Repeatability and Reliability Characterization of Phonocardiograph Systems Using Wavelet and Backpropagation Neural Network

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Abstract. Phonocardiograph (PCG) system consisting of an electronic stethoscope, mic condenser, mic preamp, and the battery has been developed. PCG system is used to detect heart abnormalities. Although PCG is not popular because of many things that affect its performance, in this research we try to reduce the factors affecting its consistency. To find out whether the system is repeatable and reliable the system have to be characterized first. This research aims to see whether the PCG system can provide the same results for measurements of the same patient. Characterization of the system is done by analyzing whether the PCG system can recognize the S1 and S2 part of the same person. From the recording result, S1 and S2 then transformed by using Discrete Wavelet Transform of Haar mother wavelet of level 1 and extracted the feature by using data range of approximation coefficients. The result was analyzed by using pattern recognition system of backpropagation neural network. Partially obtained data used as training data and partly used as test data. From the results of the pattern recognition system, it can be concluded that the system accuracy in recognizing S1 reach 87.5% and S2 only hit 67%.

Keywords: Phonocardiograph, wavelet, backpropagation, neural network

1. Introduction
Heart disease is one of the main causes of death [1]. One method to monitor heart abnormalities is auscultation technique by using a stethoscope. This is usually done by medician and requires special skills and very difficult to do. Furthermore, a stethoscope cannot hear the low-frequency component of heartbeat while it sometimes carries important information of heart condition [1][2]. One method to overcome the problems of the stethoscope is by using Electrocardiograph. Electrocardiograph (ECG) shows heart condition from heart muscle relaxation and contraction. ECG output analysis is used to determine the existence of heart abnormalities [3]. However, ECG is quite expensive and cannot be afforded by many health facilities in remote areas. Therefore, in this research PCG system that is cheaper than ECG but easier to use than stethoscopes was built.

Phonocardiography (PCG) is a method for recording heart sound from mechanical pulses of heartbeat using stethoscope and recording of heart sounds is in the form of graphics [4]. PCG system in this research consists of a stethoscope, mic condenser, mic preamp, and PC as can be seen in Figure 1.
Although PCG has advantages compared to other cardiovascular recording devices, PCG is rarely used because of many things that affect its consistency such as the position of chest pieces, the type of chest pieces, the length of the filter pipe, the working point of the transistor on the amplifier and so forth. The novelty in this study is the use of PCG as a cardiac device and we try to overcome its weakness by aligning the components that cause instrument inconsistencies.

To determine whether the PCG system designed and constructed in this research is repeatable and reliable, the PCG system output results should be analyzed. PCG output result is a graph depicting a person's heartbeat. Heartbeat comes from opening and closing of heart valves. The closing of the mitral and tricuspid valves at the beginning of the ventricular systole phase causes the first heart sound (S1) to occur. The closing of the pulmonic and aortic valves occurring at the beginning of the ventricular diastole phase results in a second heart sound (S2) [4]. If the output signal from PCG is consistent then for the heartbeat of the same person the results should remain the same. Therefore, to demonstrate the repeatability and reliability of the PCG system that has been made, recording of the heartbeat was cut into sections S1 and S2 and then processed by the pattern recognition system. If the repeatability and reliability of the system are decent then the value of S1 and S2 in various data retrieval with the same conditions will be recognizable by the pattern recognition system.

The signal processing of PCG system is done in three stages which are preprocessing, feature extraction and pattern recognition. Preprocessing is performed on the PCG's output response with the aim of eliminating noise obtained from the surrounding environment and also preparing signals for the next stage by using Discrete Wavelet Transform. The next step is feature extraction to select the signal character that represents the original signal, hence it can improve pattern recognition system efficiency [3]. The last step is the pattern recognition into S1 or S2.

The first stage of ECG signal processing is preprocessing, where it is necessary to remove noise from the input signal using Wavelet Transform. Wavelet transforms decompose signals into a number of scales related to the frequency components and analyzes each scale by a certain resolution. Wavelet Transform uses short time intervals to evaluate higher frequencies and longer time intervals for lower frequencies. One of the advantages of Wavelet Transform is that it is capable of deciphering signals at various resolutions [3]. Signal decomposition of wavelet transform can be seen as a process of signal filtering. In decomposition, the signal is passing a low-pass filter and high-pass filter. The output of low pass filter is called approximation and those come from high pass filter is called detail. The approximation is considered as original signal while detail usually comes from noise [5].

