

An Optimized Analysis of Phonocardiogram Signals Using Discrete Wavelet Transform

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Abstract: Heart related diseases presently pose one of the major threat worldwide. Heart abnormalities show a wide variation because of which accurate diagnosis becomes challenging. Phonocardiogram (PCG) signals and their analysis has opened up a new paradigm in telemedicine. The abrupt fluctuations and the randomness of the PCG signals make them difficult to analyze and extract key parameters called features. Conventional Fourier techniques fail in this regard. In this paper, we have proposed a wavelet based technique wherein the discrete wavelet transform (DWT) have been used for the processing and feature extraction of the PCG signals using a sliding window approach. The results obtained for various Wavelet Families have been tabulated for ready reference. The features extracted are maximum energy, variance, entropy and standard deviation. The features extracted can be subsequently utilized for the classification of the PCG signals.

Keywords:-ECG-Electrocardiogram , PCG-Phonocardiogram, AS- Aortic Stenosis , AR- Aortic Regurgitation , MS- Mitral Stenosis, MR- Mitral Regurgitation , DWT- Discrete Wavelet Transform, ENER-Energy ,STD-Standard Deviation,VAR-Variance, NHS- Normal Heart Sound

I. Introduction

The heart is divided into 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 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 techniques has been carried out from the past few years, due to its good performance in analyzing the signals that present 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 chordatendineae (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].

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. Due to this, expert PCG-based systems 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 the 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. The PCG is of major importance to achieve a basic diagnosis when high-cost techniques, like echocardiography, are not available [7][12][14]. 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 signal data. The main goal of any compression technique is to attain maximum data reduction while preserving the significant signal morphology features upon reconstruction.[11][15]

II. 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. [13]

A. Input Heart Signal obtainment:

Input heart signals for investigation are downloaded from standard biomedical website, these signals are converted into (.wav) format. They are:

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

1) Normal Heart Sound

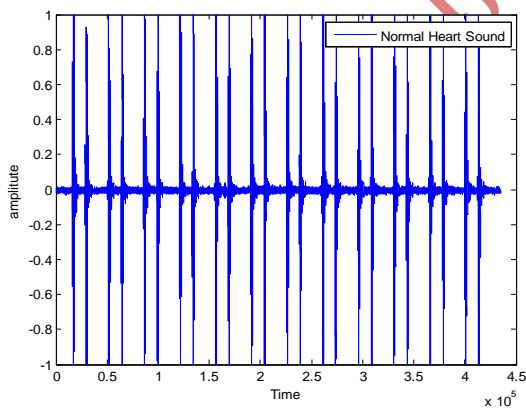


Fig.1 Normal heart sound

2) Aortic Stenosis

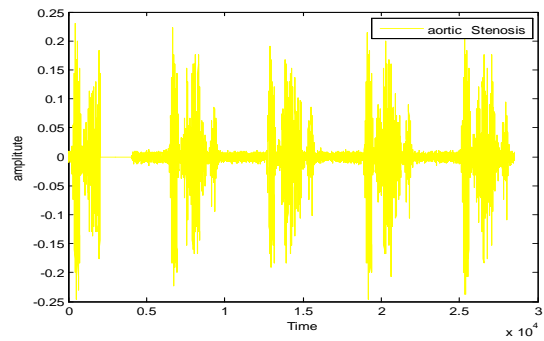


Fig.2 Aortic Stenosis

3) Mitral Stenosis

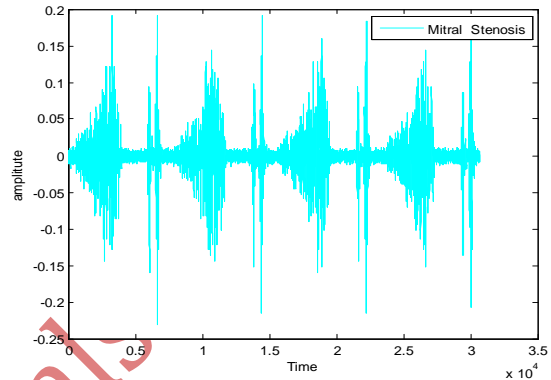


Fig3: Mitral Stenosis

4) Aortic Regurgitation

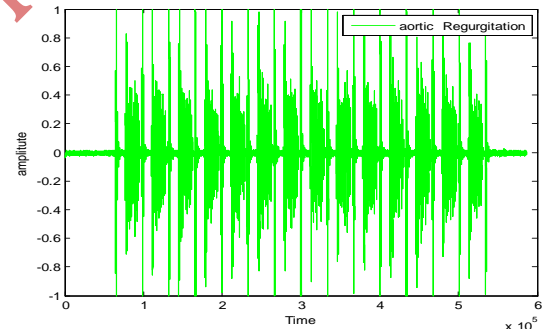


Fig4: Aortic Regurgitation

5) Mitral Regurgitation

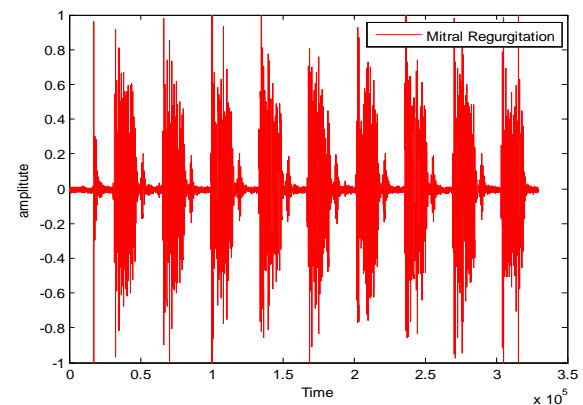


Fig5: Mitral Regurgitation

B. Discrete wavelet transform

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. The general definition of the wavelet transform is given as [9]:

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

Where a and b are real and *denote complex conjugate and (t) is wavelet function.

C.Parameters

1) Variance

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

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

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

2) 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

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

3) 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.

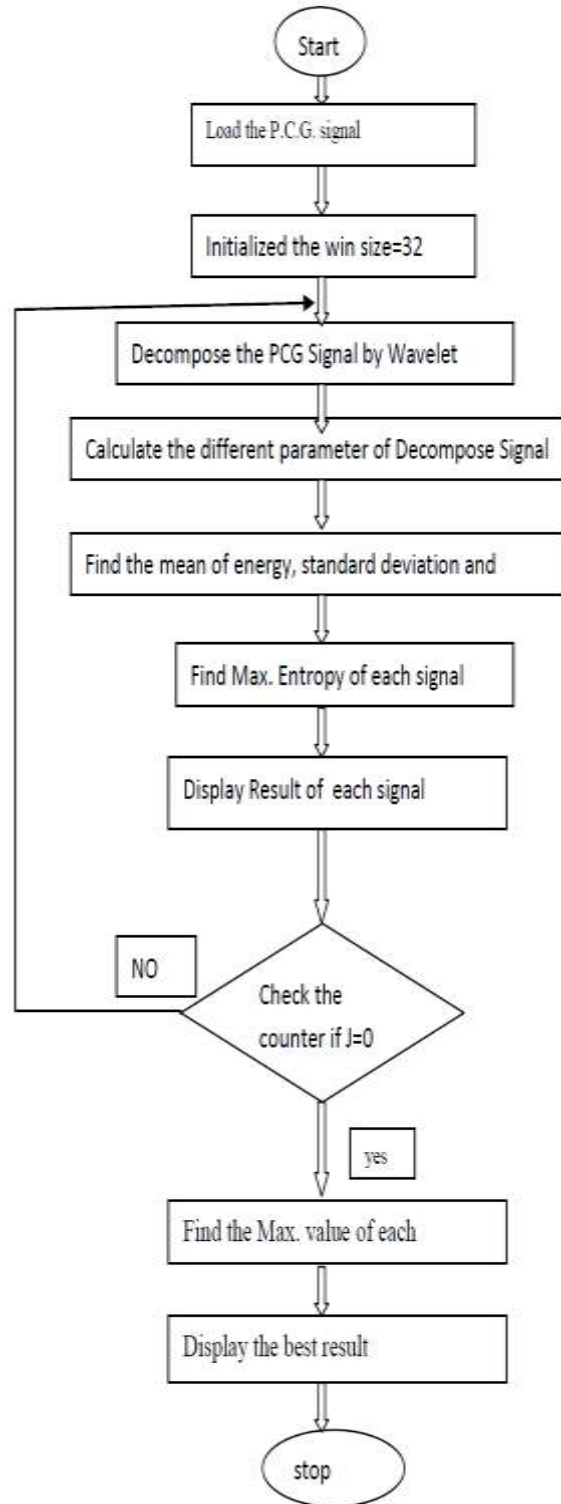
$$E_f = \sum_{-\infty}^{\infty} |x[n]|^2 \quad \dots\dots\dots(iv)$$

4) 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 the average amount of information that an event contains.

Entropy = -sum (P * log (P)). (P=probability vector)
(v)

III Flow Diagram of Methodology



IV Experimental results

In this study, for the diagnosis of heart diseases we worked on db4 discrete wavelet transform from level-1 to 10 for getting best feature of respective heart sound .DWT based biomedical systems has been developed by using the heart sounds, obtained from a total of 5 heart sounds. Stages of feature extraction

have been realized by using MATLAB R2009a software package.

