Analysis of Heart Sounds Based on Continuous Wavelet Transform

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Abstract
This paper presents the application of wavelet transform analysis method to the heart sounds signal. The heart sounds is a non-stationery signal, thus it is very important to study the frequency and time information. One of the time-frequency analysis methods is short time Fourier transforms. However, the STFT analysis is limited by the time and frequency resolution. The wavelet transform was introduced to curb the resolution problem in STFT. The wavelet transform is a multi-resolution time-scale analysis that gives high resolution for low frequency components and low resolution for high frequency components. Since majority of heart sounds component lies in low frequency, thus the application of wavelet transform to heart sounds is very suitable. Results in time-frequency representation clearly show that the wavelet transform is capable to distinguish between the normal with a few types of abnormal heart sounds. The murmurs caused by particular heart diseases such as aortic regurgitation, aortic stenosis, mitral regurgitation, mitral stenosis, pulmonary regurgitation and tricuspid regurgitation were clearly shown under continuous wavelet representation.

Keywords:
Heart sounds, analysis, Wavelet Transform.

I. INTRODUCTION

Although there are new cardiac examination methods such as echocardiography, auscultation with a stethoscope remains as the most important tools in diagnosing the heart diseases. It is because of the efficiency, simplicity and non-invasive property of a stethoscope which became fundamental diagnosing method for indication of a potential heart diseases.

However diagnosing the heart sounds through auscultation is subjective since it depends largely on hearing ability and skill of physicians. Thus, our research is to develop a standard heart sounds diagnosing tools which is able to recognize the characteristic of the heart sounds and able to classify the heart sounds automatically.

The analysis of non-stationery signal requires time dependency analysis since it has sharp changes in time [1]. The common solution to analyze the non-stationery signal is by using the short time Fourier Transform which calculates the transformation of signal in short duration of window. Choosing the size of window is the crucial point since large window will cause low time resolution while small window will cause low frequency resolution.

In contrast to the Short Time Fourier Transform, the wavelet transform uses narrow windows when observing the high frequency and automatically uses wide window when observing the low frequency. This particular property of wavelet generates good time resolution at high frequency and good frequency resolution at low frequency.

The continuous wavelet transform (CWT) provides more information than other type of wavelet transform. The CWT transforms the signal at every possible number of scales. This is the advantage of CWT since the small changes in frequency content of heart sounds can be detected under CWT.

II. METHOD

2.1 Data acquisition

The heart sounds were obtained from cardiology unit, Hospital Universiti Kebangsaan Malaysia. The heart sounds was captured through the electronic stethoscope (Super-Tone Deluxe, model FS-203) and recorded through the sound card of laptop computer at sampling frequency of 2000Hz. The data were recorded from 80 patients from various types of heart sounds such as normal heart, mitral regurgitation, mitral stenosis, aortic regurgitation, aortic stenosis, tricuspid regurgitation and pulmonary regurgitation.

2.1 Continuous Wavelet transforms.

The wavelet transform provides information that is localized in time and at a particular scale. The transform basically decomposes the signal to a series of functions as a result of the shifting and scaling a basis function called 'mother wavelet'. The continuous wavelet transform is defined as:

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

The transformed signal is a function of two variables: tau and a, the translation and scale parameters, respectively. The x(t) is the signal to be analyzed and $\psi(t)$ is the analyzing wavelet. The term $\frac{1}{\sqrt{|a|}}$ denotes the normalization of energy, thus the transformed signal will have same energy at every scales. The suitable wavelet for heart sounds signal analysis is Morlet wavelet since it has the best property of localization in joint time-frequency plane among all wavelet [2-4]. The Morlet wavelet is defined as:

$$\psi(t)=e^{\frac{-t^{2}}{2}}+j\omega_{0}t$$

where ω_0=5.33 [4]. The computation of the continuous wavelet transform involves the convolution of the signal with the analyzing wavelet at different values of scaling factor. The wavelet coefficient which is W(τ ,a) is a matrix coefficient that indicates the similarity of the analyzed signal to the mother wavelet. Detail derivation of continuous wavelet transform can be found in [5].

2.2 Data analysis

To remove the unwanted signal, the heart sound signals were filtered by a low pass FIR filter with cutoff frequency at 1000Hz. The signals are segmented into two heart cycles per segment. The segmentation was based on the fact that the systole is faster than diastole for common heart [6]. The continuous wavelet transform then applied to the signals with scale 1 to 200. The absolute value of wavelet coefficient then been taken by assumption that there is no negative energy.

III. RESULTS

The absolute wavelet coefficient is then presented in contour plot. The lowest energy represented by blue color and the highest energy represented by red color. Below is an example of wavelet transform for various types of heart sounds:

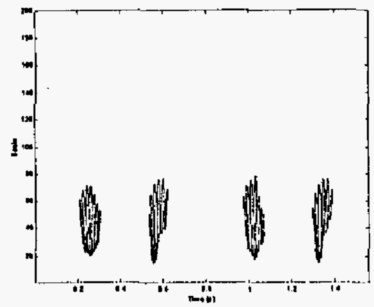


Figure 1: WT of normal heart.

