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# Analysis of Various DWT Methods for Feature Extracted PCG Signals

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***Abstract*: One of the main obstacles states that the widespread use of phonocardiogram (PCG) in modern day's medicine is the various noise components they invariably contain. Although many advances have been made towards automated heart sound segmentation and heart pathology detection and classification, an efficient method for noise handling would come as a major aid for further development in this field, especially when it comes to working with PCGs collected in realistic environments such as hospitals and clinics. The feature extraction has been gone through 10 levels on PCG recorded signals using transformation techniques. Analyzing PCG signals with calculating parameters Energy, Standard deviation, Variance, Mean square error (MSE), Peak Signal to Noise Ratio (PSNR), Root Mean Square Error (RMSE) and Maximum Entropy (ME) values of human heart signal which were extracted from Phonocardiogram were calculated. These calculations are based on the filtration process. Wavelets considered as filtration technique as well as under goes 10 leveling factors. Different wavelets compared for analysis part such as Haar, Daubechies, Orthogonal, Coiflets and Biorthogonal and also finding histograms and denoising the signal were part in this proposed scheme using wave menu analysis.**

***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 a hollow muscular organ that pumps blood throughout the blood vessels to various parts of the body by repeated, rhythmic contractions. It is found in all animals with a circulatory system, which includes the vertebrates and 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.

The average human heart, beating at 72 beats per minute, will beat approximately 2.5 billion times during an average 66 year lifespan, and pumps approximately 4.7-5.7 litres of blood per minute. It weighs approximately 250 to 300 grams (9 to 11 oz) in females and 300 to 350 grams (11 to 12 oz) in males.

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

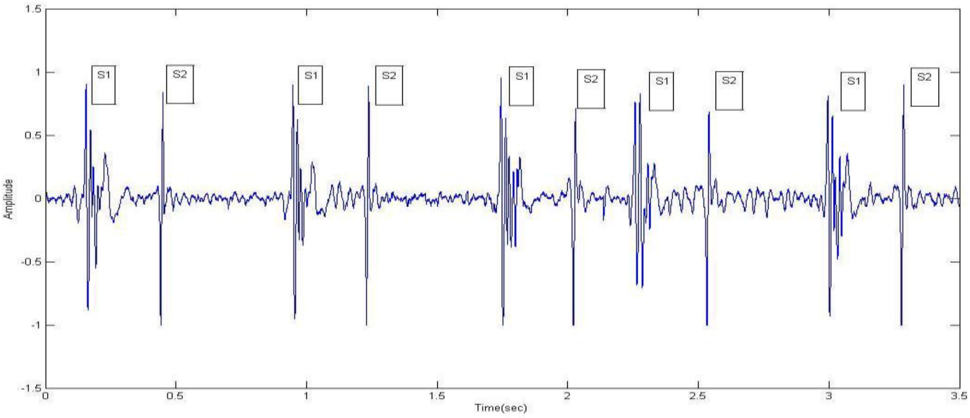



Figure (1): Heart Sounds for S1and S2 Signals.

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].

## II. Methodology

### *A. Input Heart signal Acquisition:*

Input heart signals for investigation are downloaded from standard biomedical website, these signals are converted into (.wav) format. Phonocardiogram is a graphic method of recording noises during his heart activity. Heart and vessels sounds are composed by audible and inaudible oscillations, but recordable. If a microphone specially designed to detect low-frequency sound is placed on the chest, the heart sounds can be amplified and recorded by a high-speed recording apparatus.

Figure 2. Recording A is an example of normal heart sounds, showing the vibrations of the first, second and third heart sounds and even the very weak atrial sound. Note specifically that the third and atrial heart sounds are each a very low rumble. The third heart sound can be recorded in only one third to one half of all people, and the atrial heart sound can be recorded in perhaps one fourth of all people.

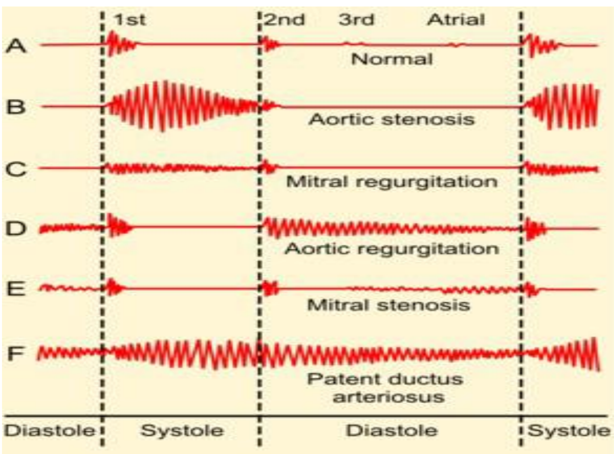



Figure 2: Phonocardiogram’s for normal (A) and abnormal heart sounds

### *B. Wavelet families:*

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.

