ANALYSIS OF PHONOCARDIOGRAM FOR DETECTION OF CARDIAC MURMURS USING WAVELET TRANSFORM

[1]Namitha Shankar, [2]M.S.Sangeetha

[1]Assistant Professor, VimalJothi Engineering College, Kerala, India.
[2]Assistant Professor, Department of Electronics and Instrumentation , Karunya University, Coimbatore, India.

Abstract—The main objective of this paper is to develop a Signal Processing Module (SPM) for the computer-aided analysis of heart sounds using Discrete Wavelet Transform (DWT). The SPM reveals important information of cardiovascular disorders and can assist general physician to come up with more accurate and reliable diagnosis at early stages. The module has four main blocks: Data Acquisition, Segmentation, Feature Extraction and Murmur Detection. The segmentation of phonocardiogram signal is the first step of analysis and the most important procedure in the automatic diagnosis of heart sounds.As an initial approach, an algorithm for detection of S1 and S2 heart sounds was developed and the signals are segmented into individual components using the wavelet transform and Shannon energy. Then the features are extracted from the individual components can be used as an input to Neural Network which could be trained to detect the presence of heart murmurs.

Keywords-Heart sound, PCG, Cardiac murmurs, DWT (Discrete Wavelet Transform), Shannon energy

I . INTRODUCTION

Heart Auscultation, defined as the process of interpreting acoustic waves produced by the mechanical action of heart is a non-invasive, low-cost screening method and is used as a fundamental tool in the diagnosis of cardiac diseases. It can provide valuable information concerning the function of heart valves and the hemo-dynamics of the heart and has high potential for detecting various heart disorders especially valvular problems. New advanced imaging techniques like EKG, MRI and CT although can provide more direct evidence but require expensive equipment, specialized technicians to operate, experienced cardiologists to interpret the results, high maintenance cost, a permanent place to be installed and generally require more resources to function properly. These requirements are usually met in advanced hospitals and are not suitable in homecare, in rural hospitals and rural as well as urban clinics. Therefore in numerous cases the heart sound diagnosis is the possible economical and quick alternative to detect the heart condition under emergency conditions[1].

The basic aim of phonocardiography (the graphical recording of the heart sounds) is to provide the clinicians with a complementary tool to record the heart sounds and murmurs heard during cardiac auscultation. Since phonocardiography is non-invasive and provides valuable information concerning the functional integrity of the heart, it has a high potential for detecting various heart diseases.

Digital analysis of phonocardiograms allows extracting features from the heart sounds that could not be detected by the human ear, such as muffled components of heart sounds, musical murmurs, rumble, or whiffs. Main characteristics of heart sounds such as their timing relationships and components, frequency content, time of occurrence in the cardiac cycle and envelope shape of murmurs can be quantified using advanced DSP techniques.

II .OVERVIEW OF PHONOCARDIOGRAM AND CARDIAC MURMURS

A. Phonocardiogram

A **Phonocardiogram** or **PCG** is a plot of high fidelity recording of the sounds and murmurs made by the heart with the help of the machine called phonocardiograph, or "Recording of the sounds made by the heart during a cardiac cycle." The sounds are thought to result from vibrations created by closure of the heart valves.