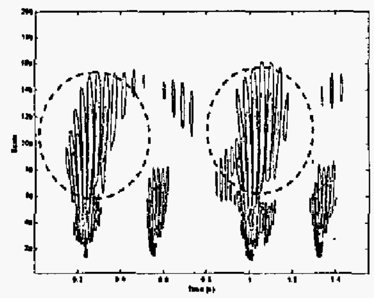


Figure 2: WT of mitral regurgitation.

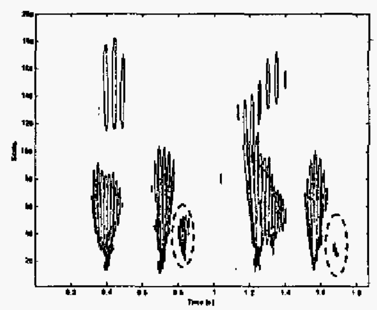


Figure 3: WT of mitral stenosis

In figure 2, the wavelet transform clearly shows that there is low frequency murmurs from scale 80 to 150 and begins at first heart sound. This murmur is the result of turbulence of back flow blood from left ventricle to left atrium during ventricle systole due to regurgitation of mitral valve.In figure 3, the wavelet transform shows the high frequency murmurs that caused by the stenosis of mitral valve during the ventricle diastole.

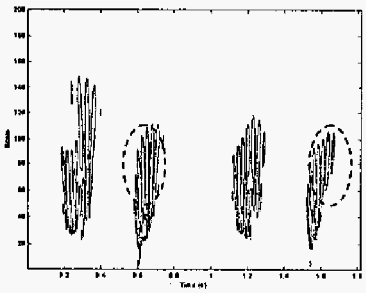


Figure 4: WT of aortic regurgitation.

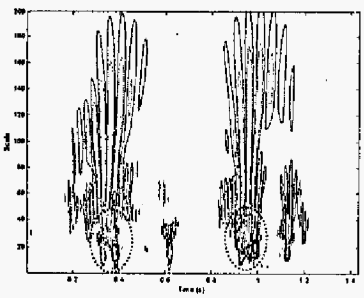


Figure 5: WT of aortic stenosis.

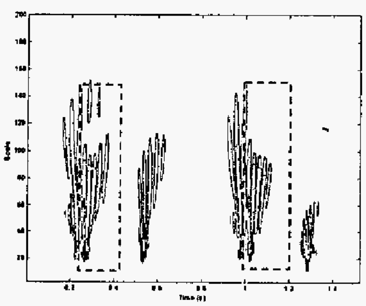
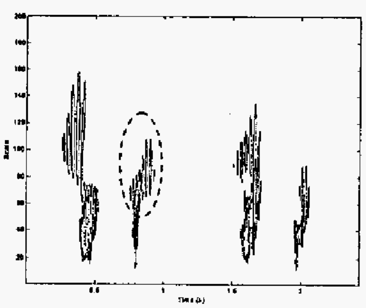
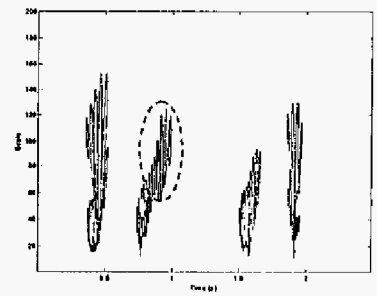


Figure 6: WT of tricuspid regurgitation



(a)



(b)

Figure 7(a, b): WT of pulmonary regurgitation.

In figure 4, the murmur that caused by backflow of the blood from aorta to left ventricle during diastole can be seen clearly. In figure 5, the wavelet transform shows systolic click which is high frequency and followed by murmurs at low frequency. These particular patents indicate the aortic stenosis. In figure 6, the murmur of tricuspid regurgitation can be seen clearly as an extension of first heart sound at low frequency. This murmur is caused by turbulence of the blood due to back flow of the blood from artery pulmonary back to right ventricle. In figure 7, the murmur that caused by regurgitation of pulmonary valve during ventricle diastole is clearly shown under wavelet transform as a extended low frequency murmur after second heart sound.

IV. CONCLUSIONS

As shown in the result, the characteristic of various types of heart sounds is perfectly described by continuous wavelet transform. From this finding, we conclude that the continuous wavelet transform based on Morlet wavelet is the best method to describe the characteristic of heart sounds. The graphical representation of continuous wavelet transform can be used to help the physician in diagnosing. These features can also be fed to the automatic classifiers such as artificial neural network to develop an automatic heart sounds classification. The wavelet transform provides more features and characteristics of heart sounds signal that will help physician to obtain qualitative and quantitative measurements of the heart sounds.

V. REFERENCES

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