Several families of wavelets that have proven to be especially useful. Some wavelet Families are: Haar, Daubechies, Bi-orthogonal, Coiflets, Sym lets, Morlet's, Mexican hat, Meyer, Other real wavelets, complex wavelets

- Haar:

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

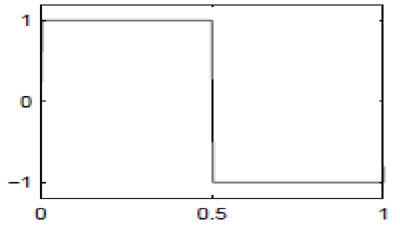



Figure 3: Step Response for Haar Wavelet

- Daubechies:

Ingrid Daubechies, one of the brightest stars in the world of wavelet research, invented what are called compactly supported orthonormal wavelets — thus making discrete wavelet analysis practicable. The names of the Daubechies family wavelets are written dbN, where N is the order, and db the "surname" of the wavelet. The db1 wavelet, as mentioned above, is the same as Haar wavelet. Here is the wavelet functions psi of the next nine members of the family:

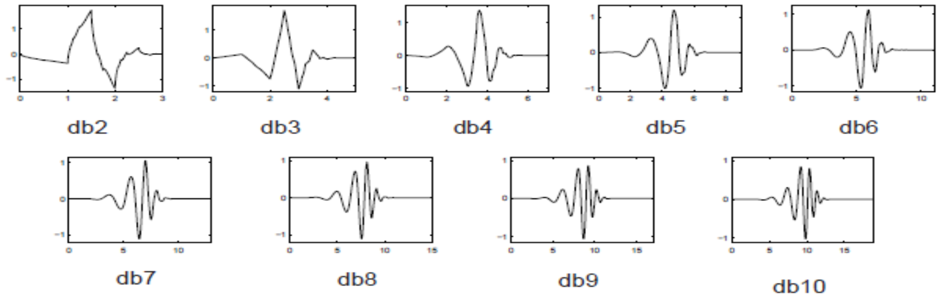



Figure 4: Different Daubechies Wavelets

- Bi-orthogonal Wavelet: This family of wavelets exhibits the property of linear phase, which is needed for signal and image reconstruction. By using two wavelets, one for decomposition (on the left side) and the other for reconstruction (on the right side) instead of the same single one, interesting properties are derived.

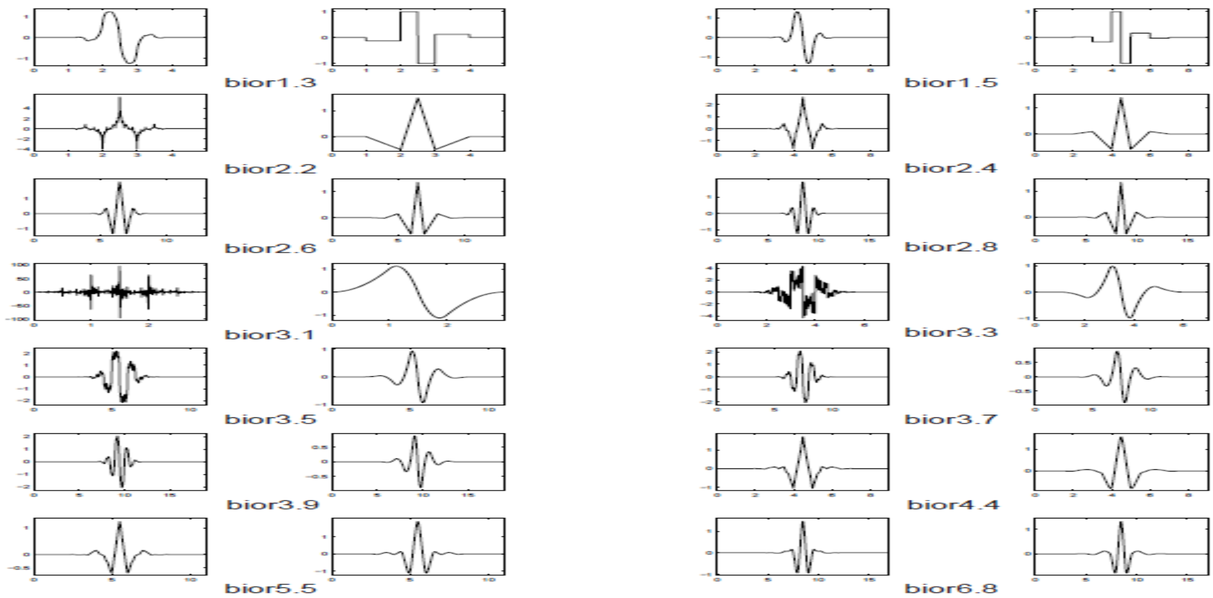



Figure 5: Different Biorhogonal Wavelets

- Coiflets: Built by I. Daubechies at the request of R. Coifman. 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. You can obtain a survey of the main properties of this family by typing wave info ('coif') from the MATLAB command line

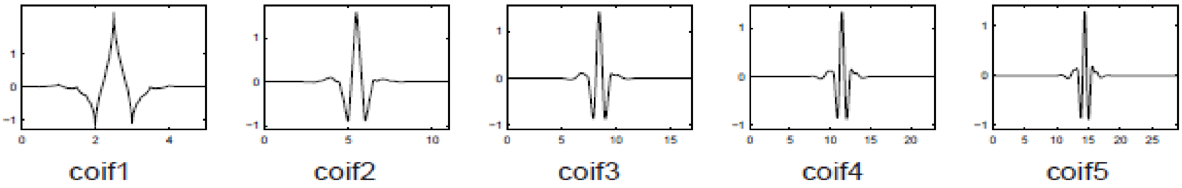



Figure 6: Various coiflets

- Symlets: The symlets are nearly symmetrical wavelets proposed by Daubechies as modifications to the db family. The properties of the two wavelet families are similar. Here is the wavelet functions psi.

