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Feature Extraction of Phonocardiogram Signals Using Discrete Wavelet Transform: A Survey

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Abstract: With the increasing number of casualties due to heart diseases, researchers have started looking at newer avenues for heart disease analysis. Apart from ECG, EEG and EMG signals, a particular type of sound signal produced by the heart while pumping blood also called phonocardiogram signals has become an a popular area of research off late. The interpretation of various heart sounds depends on physician's ability of hearing, experience, and skill. Such limitations may be reduced by developing biomedical-based decision support systems. In this study, A biomedical-based support system was developed for the Feature Extraction of PCG Signal by using Wavelet Transform .we generally deal with the four heart valve diseases under investigation. They are aortic stenosis, aortic regurgitation, mitral stenosis & mitral regurgitation. In this paper we are extracting the feature of these diseases for getting clarity in classifiers stage by using Level-10 Decomposition DWT. The feature extraction result giving as the compare between all these four diseases through the parameter like Energy, Variance ,Standard Deviation, Entropy of given signal by keeping atmospheric condition same for all sound input.

Keywords:-
ECG-Electrocardiogram, PCG-Phonocardiogram, AS-Aortic Stenosis, AR- Aortic Regurgitation, MS- Mitral Stenosis, MR- Mitral Regurgitation, DWT- Discrete Wavelet Transform

Introduction

The heart is divided into four chambers namely atrium and ventricles. The upper two chambers are known as atria while the lower two chambers are known as ventricles. Heart muscles squeeze the blood from chamber to chamber. During this squeezing process, the valves help the blood to keep flowing smoothly in and out of the heart. This is done by automatically opening of valves to let blood in from chamber to chamber and closing to prevent the backflow of blood [1]. Heart sounds are the composite sounds produced by myocardial systolic and diastolic, hoist valve, blood flow and cardiovascular vibration impact, and contain a great deal of physiological and pathological information regarding human heart and vascular.

Research on diagnosis of cardiac abnormalities using wavelet technique has been carried out from past few years, due to its good performance in analyzing the signals that presents non stationary characteristics. This technique has eventually become a powerful alternative when compared to the traditional Fourier Transform (FT) [1] [2].Fig.1 shows the normal heart sounds, composed of four different sounds, namely S1, S2, S3 and S4.The pumping action of a normal heart is audible by the 1st heart sound (S1) and 2nd heart sound (S2). During systole, the AV valves are closed and blood tries to flow back to the atrium, causing back bulging of the AV valves. But the taut chordatetendineae (cord-like tendons that connect the papillary muscles to the tricuspid valve and the mitral valve in the heart) stop the back bulging and causes the blood to flow forward. This leads to vibration of the valves, blood and the walls of the ventricles which is presented as the 1st heart sound. During diastole, blood in the blood vessels tries to flow back to the ventricles causing the semi lunar valves to bulge. But the elastic recoil of the arteries cause the blood to bounce forward which vibrates the blood, the walls and the ventricular valves which is presented as the 2nd heart sound . The 3rd heart sound (S3) is heard in the mid diastole due to the blood that fills the ventricles. The 4th heart sound (S4), also known as atrial heart sound, occurs when the atrium contracts and pumps blood to the ventricles. S4 appears with a low energy and is almost never heard by the stethoscope [3].

