Segmentation of PCG Signal: A Survey

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Abstract - *All around the world there are various diseases acquired by the human being. These diseases are of various kinds and affect almost all the part of the human body. Including the diseases that are related to heart like Aortic Stenosis, Miteral Stenosis, Aortic Regurgitation and Miteral Regurgitation, takes a large group of people suffering from various kind of cardiac abnormalities. Heart diseases are now a days becoming vary painstaking part that needs to be taken care of. The major part of solving such problems involves a considerable amount of work to identify the disease. As heart is the most complex and delicate structure of human body it is very difficult to deal with it physically. The area of biomedical signal processing is vast and very useful to accurately analyze and detect the disease. It provides a comfortable way to deal with the disease and cure it as soon as possible. ECG signal processing has been proved to be useful but was not up to the mark that the people and doctors desired it to be. PCG (Phonocardiogram) signal is becoming a very common and reliable alternative to this. A fully developed system which detects the disease as soon as the PCG signal is given to it can help a group of novice doctors to cure the disease before it become late to handle the disease. In this paper a review of the previous work has been done to analyze and understand the processing on PCG Signal.*

***Key Words* -** PCG, Wavelet Transform, Segmentation, classification, denoising, decomposition level etc.

Broad Area- Signal Processing, Computer Engineering.

1. INTRODUCTION

Heart is the vital component of the body. It is responsible for the proper functioning of each and every part of the body including brain, because the flow of blood to every part of the body is the main task that any heart performs, failing to which whole body gets affected leading to improper functioning of various part of the body. Various abnormalities in the heart are categorized as Aortic Stenosis, Miteral Stenosis, Aortic Regurgitation and Miteral Regurgitation [7]. In recent years, it is seen that the deaths have highly increased due to heart disease all over the world. The requirement of accurate detection of heart disease has forced researchers to develop a system which can help to detect the disease and cure it as soon as possible. PCG (Phonocardiogram) signal is becoming a very common and reliable alternative to ECG [3]. The discovery of PCG signal gained the attention of researchers towards this area. Even from the heuristic point of view, which the cardiologist do while analyzing the disease is hearing the heart sound using a stethoscope, which is nothing but listening to the PCG signal generated by the heart while transferring the blood form one chamber of the heart to another chamber. The blood flows from heart to lungs and then from lungs to heart and to different parts of the body. This flow of bloods with specific pressure and volume produces the heart sound [4]. Phonocardiogram signal is non-stationary signals with a frequency of 10 KHz. Although ECG signal has been analyzed to a greater level, it is not efficient to detect the heart disease because it deals with the electrical behavior of the heart, while abnormalities in heart are mostly due to change in shape of the chambers of the heart. This change in the heart's shape leads to production of unnatural sound in the heart, and is the key to detect the abnormalities in the heart [9, 10]. These sounds provide the vital information to the cardiologist to identify the disease. The skill which a cardiologist must have, to detect the disease accurately can be imagined by the complexity of the task. A skilled cardiologist emerges by constantly working for a long time in the field of cardiac systems. This is where a novice cardiologist may fail. There always exists a chance of wrong detection of disease because of the doctor's inability to hear the sound properly, his perseverance and his experience. Due to lack of experience and skill they may not be able to handle the case and refer the patient to more experienced and skilled cardiologist. Although they have the theoretical knowledge to cure the disease but that is not enough. The skill of the doctor coupled with the experience can only detect the disease properly and accurately. This leads to the need of developing a decision support system (DSS) that can support doctors independent of their experience and any unfavorable physical conditions, which forced researchers to work and come up with a better system. The system developed here provides such a method. The system includes the feature extraction of PCG signal, using discrete wavelet transform specially Daubechies wavelet because this can provide better information than other wavelets like Haar, Symlet, Coiflet etc. Phonocardiogram signal is a nonstationary signal. We need to apply discrete wavelet transform to analyze it [13]. Then for the purpose of classification of PCG signal, Adaptive Neuro Fuzzy Inference System (ANFIS) has been used [2]. The training of the system is done by the heart sound available in various website of medical science on the World Wide Web. Although we are available with echocardiography for heart examinations, cardiac auscultation remains the most important and screening diagnostic method for early diagnosis of heart valve diseases. Phonocardiography displays the graphical representation of the heart sounds. It is easy to use and non-invasive. It provides the diagnostic information for detection of the abnormal function of the cardiac valves in clinical practice.