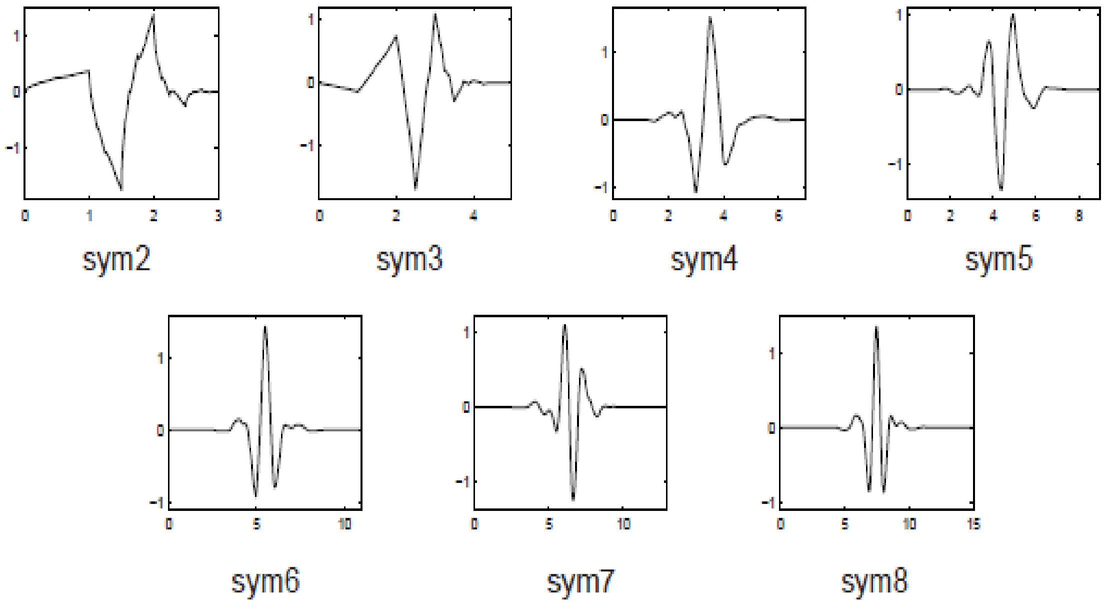



Figure 7: Representing the Symlets

*C. PARAMETERS:*

- Variance:

The variance of a random variable *X* is its second central moment, the expected value of the squared deviation from the mean $\mu = \mathrm{E}[X]$:

$$\mathrm{Var}(X) = \mathrm{E}\left[(X-\mu)^2\right].$$

This definition encompasses random variables that are discrete, continuous, neither, or mixed. The variance can also be thought of as the covariance of a random variable with itself:

$$\mathrm{Var}(X) = \mathrm{Cov}(X, X).$$

The expression for the variance can be expanded:

$$\begin{aligned}\operatorname{Var}(X) &= \operatorname{E}\left[(X - \operatorname{E}[X])^2\right] \\ &= \operatorname{E}\left[X^2 - 2X\operatorname{E}[X] + (\operatorname{E}[X])^2\right] \\ &= \operatorname{E}\left[X^2\right] - 2\operatorname{E}[X]\operatorname{E}[X] + (\operatorname{E}[X])^2 \\ &= \operatorname{E}\left[X^2\right] - (\operatorname{E}[X])^2\end{aligned}$$

- MAX ENTROPY:

The statistics and information theory, a maximum entropy probability distribution is a probability distribution whose entropy is at least as great as that of all other members of a specified class of distributions.

$$H^c(p(x)\|m(x)) = -\int p(x)\log\frac{p(x)}{m(x)}\,dx,$$

- Standard Deviation:

The standard deviation (SD) measures the amount of variation or dispersion from the average. A low standard deviation indicates that the data points tend to be very close to the mean (also called expected value); a high standard deviation indicates that the data points are spread out over a large range of values.

- ENERGY:

Energy is a word with more than one meaning. Energy means something has the ability to cause change.

Mostly it is used in science to describe how much potential a physical system has to change.

It may also be used in economics to describe the part of the market where energy itself is harnessed and sold to consumers.

It can sometimes refer to the ability for someone to act or speak in a lively and vigorous way.

- Peak signal-to noise-ratio:

Peak signal-to-noise ratio, often abbreviated **PSNR**, is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale.

Signal-to-noise ratio (often abbreviated **SNR** or **S/N**) is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power, often expressed in decibels. A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise. While SNR is commonly quoted for electrical signals, it can be applied to any form of signal (such as isotope levels in an ice core or biochemical signalling between cells).

$$\mathrm{SNR} = \frac{P_{\mathrm{signal}}}{P_{\mathrm{noise}}},$$

## III. EXPERIMENTAL RESULTS


Figure 8: Block Diagram for Proposed Scheme.

*A. SIGNAL ACQUISITION*:

Acquiring the heart beat signal from the database which is extracted from heart biometrics. 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 R2012R software package. Using wave read function converting the heart signal into a graphical representation.

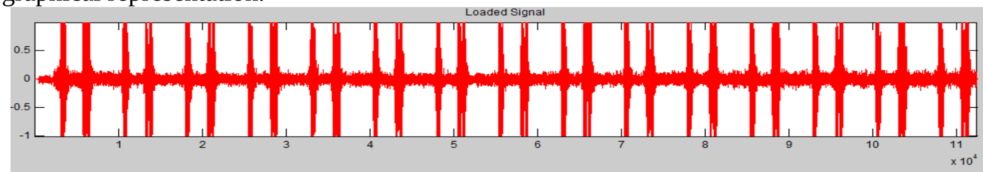



Fig 9. Converting heart signal in to Graphical form

*B. Wave menu:* By accessing wave menu comparing different wavelets along denoising the signal.