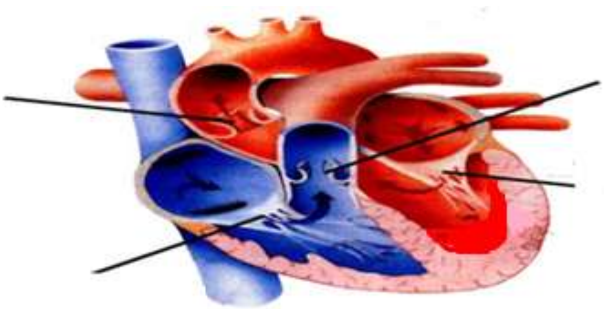

Fig 1: Anatomy of the Heart

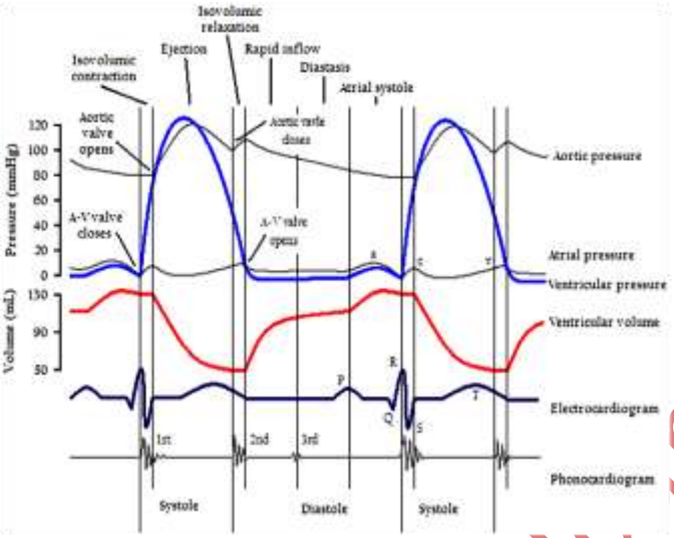

Fig 2: The Cardiac Cycle

Sound	Origin
1st heart sound	Closure of mitral and tricuspid valves
2nd heart sound	Closure of aortic and pulmonary valves
3rd heart sound	Rapid ventricular filling in early diastole
4th heart sound	Ventricular filling due to atrial contraction
Murmurs	Turbulent flow of blood
Others (Clicks, Snaps, Rubs)	Clicks: Aortic and pulmonary stenosis Snaps: AV valve stenosis Rubs: Inflammation of sac surrounding heart

Table 1: Various Heart Sounds

PCG is the graphical representation of heart sounds and murmurs. The timing and pitch of a heart sound are of significant importance in a diagnosis of a heart condition [4]. The features of a PCG signal such as heart sounds, the number of components for each sound, their frequency content and their time interval, can be measured more accurately by recent digital signal processing techniques [5]. According to the advances of signal processing techniques, PCG can be a useful diagnostic tool, revealing information that the human ear cannot offer. By the fact, expert systems PCG-based can be made. A new tentative to materialize such systems can be found in [5, 6, 7]. Compared to ECG, PCG diagnosis is much easier by just placing the stethoscope against the skin. The current problem with many PCG systems is noises from sounds of breathes, contact of the stethoscope with the skin and other ambient noises, which may corrupt the heart signals. Consequently, the PCG would be much more useful for diagnosis in home care system, if the noises were eliminated.

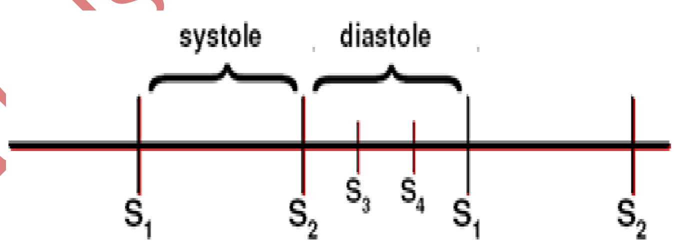

Fig 3: Locations of the Heart Sounds during Systole and Diastole

The PCG is of major importance to achieve a basic diagnosis when high-cost techniques, like echocardiography, are not available [7]. To record PCG signal waveform, a large amount of data is stored. Therefore, using the compression methods, one can reduce the space of the PCG signals data storage. The main goal of any compression technique is to attain maximum data reduction while preserving the significant signal morphology features upon reconstruction.

Materials and methods

Congenital heart defects or acquired heart valve diseases are often the cause of abnormal heart murmurs. Aortic stenosis, mitral regurgitation, aortic regurgitation, and mitral stenosis are among the most common pathological types of murmurs.