A) Feature extraction using DWT

In this study, DWT has been used to derive feature vectors from the heart sound signals. Selecting proper level of wavelet (DWT) and determining decomposition at best level play a significant role in the analysis of Heart Sound using discrete wavelet transform method. This decomposition levels is figured out based on the sampling frequency components of the signal.[8] Using DWT as a filter at several levels helps in finding the best level of decomposition.[9] There are apparent differences between the graphics of the heart sound of a normal subject and those from patients with Aortic Stenosis ,Mitral Stenosis ,Aortic Regurgitation & Mitral Regurgitation diseases. These differences, being reflected to heart sound graphics, are also reflected largely to DWT graphics. Therefore, such a classification system, established by taking such variances in DWT graphics into consideration, enables to decide on respective diseases.[10]

V Results

A) Normal heart sound Analysis for Level-1 to 10 with each parameter.

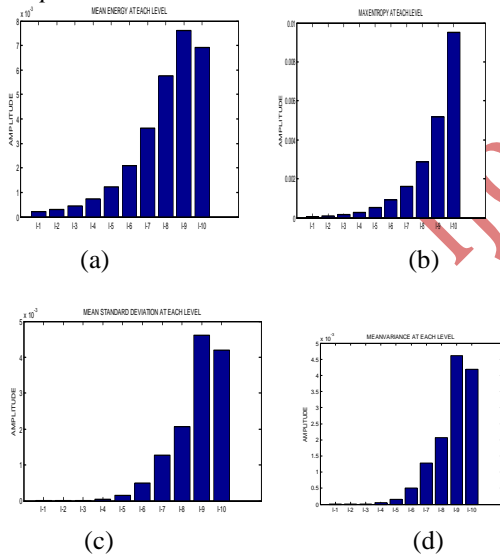


Fig (a) Max.Entropy, (b) Mean Energy, (c) Mean STD,(d)Mean VAR for Normal Heart Sound.

In this bar graph we plot the Normal Heart Sound. It's evaluated by the parameter like Mean Energy, Mean Standard deviation, Mean Variance & Max. Entropy for DWT Level-1 to 10 keeping the spacing of the windows (win size), 32 for each parameter.

B) Aortic Regurgitation heart sound Analysis for Level-1 to 10 with each parameter

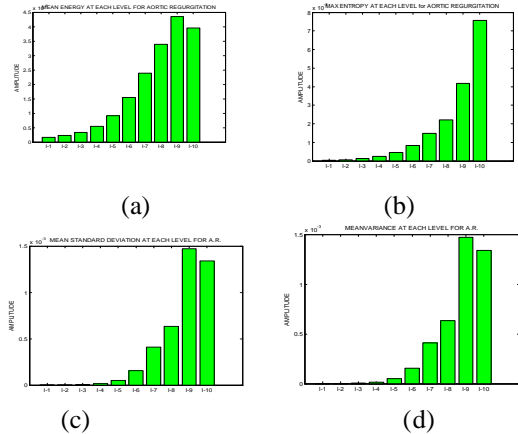


Fig (a) Max.Entropy,(b) Mean Energy,(c) Mean STD,(d)Mean VAR for Aortic Regurgitation Heart Sound.

In this bar graph we plot the Aortic Regurgitation. It's evaluated by the parameter like Mean Energy, Mean Standard deviation, Mean Variance & Max. Entropy for DWT Level-1 to 10 keeping the spacing of the windows (win size), 32 for each parameter.

C) Mitral Regurgitation heart sound Analysis for Level-1 to 10 with each parameter.

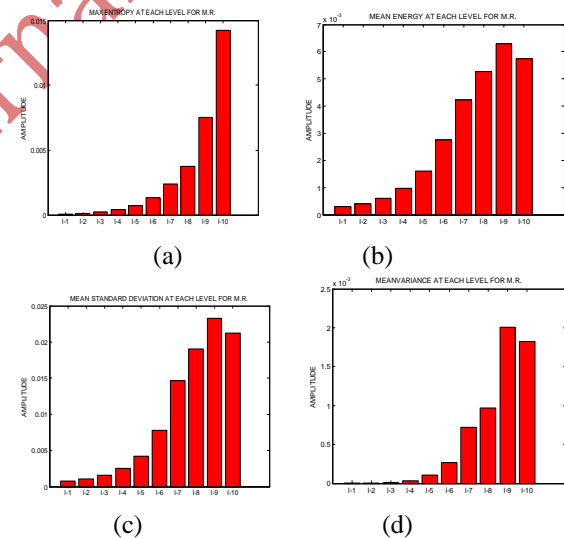


Fig (a) Max.Entropy,(b) Mean Energy,(c) Mean STD,(d)Mean VAR for Mitral Regurgitation Heart Sound.