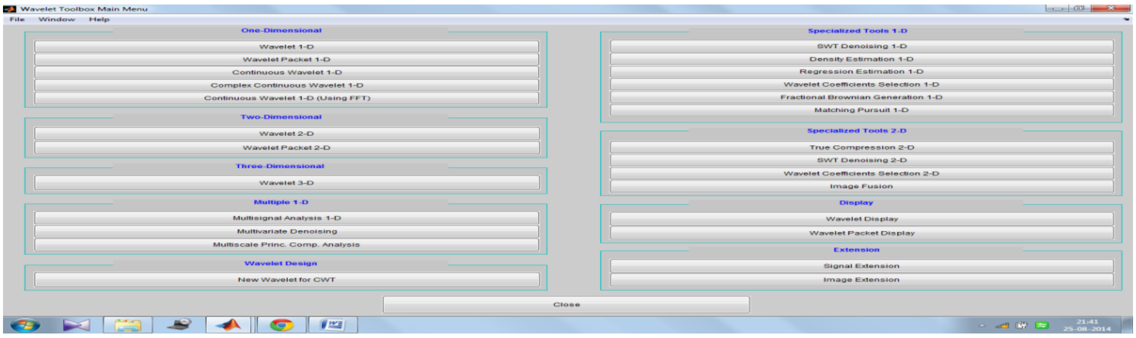
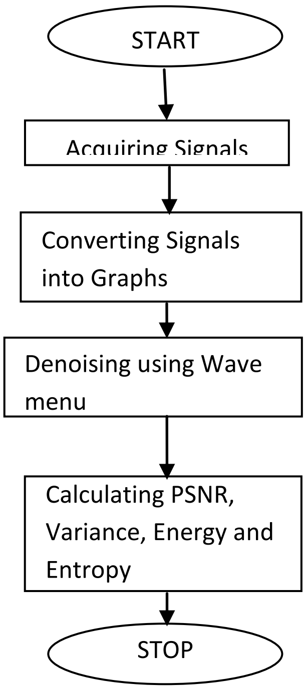



Fig 10. Wave menu

DWT has been used to derive feature Vectors from the heart sound signals. Selecting proper level of Wavelet 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. Using DWT as a filter at several levels helps in finding the best level of decomposition. 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.

*C. Calculation:* After wave menu and denoising signal PSNR, Variance, Energy, Entropy were calculated.