Pattern recognition system used in this research is Backpropagation Neural Network (BPNN). The neural network consists of a group of artificially linked neurons. This research uses the artificial neural network in the classification of S1 and S2, where the input is the approximation coefficient range of wavelet transformation results from the feature extraction and the output unit representing the class of S1 and S2. Each hidden unit counts the weighted amount of its input. BPNN allows the acquisition of practical input/output mapping information within multilayer networks. BPNN executes gradient descent searches to minimize mean square error (MSE) between the desired output and actual network output by adjusting the weights [3].

2. Research Methodology

This research investigated the ability of the PCG system in recognizing S1 and S2 from the patient's heart condition. Heartbeat recording was performed for 15 seconds. The signals then cut on
the part of S1 and S2 for data analyzing. For data analysis 9 data of S1 and 9 data of S2 was used. Data S1 and S2 are then pre-processed by using DWT (Discrete Wavelet Transform). DWT divided signals into approximations and details. The next step is to extract the feature by selecting the range of highest and lowest of approximation coefficient. This range of values is then used as training data and test data on the pattern recognition system by using BPNN. The block diagram of S1 and S2 detection method in PCG system is depicted in Figure 2.

3. Results and Discussion

3.1. Pre-processing by using Discrete Wavelet Transform and Feature Extraction

The recorded heartbeat from PCG system can be seen from Figure 3. The signal than cut at S1 and S2 part. S1 and S2 from different measurement almost show the same result. The cutting signal started from the beginning of the first peak and ended at the lowest point of the latest peak.

After cutting the signal, S1 and S2 than transform into Discrete Wavelet Transform of Haar level 1 where they filtered into low pass filter and high pass filter as can be seen in Figure 4. The low pass filter part called approximations and considered as the original signal while the high pass one considered as noise and called details. The coefficient approximation then used as input in BPNN.
However to improve the efficiency of pattern recognition, feature extraction stage has to be done and it was done by selecting the range of approximation coefficient. Table 1 shows the feature extraction result of nine data retrieval.

| No. | Coefficient of approximation range of S1 | Coefficient of approximation range of S2 |
|-----|----------------------------------------|----------------------------------------|
| 1   | 1.810                                  | 1.730                                  |
| 2   | 1.995                                  | 1.230                                  |
| 3   | 2.078                                  | 1.573                                  |
| 4   | 2.095                                  | 1.635                                  |
| 5   | 2.248                                  | 1.804                                  |
| 6   | 2.140                                  | 1.376                                  |
| 7   | 1.589                                  | 1.366                                  |
| 8   | 1.860                                  | 1.259                                  |
| 9   | 1.934                                  | 0.992                                  |

3.2. Pattern Recognition by using BPNN

The signal is divided into two separate classes that are S1 and S2. Each file of nine data retrieval in 15 seconds recording was selected. The approximation coefficients are given as an input to the BPNN. To train the network, 4 data (two from S1 and two from S2) are utilized while 14 (seven from S1 and seven from S2) data are used for testing the network. One input from feature extraction result, two hidden layers and 25 numbers of neurons in each hidden layer is used for training and testing the PCG signal. At the output layer two neurons were used, and the target matrix is \((1,0)\) for S1 and \((0,1)\) for S2. After several training steps the weight of matrix that gave the highest accuracy was saved. The picture of BPNN architecture is depicted in Figure 5.
Figure 5. BPNN architecture

From pattern recognition by using BPNN, the results show that the PCG system recognition of S1 reaches 87.5% while S2 only hit 67% as can be seen in Table 2.

Table 2. BPNN result

| Output/Target | Accuracy |
|---------------|----------|
| S1            | 87.5%    |
| S2            | 67%      |

As can be seen in Table 2, the accuracy of the system is not high. It is because the wavelet that was used in analyzing process not suitable for the signal waveform. Therefore, the research to determine kind of wavelet is still needed.

4. Conclusion
The S1 and S2 detection of the PCG signal based on DWT, feature extraction and BPNN shows that the recognition of S1 reaches 87.5% while S2 only hit 67%. The accuracy can be improved by using different wavelet in DWT, different method in feature extraction and different architecture in BPNN.

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