Input Heart Signal obtainment:

Input heart signals for investigation is downloaded from net These signals are converted into (.wav) format. These signals are:

- Normal Heart Sound
- Aortic Stenosis
- Mitral Stenosis
- Aortic Regurgitation
- Mitral Regurgitation

1) Normal Heart Sound

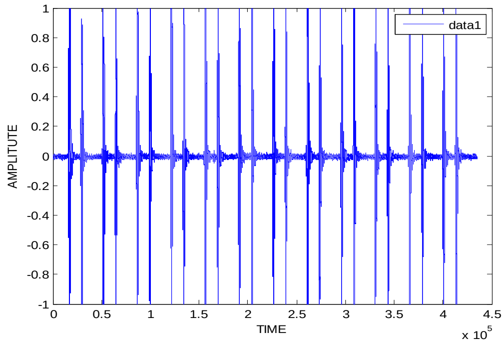

Fig.4 Normal heart sound

2) Aortic Stenosis

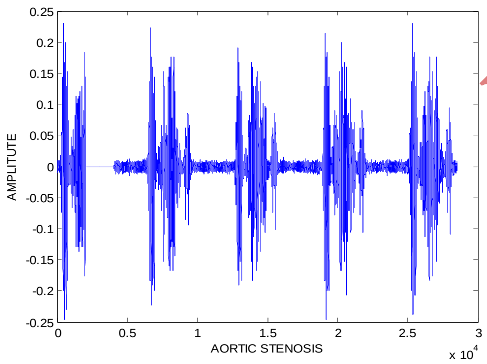

Fig.5Aortic Stenosis

3) Mitral Stenosis

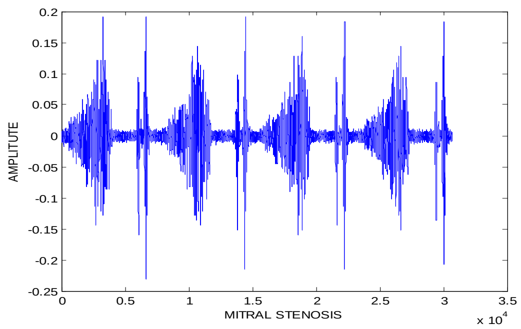

Fig6: Mitral Stenosis

4) Aortic Regurgitation

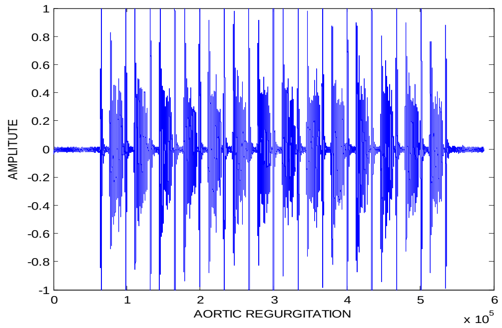

Fig7: Aortic Regurgitation

5) Mitral Regurgitation

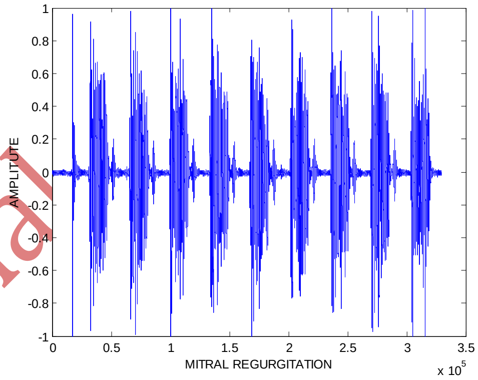

Fig8: Mitral Regurgitation

PCG Signal Analysis Challenges

The relations between the volume, the pressure, and flow of the blood in the heart determine the opening and closing of cardiac valves. Normal heart sounds occur as closing of the valves. In addition, the sounds, coming from flow of the blood inside the heart and vessels, are components of the heart sounds. Heart sounds and murmurs come in general from the movements of myocardial walls, opening and closing of valves, as well as from the flow of blood in and out of chambers. The sound emitted by a human heart during a single cardiac cycle consists of two dominant events, known as the first heart sound S1 and second heart sound S2. While S1 comes from closing of mitral and tricuspid valves, the S2 comes from closing of aortic and pulmonary valves. For the analysis of heart sounds, and for their naming within the literature as well, the heart has been divided into four regions. These are named as mitral, tricuspid, pulmonary, and aortic regions. These regions are not the anatomical locations of the heart valves, but the direction of blood flow through these valves. Comparing the sounds coming from each region with those coming from other regions, troubled region and reason for the related trouble are attempted to be identified [8]. In this study, using heart sounds obtained from mitral and pulmonary regions, mitral stenosis and pulmonary stenosis diseases have been diagnosed.

