# Wavelet Transform As Method for ECG Signal Analysis

**Pooja Sabherwal**

***Abstract*—Theory of wavelet transform is a young branch of applied mathematics extensively developing from early 1980's. Recently, the wavelet transform is studied as applications to digital signal processing. Its application to biomedical signal processing has been found particularly useful in the study of the signals like ECG. In this review, the emerging role of the wavelet transform in the interrogation of the ECG is discussed in detail. In this paper an algorithm has been proposed to determine the r peaks and the number of betas in sampled signal. In the first step an attempt was made to generate ECG waveforms by developing a suitable MATLAB simulator and in the second step, using wavelet transform, the ECG signal was denoised by removing the corresponding wavelet coefficients at higher scales. Then R-Peak in QRS complexes were detected and the last step is to calculate the beat. For this Mat lab 7.4.0 environment has been, used and Db4 taken as mother wavelet. The maximum value of the approximation coefficients of level 4 is selected as the indicating parameter.***

***Keywords: ECG, Wavelet transform, beat calculation, R-peak.***

## I. INTRODUCTION

Electrocardiograms (ECGs) are signals that originate from the action of the human heart. The ECG is the graphical representation of the potential difference between two points on the body surface, versus time. ECG recordings are examined by a physician who visually checks features of the signal and estimates the most important parameters of the signal. Using this expertise the physician judges the status of a patient. Therefore the recognition and analysis of the ECG signals is a very important task and difficult also because of the size and form of these signals (due to noise and other artifacts).

However, ECG being a non-stationary signal, the irregularities may not be periodic and may show up at different intervals. Clinical observation of ECG can hence take long hours and can be very tedious.ECG gives two kinds of information. One, the duration of the electrical wave crossing the heart which in turn decides whether the electrical activity is normal or slow or irregular and the second is the amount of electrical activity passing through the heart muscle which enables to find whether the parts of the heart are too large or overworked.

The ECG signal is characterized by five peaks that are P, Q, R, S, and T. In some cases we also use another peak called U (with an uncertain origin). The performance of ECG analyzing system depends mainly on the accurate and reliable detection of the R-peak in the QRS complex. The QRS complex corresponds to the current that causes contraction of the left and right ventricles.

**Manuscript received November 15, 2013.**

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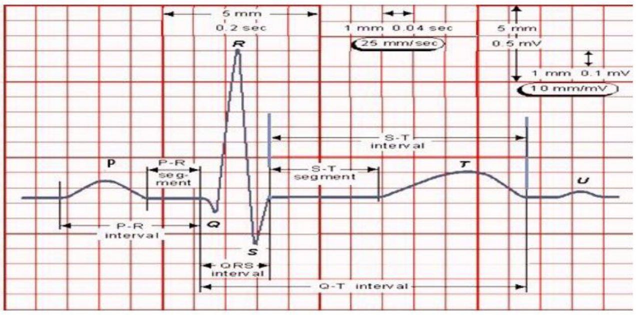
A typical ECG tracing of electrocardiogram baseline voltage is known as the isoelectric line. It is measured as the portion of the tracing following the *T* wave and preceding the next *P* wave. The cardiac cycle begins with the P wave, which corresponds to the period of atrial depolarization in the heart. This is followed by the QRS complex, which is usually the most relevant (recognizable) feature of an ECG waveform. The end point of the T wave represents the end of the cardiac cycle (presuming the absence of U wave).In the normal sinus rhythm (normal state of the heart) the P-R interval, QRS interval and amplitude of P, Q, R peaks are specified (fix value). So, from the recorded shape of the ECG, we can say whether the heart activity is normal or abnormal.




A lot of work has been done in the field of ECG signal Analysis using various approaches and methods. The basic principle of all the methods however involves transformation of ECG signal using different transformation techniques including Fourier Transform, Hilbert Transform, Wavelet transform etc. Physiological signals like ECG are considered to be quasi-periodic in nature. They are of finite duration and non stationary. Hence, a technique like Fourier series (based on sinusoids of infinite duration) is inefficient for ECG.Earlier method of ECG signal analysis was based on time domain method. But this is not always sufficient to study all the features of ECG signals.