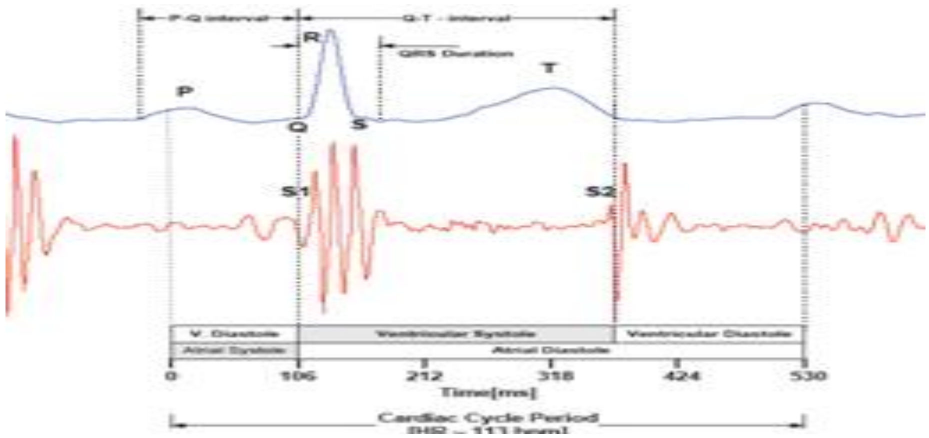

Fig 1: The normal PCG with reference to ECG

There are at least two: the first when the atrioventricular valves close at the beginning of systole and the second when the aortic valve closes at the end of systole. It allows the detection of sub audible sounds and murmurs, and makes a permanent record of these events. In contrast, the ordinary stethoscope cannot detect such sounds or murmurs, and provides no record of their occurrence. The ability to quantitate the sounds made by the heart provides information not readily available from more sophisticated tests, and provides vital information about the effects of certain cardiac drugs upon the heart. It is also an effective method for tracking the progress of the patient's disease.

B. Heart murmurs

Murmurs are produced by turbulent blood flow as a result of narrowing or leaking valves or from the presence of abnormal passages in the heart. More specifically, heart murmurs occur when the blood flow is accelerated above the Reynolds number. The resulting blood flow induces non-stationary random vibrations, which are transmitted through the cardiac and thoracic tissues up to the surface of the thorax. There are five main factors involved in the production of murmurs and they are high rates of flow through the valves, flow through a constricted valve (stenosis), backward flow through an incompetent valve (insufficiency orregurgitation), abnormal shunts between the left and right side of the heart (septal defects) and decreased viscosity, which causes increased turbulence.

III . WAVELET TRANSFORM

Wavelets are a powerful tool for the representation and analysis of such physiologic waveforms because a wavelet has finite duration (compact support) as contrasted with Fourier methods based on sinusoids of infinite duration. It is possible to analyse any signal by using an alternative approach called the multi resolution analysis (MRA). MRA, as implied by its name, analyses the signal at different frequencies with different resolutions. Every spectral component is not resolved equally as was the case in the STFT. MRA is designed to give good time resolution and poor frequency resolution at high frequencies and good frequency resolution and poor time resolution at low frequencies. The

Wavelet analysis does this by using a windowing technique with variable-sized regions. Discrete wavelet transform (DWT) is obtained simply by passing a discrete signal through a filter bank.

Wavelet theorycan be understood and developed only by using such digital filters [6].This is the meeting point between wavelets and sub band coding and the origin of two different nomenclatures for the same concepts.Infact,wavelettransformandsubbandcodingareso closely connected that both terms are often used interchangeably. Filter banksare structures that allow a signal to bed ecomposed into subsignals through digital filters, typicallyatlower sampling figure 2 shows a two-bandfilter bank.

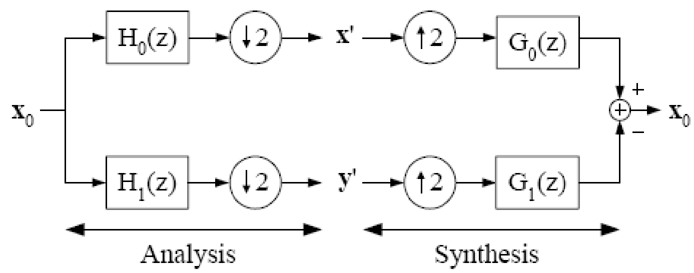

Fig 2 One-level two band perfect reconstructionfilterbank.

The DWT analyses the signal at different resolution (hence, multi-resolution) through the decomposition of the signal into several successive frequency bands. The DWT utilizes two set of functions ø(t) and Ψ(t), each associated with the low pass and the high pass filters respectively [7].These functions have a property that they can be obtained as the weighted sum of the scaled (Dilated) and shifted version of the scaling function itself:

$$\varphi(t) = \sum_n h[n]\varphi(2t-n) \text{ --- (1)}$$
$$\psi(t) = \sum_n g[n]\varphi(2t-n) \text{--- (2)}$$

Here, h[n] and g[n] are the half band low pass filter and high pass filter respectively.

IV. METHODOLOGY

The block diagram below shows the steps to segment the heart sound and detect the murmur. The individual steps are described separately in the following topics.