Abnormalities in the structure of the heart are mostly reflected in the heart sounds. Thus, in order to identify the abnormalities in the structure of the heart, physicians listen to mitral, tricuspid, pulmonary, and aortic sections. Nowadays, the most common method being used by physicians in diagnosing cardiac diseases is listening via stethoscope [7]. Listening to the voices, coming from the cardiac valves via a stethoscope, upon the flow of the blood running in the heart, physicians examine whether there is any abnormality with regard to the heart. However, listening with stethoscope has a number of constraints.

One of the main problems of PCG (phonocardiogram) signal analysis of interference of different sounds. These sounds may be external or internal. The external sound is avoided by using a soundproof room or other method its but internal sound like lung sound, vessel sound and muscle contraction sound are avoidable during the recording of PCG Signal. We separated the PCG signal from the lung sound from different wavelets and found the wavelet which gives the appropriate PCG Signal [1].

Main problem associated with parameter selection is that, for the classifier, a large number of input parameters will increase computationally intensive and time-consuming. Besides, the presence of the excess number of redundant, irrelevant, and noisy input variables may hide the meaningful variables in the data set. Therefore, choosing fewer features to represent data set is aimed rather than a large number of features [2].

The Wavelet Transform

Now that we know some situations when wavelet analysis is useful, it is worthwhile asking the questions "What is wavelet analysis?" And even more fundamentally, "What is a wavelet?" A wavelet is a waveform of effect, havinh a limited duration that has an average value of zero. Comparing wavelets with sine waves, which are the basis of Fourier analysis yields that Sinusoids do not have a limited duration, i.e.they extend from minus infinity to plus infinity, and while sinusoids are smooth and predictable, wavelets tend to be irregular and asymmetric as seen from the figure below:

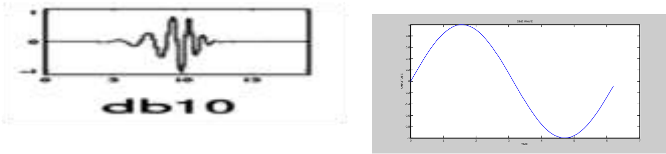

Fig 9(a) db-10 Wavelet (b) Sine wave

Fourier analysis consists of breaking up a signal into sine waves of various frequencies. Similarly, wavelet analysis is the breaking up of a signal into shifted and scaled versions of the original (or *mother*) wavelet. Just looking at pictures of wavelets and sine waves, we can see intuitively that signals with sharp changes might be better analysed with an irregular wavelet than with a smooth sinusoid, just as some foods are better handled with a fork than a spoon. It also makes sense that local features can be described better with wavelets, which have local extent.

Number of Dimensions

So far we have discussed only one-dimensional data, which encompasses most ordinary signals. However, wavelet analysis can be applied to two-dimensional data — images; and, in principle, to higher-dimensional data. This toolbox uses only one- and two-dimensional analysis techniques.

The Continuous Wavelet Transform

Mathematically, the process of Fourier analysis is represented as

$$F(w) = \int_{-\infty}^{\infty} f(t) e^{-jwt}\, dt \qquad (1)$$

Where *F(w)* represents the Fourier Transform.
It is the sum over all time of the signal *f (t)* multiplied by a complex exponential.

The results of the transform are the *Fourier coefficients*, Similarly, the *continuous wavelet transform* (CWT) is defined as the sum over all time of the signal multiplied by scaled and shifted versions of the wavelet function

$$C(scale, position) = \int_{-\infty}^{\infty} f(t)\, ((scale, position, t)\, dt \qquad (2)$$

The Discrete Wavelet Transform

Calculating wavelet coefficients at every possible scale is a fair amount of work, and it generates an awful amount of data. What if we choose only a subset of scales and positions at which to make our calculations? It turns out, rather

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remarkably, that if we choose scales and positions based on powers of two — so-called dyadic scales and positions — then our analysis will be much more efficient and just as accurate. We have obtained just such an analysis from the discrete wavelet transform (DWT). An efficient way to implement this scheme using filters was developed in 1988 by Mallat. The Mallat algorithm is in fact a classical scheme known in the signal processing community as a two-channel subband coder This very practical filtering algorithm yields a fast wavelet transform — a box into which a signal passes, and out of which wavelet coefficients quickly emerge.