Analysis of any signal refers to examine the frequency content of a signal. But the transforms like Fourier transform we might be able to determine all the frequencies present in a signal, we do not know when they are present. One more transform STFT was used for this purpose but the major drawback was that the STFT did not provide precise time and frequency precision in this with increase the time resolution reduces the frequency resolution vice versa. It also does not follow the Heisenberg Uncertainty Principle.

For STFT narrow window ===>good time resolution, poor frequency resolution.

Wide window ===>good frequency resolution, poor time resolution.

Mean we no longer know the exact frequency components that exist in the signal, but we only know a band of frequencies that exist.

So for these non stationary and time varied signals, a tool is required which can provide the accurate description of the ECG frequency Contents according to their location in time or we can say can justifies the use of time frequency representation jointly. Hence we opt a more suitable technique to overcome this drawback among the various time frequency transformations. The wavelet Transformation is found to be simple and more valuable.

The wavelet transformation is based on a set of analyzing wavelets allowing the decomposition of ECG signal in a set of coefficients. Each analyzing wavelet has its own time duration, time location and frequency band. The wavelet coefficient resulting from the wavelet transformation corresponds to a measurement of the ECG components in this time segment and frequency band.

Wavelets are the powerful tool for extracting information from such signals. The main thing behind these time frequency joint representations is to cut the signal of interest into several parts and then analyze the parts separately. The result will be a collection of time-frequency representations of the signal, all with different resolutions. Because of this collection of representations we can speak of multiresolution analysis.

## II. LITERATURE REVIEW

In 2005, Gordan Cornelia et al [3] used wavelet transforms as tool for processing non stationary signals like ECG signals.R.F.Von Borries et al [22] developed two channel filter banks to remove effectively the base line drift and S.Z.Mahmoodabadi et al [9] demonstrated the filtering of ECG signal by using Db4 and Db6 at higher scales to preserve various components of ECG signal. The distortion of R morphology occurs in classical wavelet approach and this drawback is removed by A Choukari et al [23] by applying their algorithm on detail coefficients of both noise free ECG signal and ECG signal corrupted with WGN. The authors claimed that the performance of their algorithm is superior compared to classical wavelet transform in restoring P and T waves without distorting R morphology. But the limitation is that it heavily depends upon the presence of the R waves in the first level of approximation of the noisy ECG signal. Again in 2006,S.A.Choukari et al [25] used second level decomposition for detecting QRS complex and fourth and fifth level of decomposition for detecting P and T waves.. They compared the performance of their algorithm with db5, db10, coif5, sym6, sym8, biorth5.5 by calculating MSE and SNR. This algorithm works effectively at low SNR to remove various noises but the main limitation is the presence of huge base line wonder .A robust QRS detection algorithm can be used for removing baseline wonder. In 2007, M.Kania et al [26], studied the importance of the proper selection of mother wavelet with appropriate number of decomposition levels for reducing the noise from the ECG signal. The authors claim that they obtained good quality signal for the wavelet db1 at first and fourth level of decomposition and sym3 for fourth level of decomposition. In 2008, C.Saritha et al [24] have identified different types of abnormalities using daubechies wavelets in MATLAB environment. D.T Ingole et al [27] used Dyadic wavelet Transform for extraction of ECG features, which is robust, highly efficient ,accurate and reliable. Fayyaz A.Afsar et al [28] proposed a method which is robust to noise based on DWT and PCA for classifying six different types of beats from the ECG. The merits of this algorithm are less complexity, good accuracy and time saving. In 2009 Tan Yun-fu et al [8] used Daubechies and symlet wavelets for the removal of various kinds of noises present in the ECG signal and reconstructed ECG signal with minimum distortion at faster rate. Abed Al Raof Bsoul et al [29] used two mother wavelets namely Haar for the detection of QRS morphology and db2 for the detection of P and T waves at fourth decomposition level to obtain high accuracy. In 2010, Abdel-Reman at el [7] used the high pass filtering for noisy signal before reconstruction by inverse discrete wavelet transform (IDWT).This algorithm is very robust for noise removal and it does not smoothens QRS complex. Ruchitha Goutham et al [23] have demonstrated the application of DyWT for QRS complex detection. Naregalkar Akshay et al [24] demonstrated the application of UWT for base line wonder removal and QRS morphology detection in LABVIEW environment. Antonio et al [30] used wavelet transform to detect the R-wave and wavelet segmentation approach for the extraction of ECG features.