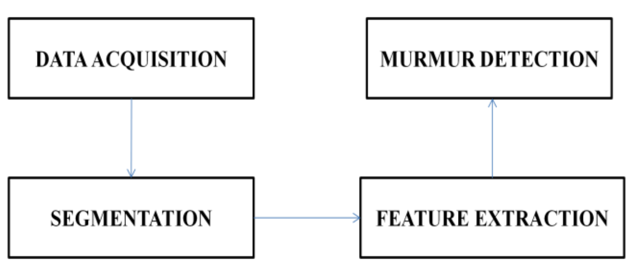

Fig 3: Block Diagram of Signal Processing Module

A. Data acquisition and normalization

The BiokitPhysiograph System is used for capturing the PCG signals from individual persons which are highly non stationary biomedical signals. The acquired PCG signal is down-sampled to reduce the sampling rate and then normalized to bring the sampled values in the range of +1 to -1.

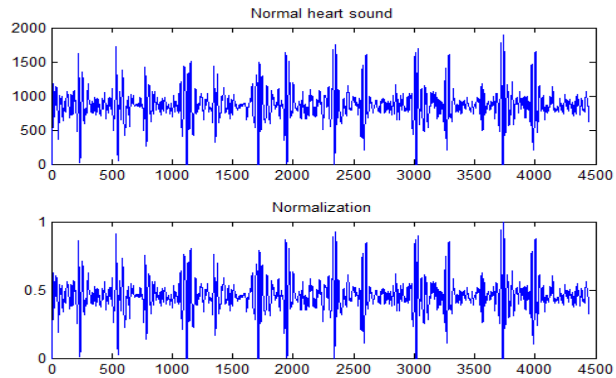

Fig4: a. Original signal b. Normalized Signal

B. Segmentation

The normalized signals are segmented into individual cycles using Wavelet Transform and Shannon Energy, with each heart cycle containing first heart sound (S1), systolic period, second heart sound (S2) and diastolic period in time. Most of the techniques used previously depend on the reference of ECG signal or/and carotid pulse for segmentation. However to avoid the time synchronization of both PCG and ECG signal and to simplify the data collection procedure no reference signal was used. The main idea is that first the location of S1 and S2 were computed and then based on that information the location of systolic and diastolic periods were calculated. This is important as the murmurs are present in systole and diastole. The whole algorithm is implemented in MATLAB.

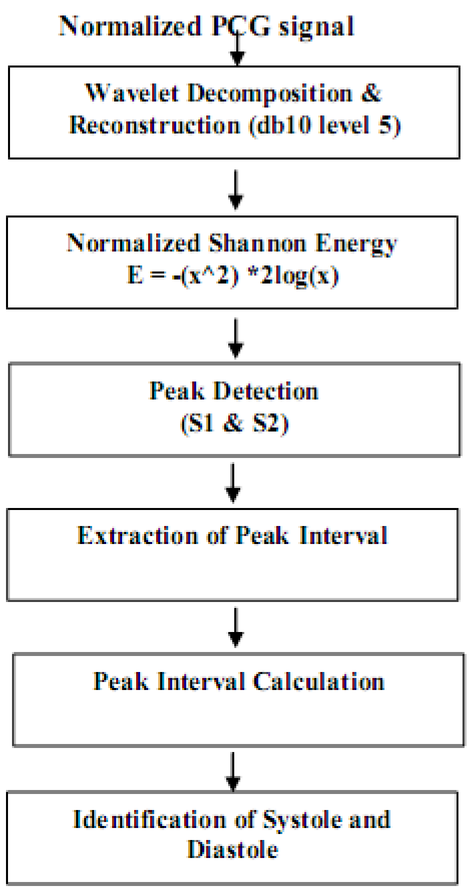

Fig 5: Heart Sound Segmentation Algorithm

The pre-processed signal was decomposed to level 5 using Daubechies 10 Wavelet Transform. The decomposed signal was then reconstructed to eliminate noise and the base line drift. The frequency bands that contain the majority powers of S1 and S2 were then chosen for further processing [2].