*D. FLOW CHART*



## IV. ANALYSIS OF DIFFERENT WAVELETS:

### 1. A. *Selecting Haar Wavelet:*

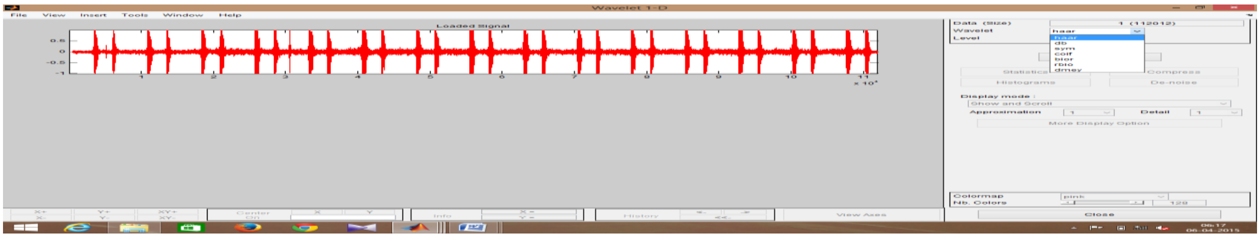


Figure 11. Haar wavelet applying the input signal

### *B. Comparison of original and denoised signal:*

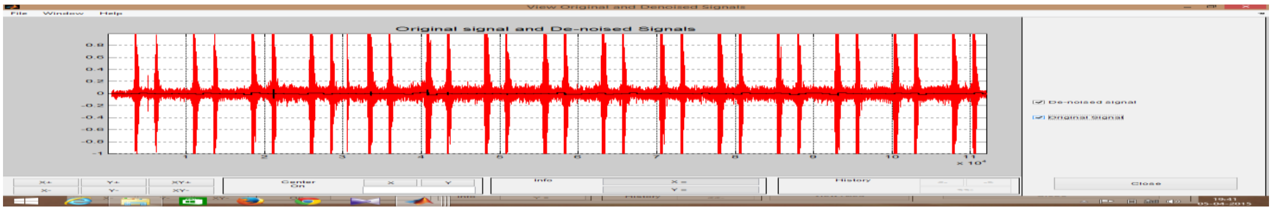


Figure 12. Comparison of original and denoised signal

### *C. Analyzing Signal with decomposition levels:*

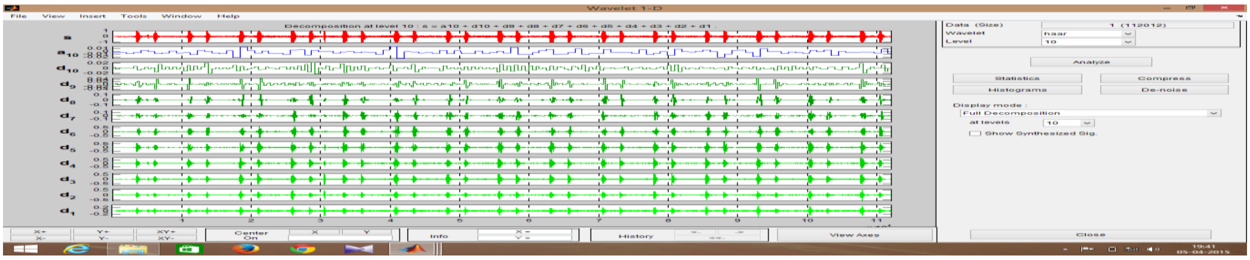


Figure 13. Analyzing the signal for all decomposition levels

Decomposition levels s =a10+d9+d8+d7+d6+d5+d5+d4+d3+d2+d1

### D. *Calculation of Parameters:*

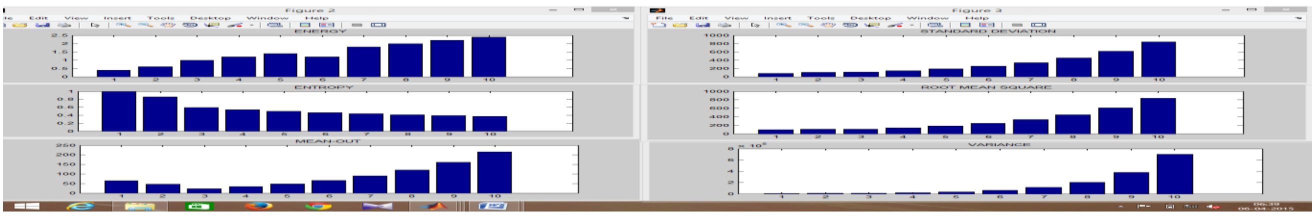


Figure 14. Different parameters

### 2. A. *Selecting Biorthogonal Wavelets:*

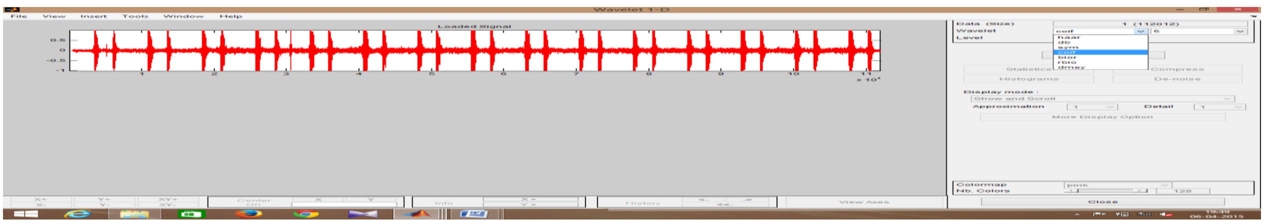


Figure 15. Biorthogonal wavelet applying the input signal

*B. Comparison of original and denoised signal:*

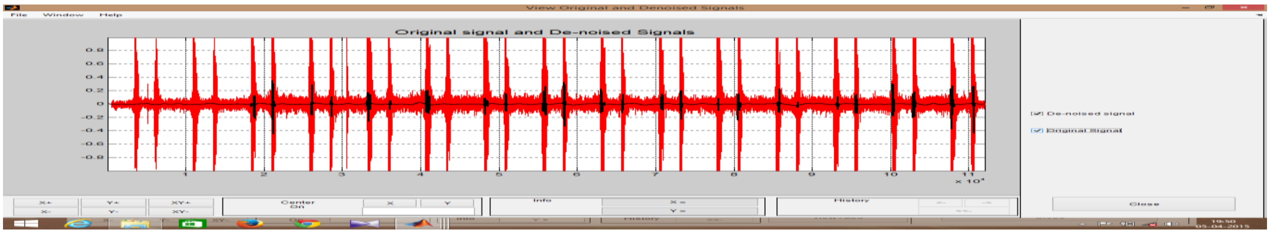



Figure 16. Comparison of denoised and original signal

*C. Analyzing Signal with decomposition levels:*

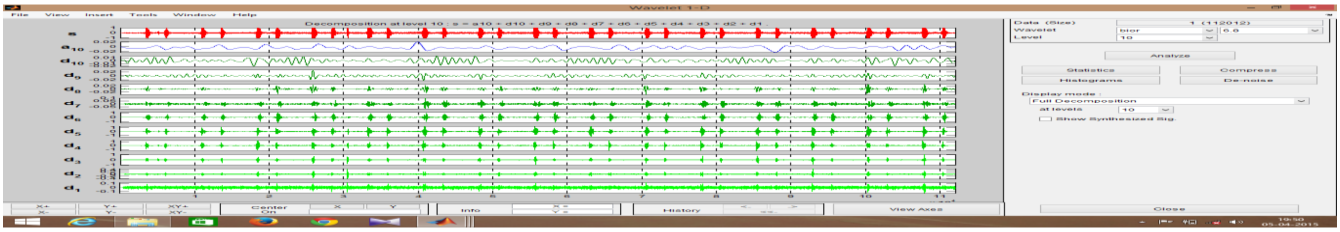


Figure 17. Analyzing the signal for all decomposition levels