2. RELATED WORK

The development of a DSS incorporates selection of optimum methods among various techniques available. The developed system here involves two main selections namely feature extraction and classification. For feature extraction there are many methods like Fourier Transform, Discrete Fourier Transform, Fast Fourier Transform, Discrete Wavelet Transform, Wavelet Transforms etc. [1, 8, 11].

Burhan Ergen focuses on the denoising of phonocardiogram (PCG) signals by means of discrete wavelet transform (DWT) using different wavelets and noise level estimation methods. The signal obtained by denoising from PCG signal contaminated white noise and the original PCG signal is compared to determine the appropriate parameters for denoising. The comparison is evaluated in terms of signal to noise ratio (SNR) before and after denoising. The results showed that the decomposition level is the most important parameter determining the denoising quality. The assessments were made for the behavior of different mother wavelets and four different threshold estimation techniques in order to find the most reliable parameters for DWT denoising of heart sounds. These have drowned from the most used wavelet families, Daubechies, Sym-lets, Coiflets, and Discrete Meyer.

The PCG signal was contaminated at SNR=5dB in order to test the performance of the wavelets and the threshold estimation techniques. A normal PCG signal generally contains only two heart sounds, first and second heart sounds. Figure below illustrates a sample PCG signal, the noisy signal, a denoised sample using DWT, and the error between the original and the denoised PCG signals. The frequency components of a normal PCG signals can be rise up 200 Hz, and the energy of the most significant components concentrates around the frequency band 100 - 150 Hz. The frequency bands of the signal are important in point of the denoising technique using DWT approaches. Because the DWT approaches decomposes.

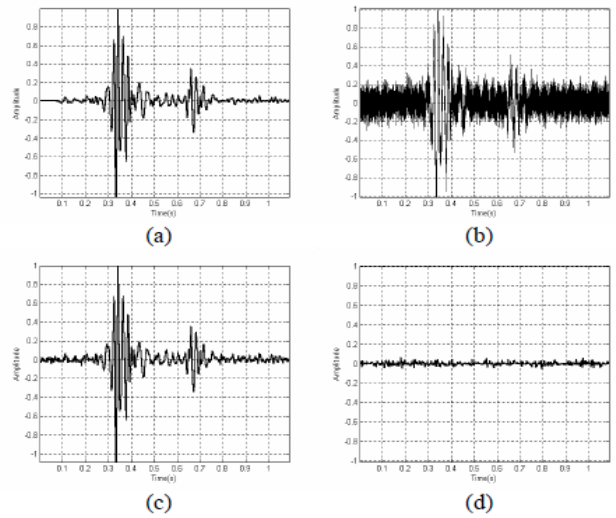

Fig.1: Wavelet denoising of a PCG signal, a) Original signal, b) Noisy signal, c) Denoised signal, d) Error between the original and the denoised signal.

The author concludes that reasonable decomposition level is absolutely depending on the sampling frequency and the frequency band of the signal. Just in this study, the de-composition level of 5 produced reasonable results be-cause the frequency band of a normal PCG signal is around 150 - 200 Hz and the sampling frequency is 11.5 KHz. Since the noise level method is one of the important parameter in wavelet denoising, it is examined for different levels. We have not seen any noteworthy differences in the methods from level 1 to level 6. After this level, rigresure method has showed superiority to the other methods in terms of SNR level. Consequently, it is determined that the wavelet type is not very important if the oscillation number is not very low, the decomposition level is absolutely depends on the frequency band of the PCG signal and its sampling frequency, and rigresure method is best of the noise estimation techniques.