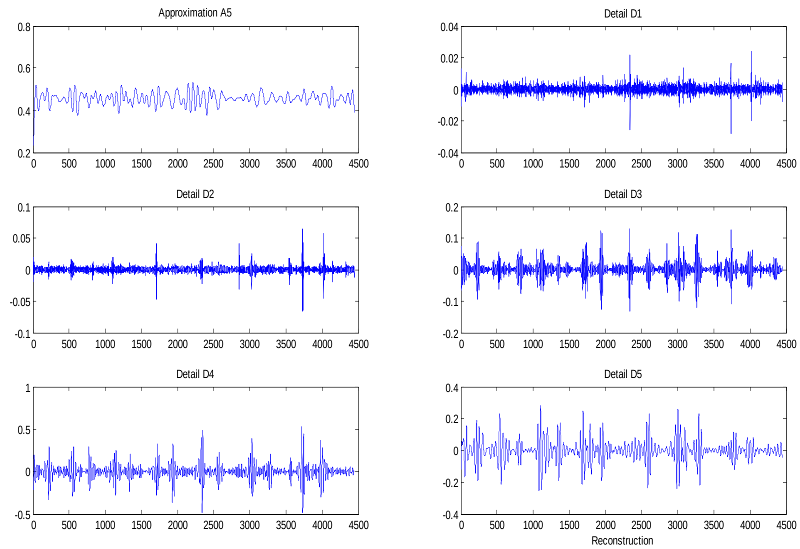

Fig.6 Multi resolution wavelet reconstruction (DWT) of normal PCG signal using DB 10 levels 5

Shannon energy

Shannon energy is used to emphasize the medium intensity signal and to eliminates the effect of noise.

Shannon Energy: $E = - x^2 \log(x^2)$

The important components of the heart sound, S1 and S2 were separated by calculating the normalized average Shannon energy for the selected approximations and details of the wavelet transformed HS. The envelope ofnormalized decimated signal is calculated. Fig.l shows different methods of calculating the envelope of the normalized signal [2].

Shannon Energy: $E = - x^{2\cdot}\log(x^2)$

Shannon Entropy: $E=-|x|. \log |x|$

Absolute Value: $E= |x|$

Energy(square) $E= x^2$

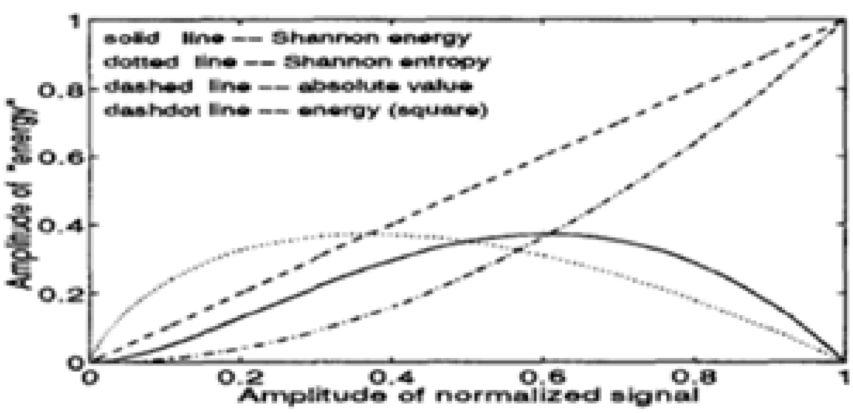

Fig 7: Comparison of different envelope methods

The figure indicates that the energy (square) will bury the low intensity sounds under the high intensity ones by enlarging the high/low intensity ratio. The Shannon entropy accentuates the effect of low value noise that makes the envelope too noisy to read. The absolute value gives the same weight to all the signal. The Shannon energy emphasizes the medium intensity signal and attenuates the effect of low intensity signal much more than that of high intensity signal. *So*, the Shannon energy is better than the absolute value in shortening the difference of the envelope intensity between the low intensity sounds and the high intensity sounds. This shortening enables the finding of low intensity sounds easier. Then, the average Shannon energy is calculated in continuous 0.02-second segments throughout the signal [3]-[5]. The average Shannon energy is calculated as:

$$E_s = -\, 1/N. \sum_{i=1}^{N} x^2_{norm}(i) \,.\, \log x^2_{norm}(i)$$

Where N is signal length in 0.02-second segments. The normalized average Shannonenergy is computed as follows:

$$P_a(t) = [E_s(t) - M(E_s(t))] / S(E_s(t))$$

Where, M (Es(t))is the mean value of Es(t)