In this bar graph we plot the Mitral Regurgitation. It's evaluated by the parameter like Mean Energy, Mean Standard deviation, Mean Variance & Max. Entropy for DWT Level-1 to 10 keeping the spacing of the windows (win size), 32 for each parameter.

D) Aortic Stenosis heart sound Analysis for Level-1 to 10 with each parameter.

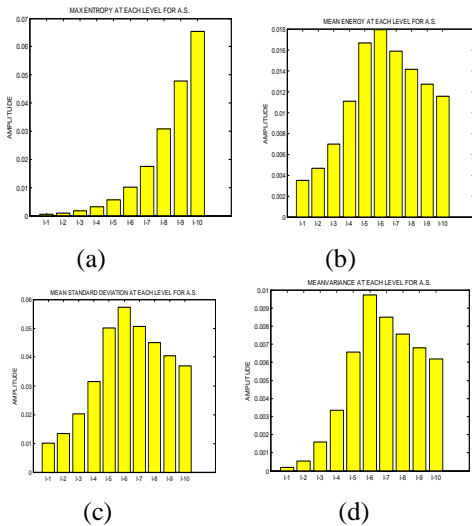


Fig (a) Max.Entropy, (b) Mean Energy, (c) Mean STD,(d)Mean VAR for Aortic Stenosis Heart Sound.

In this bar graph we plot the Aortic Stenosis. It's evaluated by the parameter like Mean Energy, Mean Standard deviation, Mean Variance & Max. Entropy for DWT Level-1 to 10 keeping the spacing of the windows (win size), 32 for each parameter.

E) Mitral Stenosis heart sound Analysis for Level-1 to 10 with each parameter.

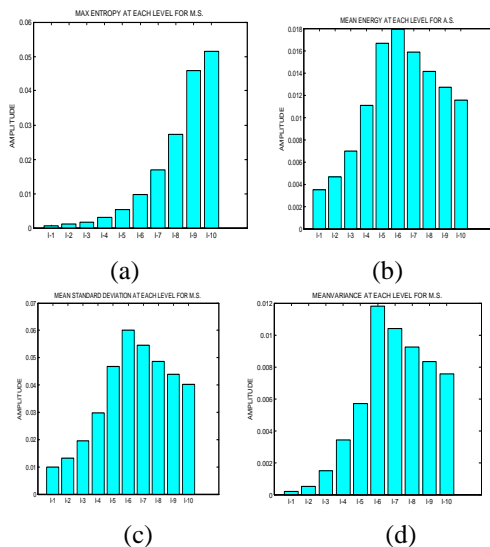


Fig (a) Max.Entropy, (b) Mean Energy, (c) Mean STD, (d) Mean VAR for Mitral Stenosis Heart Sound.

In this bar graph we plot the Stenosis. It's evaluated by the parameter like Mean Energy, Mean Standard deviation, Mean Variance & Max. Entropy for DWT Level-1 to 10 keeping the spacing of the windows (win size), 32 for each parameter.

V) Comparison Table

A) Table-1

| Signal | Mean Energy | Best level | Mean STD | Best level |
|--------|-------------|------------|----------|------------|
| NHS | 0.0076 | 9 | 0.0315 | 9 |
| AR | 0.0043 | 9 | 0.0180 | 9 |
| MR | 0.0063 | 9 | 0.0233 | 9 |
| AS | 0.0179 | 6 | 0.0572 | 6 |
| MS | 0.0204 | 6 | 0.0601 | 6 |

Table 1: Performance Analysis of P.C.G. signals with parameter like Mean Energy, Mean Standard Deviation

B) Table-2

| Signal | Mean VAR | Best Level | Max. Entropy | Best level |
|--------|----------|------------|--------------|------------|
| NHS | 0.0046 | 9 | 0.0095 | 10 |
| AR | 0.0015 | 9 | 0.0079 | 10 |
| MR | 0.0020 | 9 | 0.0143 | 10 |
| AS | 0.0097 | 6 | 0.0654 | 10 |
| MS | 0.0118 | 6 | 0.0516 | 10 |

Table 2: Performance Analysis of P.C.G. signals with parameter like Mean VAR, Max. Entropy

VI -Conclusion

In this study, a biomedical-based system has been developed for the feature Extraction of heart sound signals obtained from 5 signals with Normal, Aortic Stenosis, Mitral Stenosis, Aortic Regurgitation & Mitral Regurgitation diseases. In the first stage, for feature extraction, obtained heart sound signals were separated to its sub-bands using discrete wavelet transform (DWT) with Level-1 to Level-10. we get best feature for normal heart sound, Aortic Regurgitation & Mitral Regurgitation heart sound at level-9 for Aortic Stenosis & Mitral Stenosis, we get best feature at Level-6 because they have low amplitude & long duration signal with respect to other 3 heart signals.

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