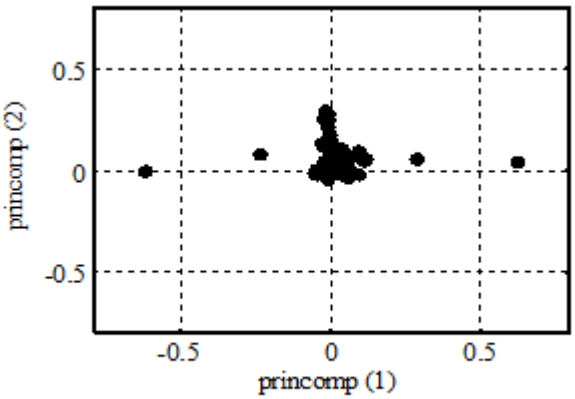
This step is a procedure to analyze and identify the result which is obtained from ECG signal. This process is used to enable us to monitor the differences between the result of the ECG signal toward the time needed by each wave and its amplitude in PCA graphic.

3. Result and Discussion

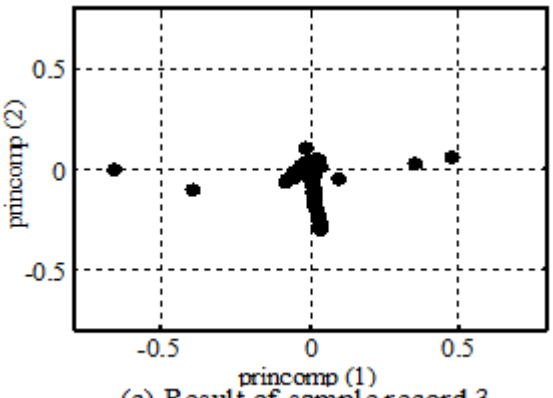
The graphic resulted from ECG signal output of the three dimensional form is processed by PCA method which connects both principal component and is plotted using MATLAB R2009a software. Thus, it results as a pattern as shown in Figure 7.



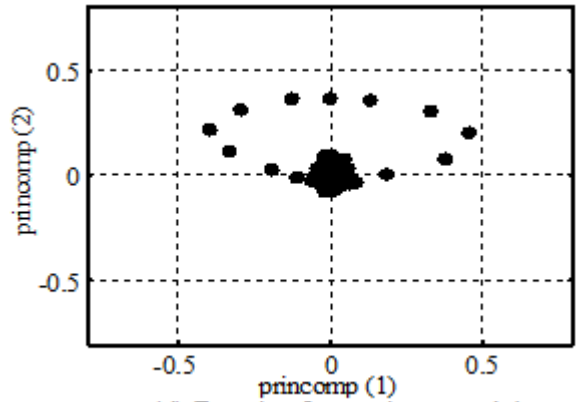
(a) Result of sample record 1



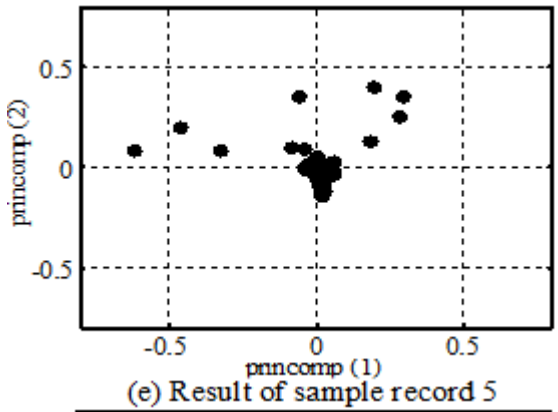
(b) Result of sample record 2



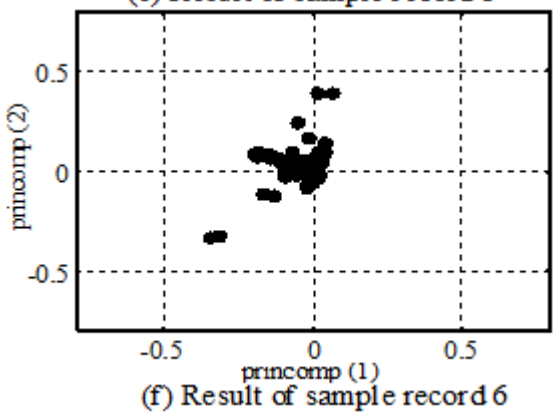
(c) Result of sample record 3



(d) Result of sample record 4



(e) Result of sample record 5



(f) Result of sample record 6

Figure 7: Plotting result of both principal components from PCA projection is indicated as principal component 1 (princomp (1)) and principal component 2 (princomp (2)).

A fundamental assumption in recognition pattern in Figure 7 is by identifying ECG output signal characteristics in PCA which is taken from ECG signal recording data. This means that the time taken by each of ECG signal wave such as P wave, QRS complex, T wave and its amplitude. PCA will show the differences and similarities of the characters of a datum which is created in a graphic.

The patterns created by both principal component of PCA projection will be gathering and getting closer to form one group if the time taken of each ECG signal and its amplitude is equal. The patterns created by each of PCA projection will spread away so that can be seen as in Figure 7(a)-7(f). The spots represent extracted ECG signal wave (see Figure 5) and is detected by PCA.

Figure 7 is the result of both principal components from PCA projection which closely related with the six samples of ECG output signal data. Pattern in Figures 7(a)-7(f) show that some spots on the PCA graphic is spread and is not united to the group. Those spots show that the characteristics of ECG signal wave are not the same. In other words, the time taken of each wave and its amplitude is moved or changed. The spots that are gathered to be a group show similarity in time and amplitude.

Figure 7(d) is very different compared to other Figures. Likewise, the created pattern is also interesting since it looks like ring. This result taken from a sample that has been diagnosed by doctor as seen on Figure 7(d) indicates that the heart's valve can't be closed. Figure 7(a), 7(b), 7(c), 7(e), and 7(f) are taken from the sample of healthy heart.

4. Conclusion

The obtained result of the principal component from PCA projection can inform the similarities and differences of the time taken of each ECG signal wave and its amplitude resulted from features extraction which is shown on the three dimensional graphic. However, if the time and the amplitude are the same, the achieved pattern will unite and is not apart to each other. As a result, it will form a group.

According to the finalized research, it is concluded that PCA method is very good at distinguishing the characteristics of each ECG signal wave and it is also good at showing the movement happens in the signal itself. This can be monitored from the pattern impacted by the two principal component of PCA projection. This method can also be used to detect ECG signal wave recording and is allowing very long time detection.

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Author Profile

Gil Gaspar Mascarenhas Lobo Pinto is a Bachelor student in physics at Department of Physics, Faculty of Science and Mathematics from Satya Wacana Christian University, Salatiga, Indonesia in 2011.

Nur Aji Wibowo received his B.Sc at Sebelas Maret University, Surakarta, Indonesia in 2007. He received a M.Sc degree in the same university in 2011 for his research on Thermally Assisted Magnetization Reversal on Perpendicularly Magnetized Nano-dot. He is currently working at Physics Department of Satya Wacana Christian University, Salatiga, Indonesia.

Surya Satriya Trihandaru received his B.Sc at Gadjah Mada University, Yogyakarta, Indonesia in 1993. He received a M.Sc degree in Universitaet Kaiserslautern Germany, Industrial Mathematics in 1998 and the Dr. degree in Institute Technology Bandung, Dept. Mathematics; Sandwich Program with Universitaet Kaiserslautern Germany in 2005.