S (E s (t)) is the standard deviation of E s (t)

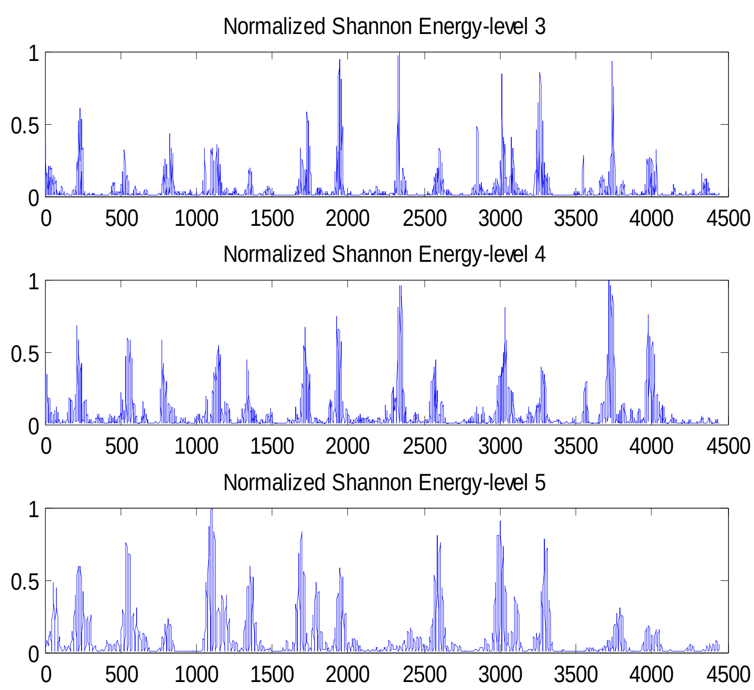

Fig 8 Normalized Shannon Energy with for Detail 3,4 and 5

By setting an appropriate threshold, i.e. root mean square of the normalized Pa (t), the main components of heart sound, S1 and S2 are picked up, eliminating the effect of noise and the very low-intensity signals.The peaks of each part whose levels exceed the threshold are picked up. S1 and S2 are identified according the intervals between adjacent peaks.

The region between S1-S2 is the systole and that between S2- S1 is the diastole. The systole and the diastole are extracted based on the peak locations of the heart sounds. The time duration between the two major heart sounds are computed and the systole and diastole are identified based on the fact that the time duration between S1-S2 will be lesser than the time duration between S2-S1. Or in other words, the duration of systole will be lesser than that of diastole.