Decomposition Levels S =a10+d9+d8+d7+d6+d5+d5+d4+d3+d2+d1

*D.Calculation of parameters:*

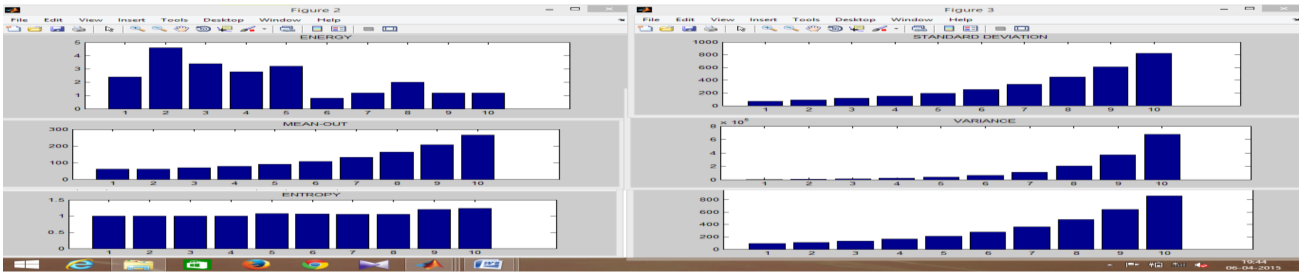



Figure 18. Different parameters

3. *A. Selecting Coiflet Wavelet:*

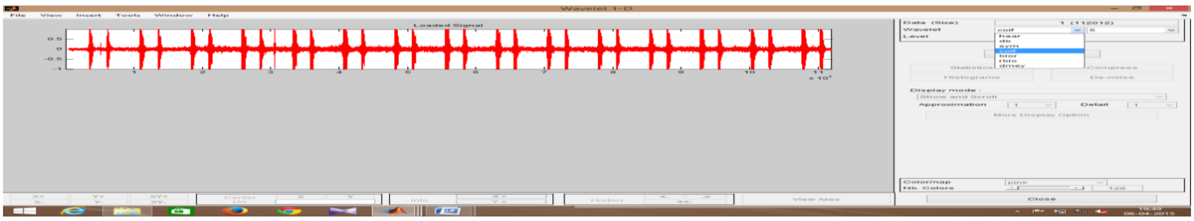


Figure 19. Coiflet wavelet applying the input signal

*B. Comparison of denoised and original signal:*

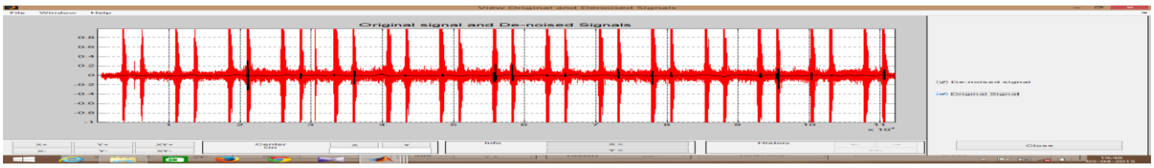



Figure 20. Comparison of original and denoised signal

*C. Analyzing Signal with decomposition levels:*

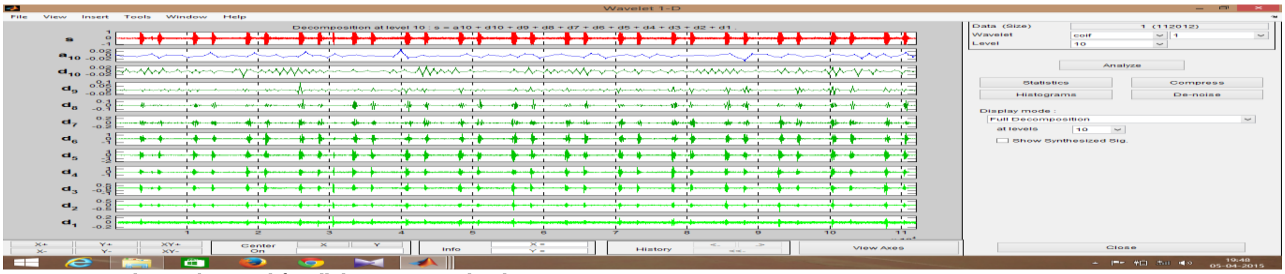


Figure 21. Analyzing the signal for all decomposition levels

Decomposition Levels S =a10+d9+d8+d7+d6+d5+d5+d4+d3+d2+d1

*D. Calculation of parameters:*

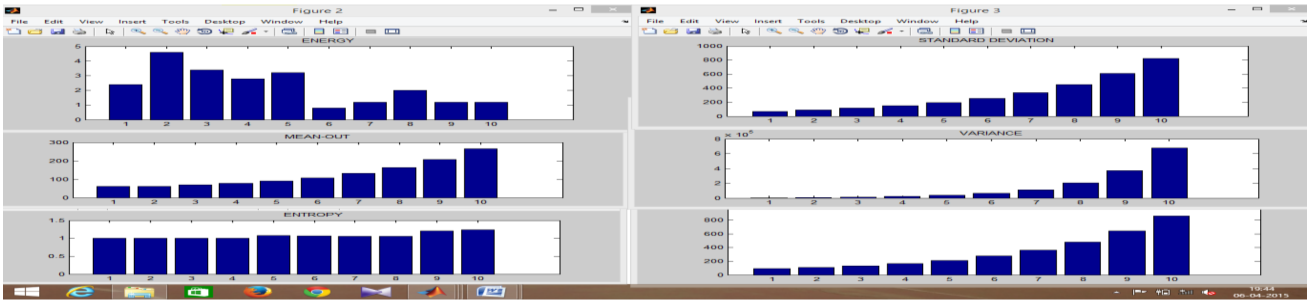



Figure 22. Different parameters

4. *A. Selecting Symlet Wavelet:*

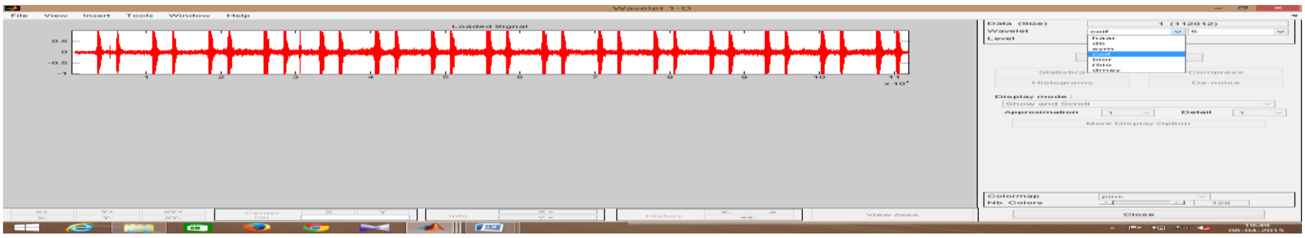


Figure 23. Symlet wavelet applying the input signal

*B. Comparison of denoised and original signal:*

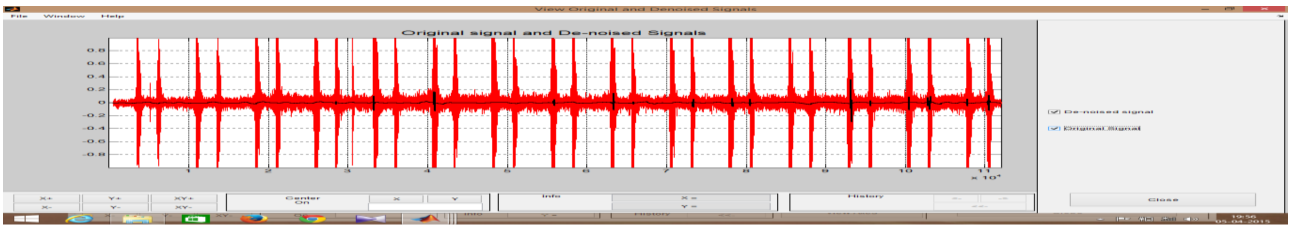



Figure 24. Comparison of original and denoised signals

*C. Analyzing Signal with decomposition levels:*

