WAVELET ANALYSIS AND CLASSIFICATION OF MITRAL REGURGITATION AND NORMAL HEART SOUNDS BASED ON ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

The application of wavelet transform for the heart sounds signal is described. The performance of integral wavelet transform and discrete wavelet transform for heart sounds analysis is discussed. The features from heart sounds were obtained from integral wavelet transform and used to train and test the artificial neural networks (ANN). The ANN was trained by 125 training data and tested with 52 data. The classification accuracy is 94.2%.

1 INTRODUCTION

Currently the heart diseases are the major killer in most countries in the world. Many life can be saved through early detection of the diseases. Auscultation using stethoscope remains the most important tools for early detection of the heart diseases. However there is limitation in using stethoscopes since it depends largely on experience, skills and hearing ability of the physicians. These limitations had forced a standard heart sounds diagnosing system to be developed. This research highlights the application of the Wavelet Transform analysis for mitral regurgitation (MR) and normal heart sound and classification based on neural networks. The heart sounds signal are non-stationary signal which characterized by transient and fast change in frequency as time progress. Thus, the suitable technique to analyze the heart sounds is the time-frequency method. Wavelet transform is a multi resolution analysis which provides time-scale distribution with good frequency resolution for low frequency signal and high time resolution for high frequency signal. Since heart sound has short duration of high frequency component and long duration of low frequency component, thus the application of wavelet transform to heart sounds is very suitable.

2 METHOD

2.1 Data acquisition

The data were collected at Hospital Universiti Kebangsaan Malaysia by using the electronic stethoscope (model FS203) and sampled by using laptop computer sound card at sampling frequency of 2 kHz. There are 102 data obtained from 22 patients who suffered MR disease and 75 data from 5 persons with healthy heart. A large number of patients for MR are needed because there are varieties of MR patent which is depend on the degree of regurgitation itself. However there is less variety for normal heart, thus 5 persons is adequate to represent the patent of normal heart. The preprocessing included DC removal and low-pass filtering using FIR filter with cut-off at 1 kHz.

2.2 Wavelet Transform.

The wavelet transform can be interpreted as a decomposition of the original signal into set of independent frequency channel. There are two popular wavelets transform used to analyze the heart sounds signal which are Discrete Wavelet Transform (DWT) and Integral Wavelet Transform (IWT).

2.2.1 Discrete Wavelet Transform

Most of wavelet features for heart sounds comes from DWT [1,2] since it can reduce the information redundancy in IWT when the reconstruction of the signal is considered. The DWT can be obtained through sequence of digital filtering and following down sample of two [6]. Figure 1 shows the example of DWT transform based on Daubechies 4 for MR which has been decomposed to 6 level details.

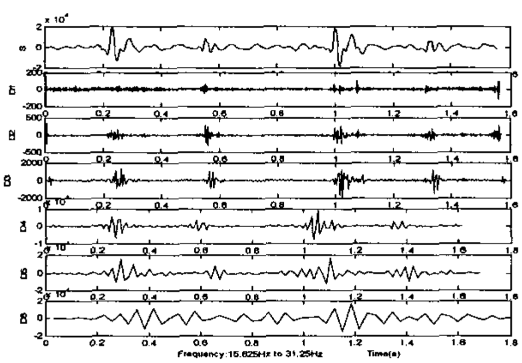

Figure 1: DWT of MR. The frequency bands for corresponding detail are: 1st level detail (D1):500-1000Hz, 2nd level detail (D2):250-500Hz, 3rd level detail (D3):125-250Hz, 4th level detail (D4):62.5-125Hz, 5th level detail (D5):31.25-62.5Hz, 6th level detail (D6):15.625-31.25Hz.

From DWT representation, the murmur of MR cannot be located accurately. Thus, the features obtained from DWT do not well represent the characteristic of heart sounds.

2.2.2 Integral Wavelet Transform

The IWT was developed as an alternative to the Short Time Fourier Transform. The wavelet transform is defined as:

$$W(\tau, a) = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{\infty} x(t).\psi^{*}\left(\frac{t-\tau}{a}\right) dt \qquad (1)$$

The $x(t)$ is the signal to be analyzed and $\psi(t)$ is the analyzing wavelet. Parameter 'a' is the scaling factor of the wavelet. The suitable wavelet for heart sounds analysis is Morlet wavelet since it has the best property of localization in joint time-frequency plane among all wavelet [3-4]. The Morlet wavelet is defined as:

$$\psi(t) = e^{\frac{-t^2}{2}} + j\omega_0 t \text{ where } \omega_0=5.33 \text{ [4].} \qquad (2)$$

Figure 2 shows the IWT transform for MR (the same signal as in Figure 1)

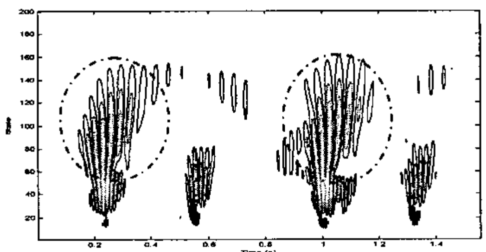

Figure 2: CWT of MR

The IWT clearly shows the murmur (in the circle) as a result of regurgitation of mitral valve. The murmur indicates the turbulence of back flow blood through mitral valve during systole. The IWT describes the characteristic of heart sounds signal better than DWT. Thus the IWT is used to extract the features of heart sounds.

2.3 Features determination

The patents of MR is the murmur starting in the first heart sounds [5] and continues up to or occasionally to beyond the second heart sounds. Thus, to identify MR, it is adequate to only study the interval from the first heart sound to the second heart sound. The peak which indicates the maximum energy of the first heart sound is used as start point and the peak of maximum energy of second heart sound is used as end point. The signal then segmented into fix number of frames and the features were obtained by taking the average of energy from each frame. The number of frame was obtained by try and error method. The varying systolic interval can be eliminated by using the fixed number of frames.

2.4 Classification with Multilayer Perceptron Neural Networks

The multilayer perceptron neural networks with an input, one hidden and an output layer were used to classify the heart sounds. The networks were trained by the back-propagation supervised learning based on least mean square error and gradient descent technique. Several experiments had been carried out to obtain the best architecture of neural networks.

3 EXPERIMENTAL RESULTS

The training set contains 125 data which are 50 data from normal heart and 75 data from MR. The neural networks were tested by 52 data which are 25 data from normal heart and 27 data from MR. Table 1 shows the results of classification in detail.

Table 1: Classification results based on neural networks

Frame number	40	60	80
Correct (accuracy)	45 (86.54%)	49 (94.28%)	41 (78.85%)

4 CONCLUSIONS

The IWT reveal more information of the analyzed signal than DWT since its transforms the signal at every number of scales and enables the detection even in small changes of heart sounds. Thus, IWT is more suitable to analyze 1 dimension signal such as heart sounds signal. The DWT decompose the signal into high frequency band and lower frequency band but it didn't show accurately the beginning and ending frequency of the signal. This property of DWT is suitable for image analysis which requires the image to be decomposed into high frequency band component and lower frequency band component. As a conclusion, the combination of IWT analysis and neural networks provide the best automatic classification system for biomedical signal such as heart sounds.

5 REFERENCES

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