Liu et al. presented a feature analysis approach of heart sound based on the improved Hilbert-Huang Transform after a large number of analyses of heart sounds in time frequency domain to analyze the feature of heart sound accurately and effectively. The validity of the proposed method has been verified through Empirical Mode Decomposition (EMD) for a typical vibratory. The author calculated and obtained the characteristic parameter of heart sound by Hilbert spectrum analysis for several cases of normal and abnormal heart sounds. Experimental results show that the presented algorithm is able to identify different heart sounds in time frequency domain, and it also establishes the basis for the classification and recognition of heart sound. In this paper, author presented a feature analysis approach of heart sound based on the improved Hilbert Huang Transform, and applied the improved HHT by Hilbert spectrum analysis of various cases of heart sounds. The results show that: this method can adaptively extract local mean curve of nonstationary data and decompose the complex heart sounds into a limited number of IMF which have physical significance. It reflected the spectral characteristics of heart sounds clearly and established the fundament for the classification and recognition of heart sound. And it has certain values for clinical application.

Backer et al. prove the Hilbert theorem for the univariate case and then for the multivariate case. The proof for the latter is slightly different than in [5]. As a base case the author took the ring of polynomilas with no variables. The author also proved that a polynomial ring with infinite number of variables is not Noetherian.

Omari et al. informs that the phonocardiograms (PCGs), recording of heart sounds, have many advantages over traditional auscultation in that they may be replayed and analyzed for spectral and frequency information. PCG is not a widely used diagnostic tool as it could be. One of the major problems with PCG is noise corruption. Many sources of noise may pollute a PCG signal including lung and breath sounds, environmental noise and blood flow noises which are known as murmurs. Murmurs contain many information on heart hemodynamic which can be used particularly in detecting heart valve diseases. Therefore such diseases can be automatically diagnosed using Murmurs. However, the first step before developing any automated system using Murmurs is the denoising and the segmentation of the PCG signal from which murmurs can be separated. Different algorithms have been developed in the literature for denoising and segmenting the PCG signal. A robust segmentation algorithm must have a robust denoising technique. The wavelet transform (WT) is among the ones which exhibits very high satisfactory results in such situations. However, the selection of level of decomposition and the mother wavelet are the major challenges. This paper proposes a novel approach for automatic wavelet selection for heart sounds denoising. The obtained results on real PCG signal embedded in different white noise intensity showed that the proposed approach can successfully and consistently extract the main PCG sound components (sound component S1 and sound component S2) from various types of murmurs with good precision. In this paper, author presented a novel automatic mother wavelet selection scheme, which selects the best mother wavelets and the best level of decomposition in PCG denoising operation. The proposed method based on the multiplication of detail coefficient by the exponential of approximation coefficient, referred as EXP, searches, at each level, for the mother wavelet that provide a smallest value, and then refers to the highest EXP value to select the wavelet and level of decomposition. The performance of the EXP scheme was compared to those of the SNR and MAX methods, previously proposed in the literature, for real PCG signal embedded in different white noise intensity. In order to evaluate the performance of the algorithm regarding murmurs extraction, the correlation coefficient was employed. The EXP method showed advantageous for most of the analyzed signals, indicating that the idea of searching the mother wavelet and the best level of decomposition using our method showed superior than maximizing the energy of approximation coefficients (MAX) or approximation coefficients to detail coefficients ratio (SNR).

Randhawa et al. informs that the Heart sounds give us information about the state of the heart. Heart diseases can be detected at an earlier stage by analyzing the heart sounds. In this paper, detailed discussion of various methodologies that have been used earlier to analyze the heart sounds has been carried out. Comparison has been done on the basis of methodology used and the performance achieved. In this paper various methodologies which have been used in analyzing the phonocardiogram signal have been compared. Performance of each methodology has also compared. Maximum accuracy of 99.74% was achieved by Shannon energy envelop algorithm in extraction of S1 and S2 heart sound components. Due to the denoising of the signal the results achieved were better. Wavelet based PCG signal analysis achieved accuracy of 90% - 97.56% [7, 13, 14, 16].