## III. THEORY

The WT uses a short time interval for evaluating higher frequencies and a long time interval for lower frequencies. Due to this property, high frequency components of short duration can be observed successfully by Wavelet Transform. Here we have used Discrete Wavelet Transform (DWT) to extract relevant information from the ECG signal. DWT performs a multilevel one-dimensional wavelet analysis using either a specific wavelet ('wname') or specific wavelet decomposition filters; the definition of DWT is given as

$$W(a,b) = \int_{-\infty}^{\infty} f(t)\psi_{a,b}(t)dt$$

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi^*\left(\frac{t-b}{a}\right)$$

Where * denotes complex conjugation and, ($\Psi$) $a$ $b$ (t) is a window function called the mother wavelet, ***a*** is a scale factor b is a translation factor. Here $\psi\left(\frac{t-b}{a}\right)$ is a shifted and scaled version of a mother wavelet which is used as bases for wavelet decomposition of the input signal. A good mother wavelet is one which has ability to fully reconstruct the signal from the decompositions. The selection of relevant wavelet is an important task before starting the detection procedure. The choice of wavelet depends upon the type of signal to be analyzed. The wavelet similar to the signal is usually selected. This similarity can also be decided on the basis of the cross-correlation between the two Functions.

There are several wavelet families like Harr, Daubechies,Biorthogonal, Coiflets, Symlets, Morlet, Mexican Hat, Meyer etc. and several other Real and Complex wavelets. However,Daubechies (Db4) Wavelet has been found to give details more accurately than others. Moreover, this Wavelet shows similarity with QRS complexes. Therefore, we have chosen Daubechies (Db4) Wavelet for extracting ECG features in our application.



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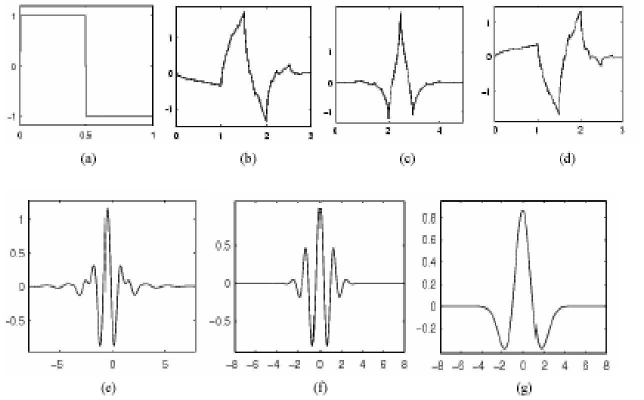

