Identification Of ECG Signal By Using Backpropagation Neural Network

Sarah Fahira Adriati¹, Sabar Setiawidaya², and Faqih Rofii³
¹,²,³ Departement of Electrical Engineering, Widyagama University of Malang
¹sarahfahiradri@gmail.com, ²masdapro@yahoo.com, ³faqih@widya-gama.ac.id

Abstract. The heart rhythm abnormalities can be detected by interpreting the ECG signal. However, there are many ECG pattern to be interpreted. Neural network is an artificial intelligent based technique which can identify pattern and one of the most used learning algorithm is backpropagation. The system is built to help interpretation process of ECG signal in heart rhythm abnormalities diagnosis. The data used in this study are obtained from MIT-BIH database. The data has been pre-processed to be used in the developed identification system of this study. The pre-processing are separating signal into one cycle and equalize the size of the signal by using zero padded technique. In this system, a good feature extraction of the ECG signal is needed to increase the accuracy. Discrete wavelet transform is used as a feature extraction and the level which carrying out is until ten. Each level results are used as an input to the identification system and derive different accuracy value. For this study, the accuracy is set to 80%. The results below 80% considered not eligible. The developed identification system of ECG signal achieves an average 91.3% accuracy using ECG signal’s feature calculated using Discrete Wavelet Transform technique in identifying normal and abnormal heart pulse.

Keyword: Neural network; identification of ECG signal; discrete wavelet transform

1. Introduction
Electrocardiograph (ECG) signal is a signal generated from periodic heartbeat rhythm. The signal is measured using a medical instrument that visualizes voltage produced by heartbeat rhythm in a monitor [1]. By using this instrument any abnormal symptom of the heartbeat can be detected [2]. It is known that a heart is one of the vital organs that regulates blood circulation in the human body. The activity of the heart to produce and regulating blood circulation in the body is happening by the effect of the heart's bioelectric flow. The bioelectric movement of the heart results in a heartbeat in producing blood. The bioelectric potential difference of the heart can be detected on the surface of the skin with an electrocardiograph. The results shown on the electrocardiograph are a pattern based on heart activity. When there is an abnormality in a heart, the electrocardiograph would emerge a different pattern. Identification of ECG recording patterns is important for the accuracy of the diagnosis of human heart abnormalities by a doctor [3]. One of the heart abnormality is arrhythmia, which is the abnormalities of heartbeat. The number of ECG recording patterns is a problem in providing an interpretation of heart conditions. Therefore, there is a need for an automatic ECG recognition system to reduce the burden of interpreting the ECG.
There is an Artificial Intelligent based method that could be applied to identification, namely neural network. There are many methods in the neural network. However, one of the methods suitable for
pattern identification is backpropagation. Backpropagation is a learning algorithm to make the error rate smaller by attuning its weight based on the desired output and target differences [4]. This method is possible to identification pattern with high accuracy. In previous research, it can identify the pattern of the object in different color and perspective. The object has been turned into 15’, 30’, 45, until 90’ but this method still be able to identify the pattern [5].

2. The ECG signal

The electrocardiogram is an image of the heart's electrical waves presented by electrocardiography (ECG). The periodic impulse propagation of Pacemaker nerve fibers (SA node, AV node, Purkinje fiber) of the heart muscles causes cycles of depolarization and repolarization in the heart muscle[6][7]. Depolarization will cause muscle contraction while repolarization will cause muscle relaxation. Heart muscle consists of the Atrium muscle (porch, left and right) and Ventricle muscles (chambers, left and right) [8]. This system is called by the heart's conduction system [9]. Based on Einthoven, there are some part of heart activities which is depicted as ECG signal, namely:

(i) The depolarization of atrium muscle as a P wave.
(ii) The depolarization of ventricle muscle as a QRS wave.
(iii) The repolarization of ventricle muscle as a T wave.

In each electrocardiogram cycle, there is a R which is the highest potential difference as result of the ventricle muscle maximum depolarization. Impulse Propagation from Pacemaker that propagates from the SA node until Purkinje fiber will reach the surface of the human skin because the human body is a good conductor[10]. In the clinical practice, ECG signal is usually used. Holter ECG device is the most used ECG signal record [11]. This device applied to a patient if the paramedics need to monitor the abnormalities of their ECG. The waves and complexes of the ECG signal will be interpreted by the paramedics. The parameters calculated to find out if the ECG is normal or not. The parameters are RR interval, PP interval, QT interval, and ST segment, which are the interval and the height of the wave [8].

Cardiac arrhythmia or irregular heartbeat is a conditions when the beat of the cardiac irregular (rapid or too slow) [12]. There are many kinds of arrhythmia, which is divided based on the place of the abnormalities.

3. Methods

In this identification system, the main process is divided into two parts namely digital signal processing and classification of the ECG signal into two classes, normal and abnormal. In Digital signal processing, The ECG signal obtained from MIT-BIH database need to be processed, so that the signal is suitable with the system. There are three sub-unit of digital signal processing, separating signal into one cycle, equalize the size of separated signal, and feature extraction using discrete wavelet transform.

![Figure 1. Selecting the cycle of ECG signal.](image-url)
Separating signal into one cycle is carried out by selecting the signal with a certain range then save as a new file. Selecting the cycle of a signal cannot be done randomly. There is a formula to calculate the length of one cycle[13]. Referring to Figure 1, one cycle of ECG signal is from point sc to c. These points have the same length with the distance of R to Rn[14] [15]. So the formula is,

\[
\begin{align*}
  dR &= Rn - R \\
  c &= Rn - (1.5 \times dR) \\
  sc &= R - (0.5 \times dR)
\end{align*}
\]

(1) (2) (3)

Where sc is start cycle, c is cycle, Rn is R peak, and dRn is distance between R and Rn.