Manikandan et al. presents a novel phonocardiogram (PCG) signal compression method based on Wavelet transform. The proposed compression method uses energy based thresholding for retaining significant coefficients, uniform scalar zero zone quantizer (USZZQ) for quantizing the amplitudes of the significant coefficients and differencing coder for integer significance map (ISM). This method is tested using the PCG records taken from qdheart and eGeneral Medical databases. The performance of the compression method is assessed in terms of compression ratio (CR), percentage root mean square difference (PRO), Wavelet energy based diagnostic distortion (WEDD) measure and mean opinion score (MOS). The compression method is evaluated with PCG signals of more than 100 records with normal sounds, murmurs, stenosis, noise and other pathologies. High compression ratios with lower distortions are achieved with the proposed method. In this paper, a novel Wavelet compression of PCG signals is proposed and its performance is evaluated using various PCG signals. Compression ratios (CRs) comparable to those reported earlier are obtained with the quality of reconstructed signals suitable for analysis of heart diseases.

The input signal is taken and then it is processed to get it into the desired form so that any extra information does not affect the output.

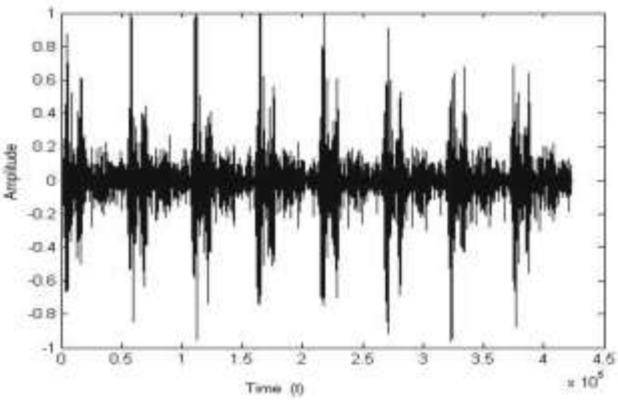

Fig.2: Input PCG Signal

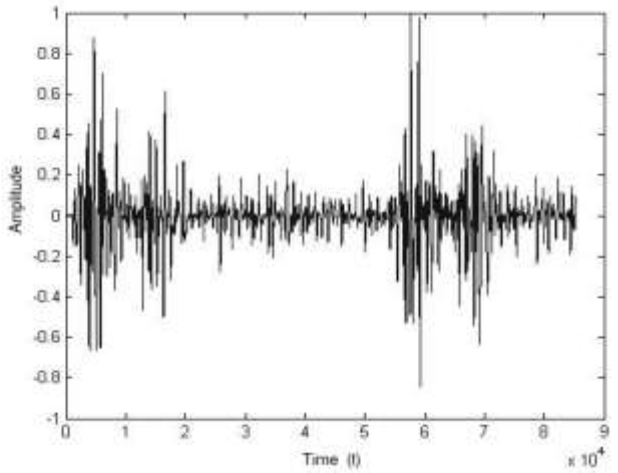

Fig.3: Transformed Input Signal

3. Result

There is a need for a fast and reliable method to detect the presence of noise in PCG signals that will allow an accurate interpretation of heart sounds and diagnosis of cardiac disorders. Various authors presented a novel low-complex and multi-channel methodology for the detection of noise, which is based on the time and frequency domain analysis of the PCG signal. The multi-channel approach is able to achieve high performance, with low computational complexity. The method is important for the comparison of the proposed algorithm with other noise detection algorithms used to analyze PCG signals and finally on the evaluation of the algorithm in a larger population consisting of both healthy and cardiovascular diseased subjects.

4. Conclusion

Heart sound is a complex signal, and the traditional signal processing methods (such as FFT, Winger-Ville and wavelet transforms etc) have lots of drawback due to this reason the processing of heart sound are limited. We have found that the daubechies wavelet gives the maximum value for all different types of sound for normal heart sound which means that daubechies wavelet is the best wavelet for denoising the biomedical sound. In general, in denoising problems the noise is assumed to be gaussian white noise. The signal energy is concentrated in a small number of wavelet coefficients and the coefficients values are relatively large compared to the noise that has its energy spread over a large number of coefficients. This allows clipping, thresholding and shrinking of the amplitude of the coefficients to remove noise. Hence by reviewing the above mentioned literatures immense information regarding the PCG signal processing has been collected and is going to help for the development of the new system.

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