**Fig-2.Wavelet Families (a) Haar (b) Daubachies4 (c) Coiflet1 (d) Symlet2 (e) Mayer (f) Morlet (g) Mexican Hat**

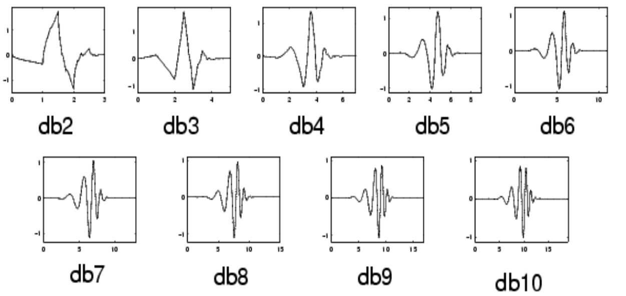


**Fig-3. Daubechies family**

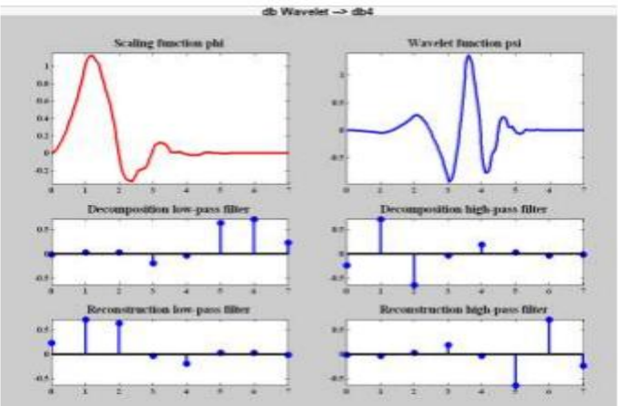


**Fig-4.Decomposition and reconstruction of Db4 Wavelet**

Discrete Wavelet Transform is also referred to as decomposition by wavelet filter banks. This is because DWT uses two filters, a low pass filter (LPF) and a high pass filter (HPF) to decompose the signal into different scales. The output coefficients of the LPF are called approximations while the output coefficients of the HPF are called details. The approximations of the signal are what define its identity while the details only imparts nuance. This decomposition process is iterative. The approximation signal may be passed down to be decomposed again by breaking the signal into many levels of lower resolution components. This is called multiple-level decomposition and may be represented in a wavelet decomposition tree. Only the last level of approximation is save among all levels of details, which provides sufficient data to fully reconstruct the original. At every level, the filtering and sub-sampling will result in half the time resolution and double the frequency resolution.

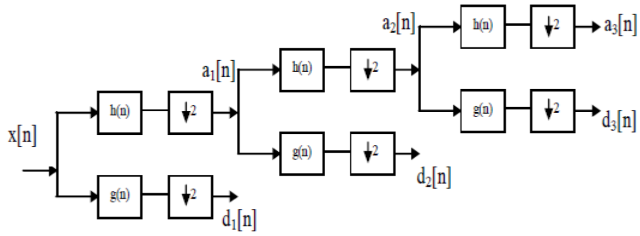


**Fig-5.Decomposition to Approximations and the Details**

The reconstruction process is the reverse of decomposition, where the approximation and detail coefficients at every level are up-sampled by 2 and passed through LPF and HPF synthesis filters and finally added as shown in Fig. The same number of levels is taken as in the case of decomposition.

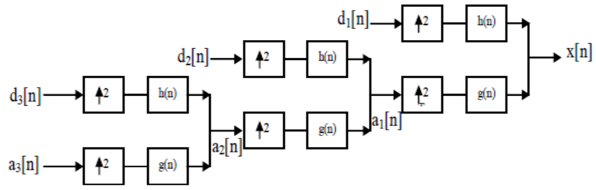


**Fig-6.Reconstruction of original signal.**

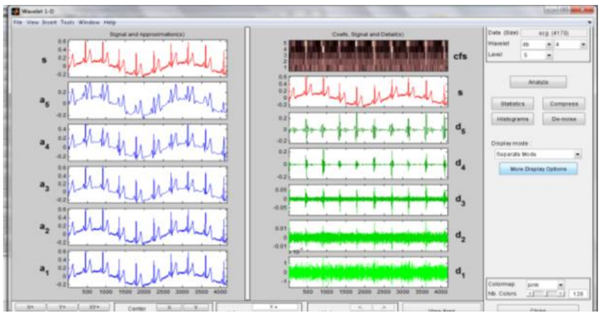

**Fig-7.**

## IV. ANALYSIS

Detection of Rpeaks in the QRS-complexes plays very important role in the analysis of ECG signal. Number of heart beats and irregularity of the heart beat can be determined from the R peak. Below is the algorithm given to preprocess the signal and determine the R –peaks in QRS complex using DWT.The developed algorithm initially makes the ECG signal smooth and then the feature extraction done (finding Rpeaks and finally Beat Calculation).