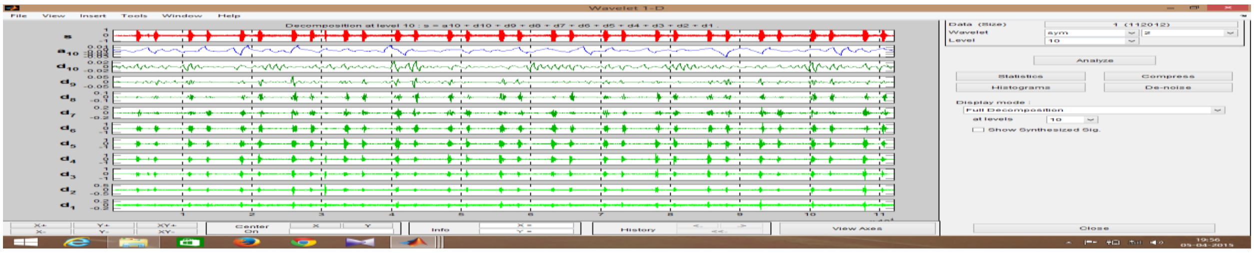


Figure 25. Analyzing the signal for all decomposition levels

Decomposition Levels S =a10+d9+d8+d7+d6+d5+d5+d4+d3+d2+d1

*D. Calculation of parameters:*

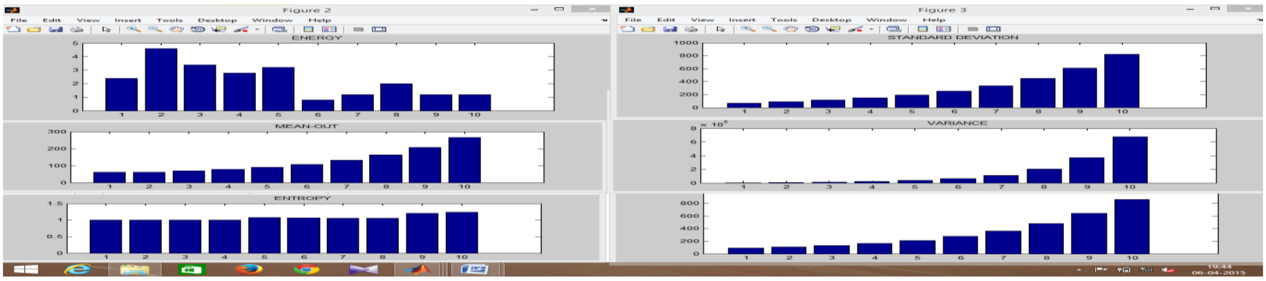



Figure 26. Different parameters

## V. COMPARISON TABLES

| BIORTHOGONAL: PARAMETERS | | | | | | |
|---|---|---|---|---|---|---|
| LEVEL | ENERGY | STD.DEVIATION | VARIANCE | RMS | MEAN | ENTROPY |
| 1 | 1.3333 | 72.32757 | 0.0552 | 102.2412 | 71.7038 | 1.0000 |
| 2 | 1.2222 | 99.0206 | 0.0981 | 120.6622 | 70.5855 | 1.1345 |
| 3 | 0.2222 | 129.1677 | 0.1668 | 148.8588 | 76.0548 | 1.1038 |
| 4 | 0 | 167.4848 | 0.2805 | 186.8588 | 85.0539 | 1.0868 |
| 5 | **1.7778** | 219.2796 | 0.4808 | 239.7027 | 99.4809 | 1.2263 |
| 6 | 1.7778 | 289.9728 | 0.8408 | 312.5573 | 119.9432 | 1.5095 |
| 7 | 0.8889 | 386.4620 | 1.4935 | 412.3109 | 147.8239 | 1.8041 |
| 8 | 0 | 518.2618 | 2.6860 | 548.6257 | 185.2386 | 2.1766 |
| 9 | 0.6667 | 698.5166 | 4.8793 | 374.9157 | 235.1667 | 2.3310 |
| 10 | 0.6667 | **945.3923** | **8.9377** | **989.7441** | **301.7005** | **2.4729** |