After the ECG signal is separated, every signal has a different size. So, the signal need to be equalized. The signal is equalized by interpolating the signal using the zero padded technique. After that, the feature of the signal is extracted. This study use discrete wavelet transform as a feature extraction. Feature extraction process makes identification easier. The ECG signal decomposed by Discrete wavelet transform into detail which are a low frequency and a high-frequency component called approximately [16]. Decomposition is a half smaller than a level before. The level of decomposition one until ten is investigated for this study. The discrete wavelet transform can be written as:

\[
T_{m,n} = \int_{-\infty}^{\infty} x(t) \psi_{m,n}(t) dt
\]

(4)

The last process in identification system is classification. After the feature of the ECG signal is extracted, the backpropagation neural network identify the signal then classify it into two classes. The structure of the neural network used is feed forward two layers. The node of the hidden layers are ten and the node of the output layers are two. For the inputs node are different depend on the level of decomposition.

4. Result

The ECG signal obtained from MIT-BIH database were 10 second with 3600 samples which are consist of more than 5 cycle signal. So the signal is separated into one cycle then equalize the signal using zero padded technique until 500 length. The result is one cycle of ECG signal with 500 length. Figure 2 and Figure 3 shows the signal before and after being processed.

![Figure 2. The ECG signal before being processed.](image-url)
Based on Figure 2, the ECG signal consist of more than one cycle. Therefore, the ECG signal must be processed which the result is shown in Figure 3. Furthermore, the ECG signal is decomposed by using discrete wavelet transform until ten level. The discrete wavelet transform features used in this project in order to classify the ECG signal into normal and abnormal. In this study, there are ten attempts of discrete wavelet transform. It is done to find the most effective discrete wavelet transform level with the best result. It only reach the maximum level at 10.

**Table 1. The result of discrete wavelet transform**

| Level | Min | Max    | Matrix    |
|-------|-----|--------|-----------|
|       |     |        | Normal    |
| 1     | 0   | 1.4135 | 250x1000  |
| 2     | 0   | 1.9846 | 125x1000  |
| 3     | 0   | 2.7587 | 63x1000   |
| 4     | 0   | 3.8700 | 32x1000   |
| 5     | 0   | 5.0730 | 16x1000   |
| 6     | 0   | 7.8074 | 8x1000    |
| 7     | 0   | 7.8305 | 4x1000    |
| 8     | 0   | 15.2462| 2x1000    |
| 9     | 6.1203 | 18.8533| 1x1000    |
| 10    | 8.6554 | 26.6626| 1x1000    |
|       |     |        | Abnormal  |
| 1     | 0   | 1.4121 | 250x1000  |
| 2     | 0   | 1.9826 | 125x1000  |
| 3     | 0   | 2.7535 | 63x1000   |
| 4     | 0   | 3.6969 | 32x1000   |
| 5     | 0   | 5.5632 | 16x1000   |
| 6     | 0   | 7.8305 | 8x1000    |
| 7     | 0   | 9.3296 | 4x1000    |
| 8     | 0   | 15.1680| 2x1000    |
| 9     | 1.7256 | 18.1268| 1x1000    |
| 10    | 2.4404 | 25.6351| 1x1000    |
Referring to Table 1, in every level of discrete wavelet transform has different range of minimum and maximum value for normal and abnormal ECG signal. A normal ECG signal has bigger number than an abnormal ECG signal. These results will be used as input to the classification system. Besides, the higher level discrete wavelet transform conduct the less matrix size. The decomposed signal then used as an input to the identification system. The identification system using backpropagation neural network as method. There are three phases of the neural network, namely training, testing, and validating, where the phase's percentage used for this study is 80% for training, 10% for testing, and 10% for validating. In this study, the minimum result of the identification set to 80%. If the result obtained less than 80%, the system will be re-train. Table 2 shows the summary of the identification result.

![Table 2. The summary of identification result.](image)

Based on Table 2, discrete wavelet transform level affect to identification system result accuracy. Start from first level until fifth level, the accuracy is increasing. However, in sixth level until tenth level, the accuracy is decreasing.

5. Discussion
In this study, there are two sub-unit in pre-processing which are separating the signal into one cycle and equalizing the size of the signal. Both are important for digital signal processing. Because if it uses the original signal without pre-processing, the result derived will different and it will make a problem for the feature extraction process. If the signal is not separated, the signal feature will not specific. Afterward, this process if the signal is not equalized its size, the data cannot be processed in feature extraction.

In feature extraction, selecting the suitable features determine the result of the ECG signal classification. For this study, the features used is discrete wavelet transform level 1 until 10 time until 10 times. Based on the ECG signal classification using these features as inputs of the neural network system the highest result obtained by discrete wavelet transform for 4 and 5 times extraction. It is known that there is an effective level which has the best result. The effective level can be found by trying the level to the system randomly.
6. Conclusion
In the classification of the ECG signal, this study has evaluated the backpropagation neural network using discrete wavelet transform as a feature extraction. There are ten attempts of discrete wavelet transform used in this study which every level of attempts has different result. The feature of the signal based on discrete wavelet transform shows that the range of minimum and maximum value for each signal is different. A normal ECG signal has bigger number than an abnormal ECG signal. These results will be used as input to the classification system. Based on the classification performance the ECG signal using backpropagation neural network, the used of four and five times extraction of discrete wavelet transform give the best result at about 91.3%. It is known that discrete wavelet transform can perform well used as a feature extraction in neural network system. It can identify the ECG signal which normal and abnormal.

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