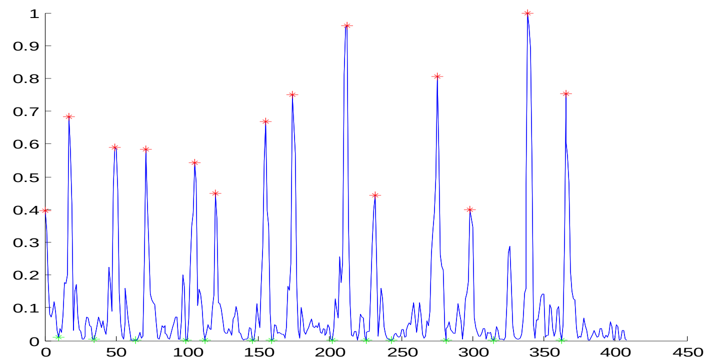

Fig 9: Detected peaks forDetail 4

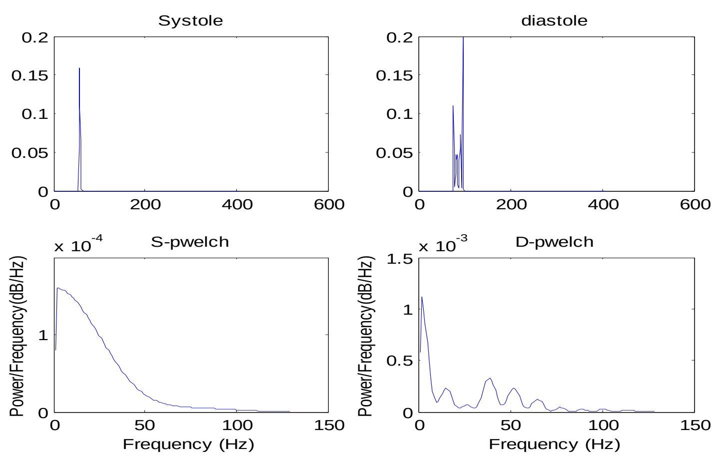

Fig 10: Extracted systole &diastole and their PSD

C. Feature extraction andmurmur detection

Feature extraction is one of the most important steps in automatic classification of biomedical signals. The selection of important features is dependent on the characteristics of the signals and the information to be extracted from them.The wavelet distribution is used to derive the energy, frequency and amplitude In the case of HS, the energy concentration of systole and diastole over time-frequency plane for normal heart sounds is of particular interest. Once this is known, any unusual distribution of energy in the time frequency plane serves as an indication of abnormality. Any HS with most of their energy concentrated between 50 Hz and 150-200 Hz should be considered normal. If there is any abnormal energy concentration, especially in the range 250 to 500 Hz, there is a strong possibility of the presence of pathology [6] [7].Features are fed as input to ANN to detect the presence of murmurs based on a threshold value [8].

V.RESULTS

Heart sounds were first down sampled and normalized to bring the sampled values in the range of +1 to -1. The normalized signals were segmented into individual cycles using Wavelet Transform and Shannon Energy. The pre-processed signal was decomposed to level 5 using Daubechies 10 Wavelet Transform. The decomposed signal was then reconstructed to eliminate noise and the base line drift. The frequency bands that contain the majority power of S1 and S2 was then chosen for further processing.The normalized Average Shannon energy of heart sounds was then calculated and passed through a peak detector to find the location and the amplitude of the peaks by computing the Shannon energy with an automatic threshold chosen based on the RMS value of the Pa(t) of the signal. Then the systole and diastole were extracted based on the interval between the peaks and their frequency spectrum is calculated.

VI. CONCLUSION AND FUTURE WORK

In this paper, an algorithm based on Wavelet Transform is presented for the extraction and analysis of systole and diastole in PCG. Here the extraction and analysis is based on Daubechies Wavelet and Shannon energy. The results show that the technique is quite effective in localizing and extracting the important components of heart sound. It accuratelydifferentiated between first and second heart sounds. The wavelet transform-based feature extraction method provides useful features of heart sounds.. So this feature extraction method can be used as a primary measurement tool for automatic and on line murmur detection. Further work is under way to improve the feature extraction and classification algorithms to achieve better accuracy. But some of the PCG waveform may show very erratic nature due to electrode contact noise or some complicated cardiac abnormalities.

REFERENCES

[1]. FaizanJaved, P A Venkatachalam and Ahmad Fadzil M H , “A Signal Processing Module for the Analysis of Heart Sounds and Heart Murmurs”,2006

[2]. P.S.Vikhe, S.T.Hamde, N.S., “Wavelet Transform Based Abnormality Analysis of Heart Sound Nehe”,IEEE,2009

[3].H Liang, S Lukkarinen, I Hartimo,Helsinki “Heart Sound Segmentation Algorithm Based on Heart Sound Envelolgram”, University of Technology, Espoo, Finland

[4]. “A Remote Monitoring Platform for Auscultation, Faculty of Sciences and Technology”, University of Coimbra ,2010

[5]. T. Cai, E. B. Pitman, X. Bian and Y. Chen, “Towards Diseases Diagnosis From Biomedical Signal Processing of Circulation System”, State University of New York, 2011

[6]. H. Nazeran, “Wavelet-based Segmentation and Feature Extraction of Heart Sounds for Intelligent PDA-based Phonocardiography”, Electrical and Computer Engineering, The University of Texas at El Paso, El Paso, Texas, USA, 2007

[7]. Reza RamezaniSarbandi, John D Doyle, Mahdi Navidbakhsh, Kamran Hassani, “A colour spectrographic PCG applied to the detection and characterization of heart murmurs”,BioMedical Engineering OnLine,2011

[8].Curt G. Degroff, Md; Sanjay Bhatikar, Phd; Jean Hertzberg, “Artificial Neural Network–Based Method of Screening Heart Murmurs in Children”,Phd Journal Of American Heart Association,2001