| HAAR WAVELET:PARAMETERS | | | | | | |
|---|---|---|---|---|---|---|
| LEVEL | ENERGY | STD.DEVIATION | VARIANCE | RMS | MEAN | ENTROPY |
| 1 | 0.6667 | 77.5479 | 0.0601 | 103.3729 | 72.6199 | **1.0000** |
| 2 | 0.5556 | 96.3941 | 0.0929 | 108.9710 | 58.5455 | 0.9457 |
| 3 | 0.6667 | 114.2607 | 0.1306 | 121.8419 | 53.6462 | 0.9183 |
| 4 | 0.6667 | 120.9712 | 0.1463 | 121.8419 | 37.8276 | 0.8113 |
| 5 | 0.7778 | 164.4227 | 0.2703 | 165.1935 | 48.3080 | 0.7793 |
| 6 | 0.8889 | 224.1892 | 0.5026 | 224.8771 | 62.4415 | 0.7496 |
| 7 | 1.2222 | 306.4556 | 0.9392 | 307.0739 | 81.4885 | 0.7219 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8 | 1.1111 | 419.8046 | 1.7624 | 420.3642 | 107.1675 | 0.6962 |
| 9 | 1.4444 | 576.1471 | 3.3195 | 576.6566 | 141.8220 | 0.6723 |
| 10 | **1.5556** | **792.0186** | **6.2739** | **792.4848** | **188.6489** | 0.6500 |
| COIFLET WAVELET:PARAMETERS | | | | | | |
| LEVEL | ENERGY | STD.DEVIATION | VARIANCE | RMS | MEAN | ENTROPY |
| 1 | 0.8889 | 76.8953 | 0.0591 | 103.8852 | 72.8121 | 1.0000 |
| 2 | 0.5556 | 100.1194 | 0.1002 | 117.7363 | 66.0721 | 0.9980 |
| 3 | 0.3333 | 126.0577 | 0.1589 | 139.9195 | 66.1651 | 1.1916 |
| 4 | 0.2222 | 164.7530 | 0.2714 | 178.9175 | 76.4024 | 1.1393 |
| 5 | 0.1111 | 217.4429 | 0.4728 | 232.7706 | 91.2881 | 1.1546 |
| 6 | 0 | 289.2748 | 0.8368 | 306.5477 | 111.7750 | 1.2784 |
| 7 | 1.0000 | 387.3072 | 1.5001 | 407.3683 | 139.3936 | 1.3991 |
| 8 | 0.2222 | 521.2832 | 2.7174 | 545.1303 | 176.3294 | 1.4917 |
| 9 | **1.0000** | 704.6552 | 4.9654 | 733.5294 | 225.5993 | **1.5744** |
| 10 | 0.4444 | **986.0221** | **9.1398** | **991.5075** | **291.3196** | 1.5374 |
| SYMLET WAVELET:PARAMETERS | | | | | | |
| LEVEL | ENERGY | STD.DEVIATION | VARIANCE | RMS | MEAN | ENTROPY |
| 1 | 0.8889 | 78.2069 | 0.0612 | 105.4748 | 74.2853 | **1.0000** |
| 2 | 0.4444 | 100.6584 | 0.1013 | 115.0163 | 61.8091 | 0.9852 |
| 3 | 0.6667 | 124.5850 | 0.1552 | 133.6927 | 57.6402 | 0.9544 |
| 4 | 1.0000 | 163.3963 | 0.2670 | 173.2281 | 68.6646 | 0.9819 |
| 5 | 1.1111 | 216.4295 | 0.4684 | 227.4835 | 83.8819 | 0.9940 |
| 6 | 1.0000 | 288.8590 | 0.8344 | 301.6666 | 104.4068 | 0.9988 |
| 7 | **1.7778** | 387.8446 | 1.5042 | 403.0321 | 131.8471 | 1.0000 |
| 8 | 1.6667 | 523.2856 | 2.7383 | 541.6296 | 168.4277 | 0.9992 |
| 9 | 1.5556 | 708.8686 | 5.0249 | 731.3587 | 217.1863 | 0.9975 |
| 10 | 1.0000 | **963.5249** | **8.2838** | **991.4417** | **282.2549** | 0.9953 |

Table 1: Comparison of different wavelets

## VI. CONCLUSION

Different wavelets are considered for the analysis of heart sounds such as HAAR, DB, Bior, Ortho, Coiflets and Symmlets. In this paper PSNR, Variance, Mean, Entropy, Energy and denoising the values along level 10decomposition has been calculated and shown the graphs above section. The decomposition and Denoising are calculated and plotted under the basis of wave menu from MATLAB. The factors are calculated and were shown their analysis under different wavelets. So, the maximum probable output has been shown and plotted as bar graphs even histogram levels were calculated and plotted in this paper. After completing all dwt methods it is found that coiflet is the best method among the various wavelet methods

## VII. REFERENCES: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