Discrete wavelet transform is having two component first one is scaling component and second one is wavelet component. In DWT S (n) in sample of signal, where, n=0, 1,2,……………..M-1, Where j is scaling factor and k is shifting factor

Scaling function

$$W\Phi\,(Jo,k) = \frac{1}{\sqrt{M}}\sum_n S(n).\Phi(n)_{jo,k} \qquad (3)$$

Wavelet Function

$$W\psi\,(j,k) = \frac{1}{\sqrt{M}}\sum_n S(n).\psi(n)_{j,k} \qquad (4)$$

Where $\frac{1}{\sqrt{M}}$ Is Normalizing term, so the S (n) can be written as

Thus the Discrete Wavelet Transform is defined as:

$$W\,(a,b) = \int_{-\infty}^{\infty} f(t)\frac{1}{\sqrt{a}}\boldsymbol{\psi} * \left\{\frac{t-b}{a}\right\} dt \qquad (5)$$

Wavelet analysis has practically become a ubiquitous tool in signal processing. Two basic properties, space and frequency localization and multi-resolution analysis, make this a very attractive tool in signal analysis. The wavelet transform method processes perfect local property in both time space and frequency space and it use widely in the region of vehicle faults detection and identification.

An Introduction to the Wavelet Families

There are many members in the wavelet family, a few of them that are generally found to be more useful, are as per the following

Haar Wavelet

Any discussion of wavelets begins with Haar, the first and simplest. Haar is discontinuous, and resembles a step function. It represents the same wavelet as Daubechies db1. Haar wavelet is one of the oldest and simplest wavelet. Therefore, any discussion of wavelets starts with the Haar wavelet

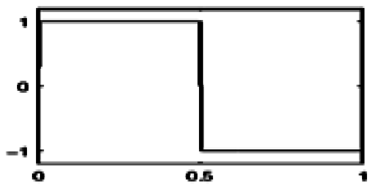

Fig 10: Haar Wavelet

Daubechies Wavelets

Daubechies is compactly supported orthonormal wavelets and found application in DWT. Its family has gotten nine members in it.

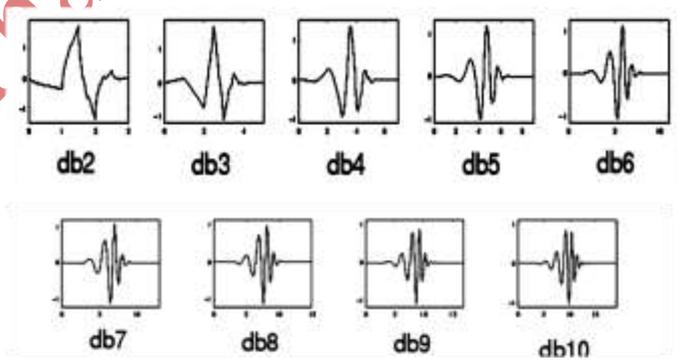

Fig 11: Daubechies Wavelets

Coiflets Wavelets

The wavelet function has 2N moments equal to 0 and the scaling function has 2N-1 moments equal to 0. The two functions have a support of length 6N-1.

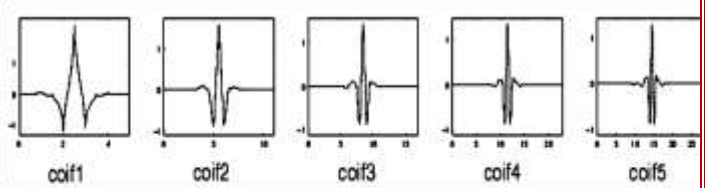

Fig 12: Coiflets Wavelets

Similarly there are various other types of wavelet families. The choice of a particular wavelet family and the level of decomposition depend on the signal to be analyzed.

Wavelet Analysis of PCG Signals

The analysis of Phonocardiogram signals is demonstrated using Discrete Wavelet Transform.
The platform chosen for this analysis is MATLAB.
Initially the PCG signal in the form of a .wav file is loaded into the MATLAB workspace.
Subsequently the file is read and decomposed using the Discrete Wavelet Transform (DWT).
The family of wavelets and the number of levels has to be chosen. An illustration for the above mentioned steps is shown below. As the number of levels increases, the time complexity of the algorithm increases. The number of levels is generally decided according to the type of signal under analysis. The following illustration shows the decomposition using Haar Wavelets at level 10.

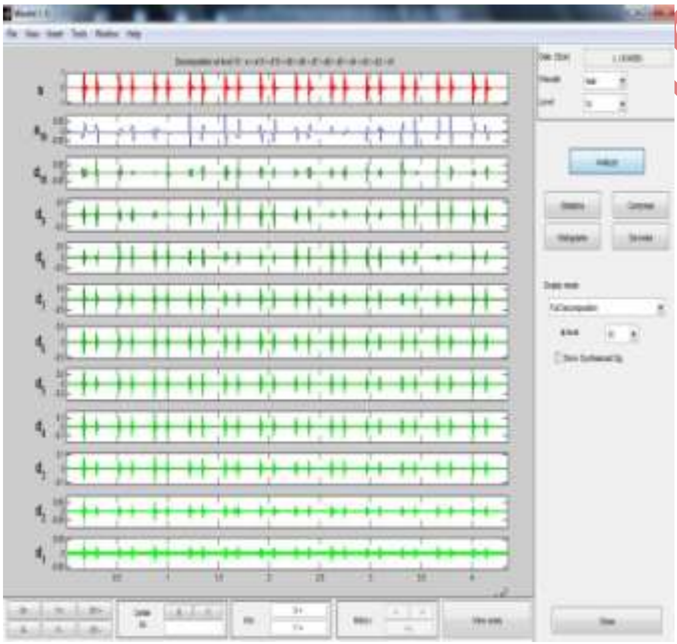

Fig. 13 Wavelet Decomposition of Normal.wav using Haar Wavelets at level 10

Parameters for Analysis

Variance

Variance is defined as Mean Square value of the signal, computed after the mean value has been removed.

$$\sigma^2 = \frac{1}{N}\sum_{i=1}^{N}(xi-\mu)^2$$

σ=Variance, N=no of samples ,Xi=input heart signal μ= mean

Standard Deviation

Standard Deviation (s) is defined as Square root of the variance i.e. MS value of the signal, computed after the mean value has been removed

$$S=\sqrt{\sigma^2} = \sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(xi-\mu)^2}$$

Spectral Energy

The energy of the signal can be computed as the squared sum of its spectral coefficients' normalized by the length of the sample window. The energy metric has been used to identify the mode of transport of a user with a single accelerometer, respectively walking, cycling, running and driving.

$$E_f = \int_{-\infty}^{\infty} f(t)^2$$

Entropy

Entropy is used to measure a system's level of disorder in physics of thermodynamics. Entropy measurement is an ideal method in order to measure the level of disorder of a non-stationary signal. Besides, entropy is also being used for the purpose of measuring average amount of information that an event contains.
Entropy = -sum (P * log (P)). (P=probability vector)

Conclusion

In this survey, phonocardiogram signals have been introduced along with their genesis. The need for the analysis of phonocardiogram signals has been validated. Subsequently the different abnormalities in the phonocardiogram signals have been introduced and the respective signals have been illustrated along with their plots. Next, the insufficiency of conventional Fourier Methods for the analysis of abruptly changing signals like the PCS has been demonstrated which leads to the need for tools like the Wavelet Transform. The wavelet transform is defined mathematically and various wavelet families and their number of decomposition levels have been introduced. Finally, a normal heart sound has been decomposed using the Discrete Wavelet Transform. It is expected that the contents of this paper will render greater insights into wavelet analysis and its application to Phonocardiogram Signals.

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