The process of analyzing the ECG signal can be divided into two stages: the stage of preprocessing and feature extraction. Preprocessing means removing noise (baseline wandering).Noise removal leads to compression and smoothing the ECG signal. The stage of feature extraction from cardio signal is the process of finding the required information (the R-Peak, complexes, etc.)

*A.Removal of the baseline drift*-Baseline wander can be caused by respiration. Baseline wander makes manual and automatic analysis of ECG records difficult especially makes difficulty in diagnosing ischemia. In wandering baseline, the isoelectric line changes position.

Removal of baseline wander is therefore required in the analysis of the ECG signal.

a). The original ECG signal is processed with a filter (moving avg filter).

b) By subtracting the filtered signal from the original signal, a signal with baseline drift elimination can be obtained

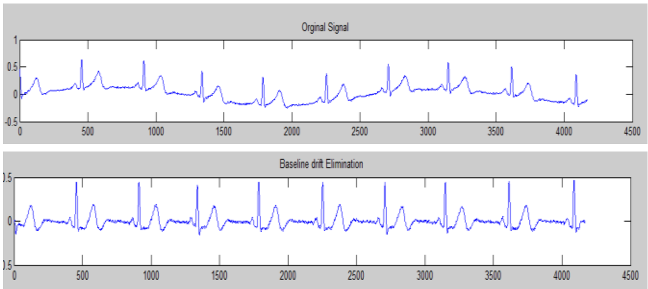


**Fig-8**

*B. Removal of the NOISE*- To remove the noise, we use Discrete Wavelet transform. This first decomposes the ECG signal into several sub bands by applying the Wavelet Transform, and then modifies each wavelet coefficient by applying a threshold function, and finally reconstructs the denoised signal.

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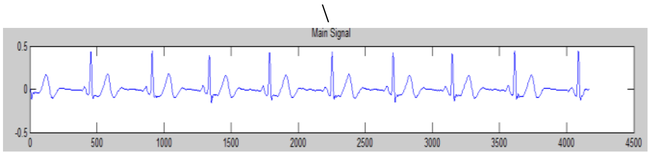


**Fig-9.Denoised signal**

After removing baseline wander, the resulting ECG signal is more stationary and explicit than the original signal.

*C.Thresholding*-At wavelet analysis the signal is decomposed into approximate coefficients, which represent the smoothed signal, and the detailing coefficients that describe the noise. Such components can be removed using the process of thresholding that is by removing the coefficients whose values are less than the value threshold.

Thresholding today is a perspective tool for the treatment of cardio noise (high frequency components). Here we have used soft thresholding.

Threshold= (max_value-mean_value)/2

*D.R-Peak detection*-In order to detect the peaks, specific details of the signal are selected. The R peak in the has the largest amplitude among all the waves compared to other leads. To detect R-waves, the specific detail components of decomposed signals are kept and the other components of low frequency and high frequency are removed The QRS complex detection consists of determining the R point of the heartbeat. To make the R wave more noticeable the obtained signal is squared. Finally the number of beats was calculated. For this we need to know the time interval between successive heartbeats.

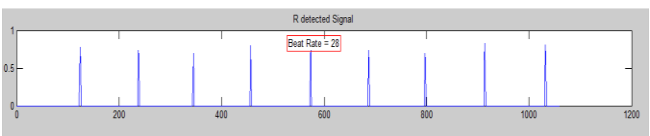


**Fig-10**

## V. CONCLUSION

Our sole objective of this project was to develop a method for efficient analysis of ECG signal. In this piece of work, we have proposed an algorithm to smooth the ECG signal and Find the most valuable R-peaks. Same approach can be extending further to find the P, T, U waves. Hence our future work will be dedicated to more of feature extraction and classification. As the irregularity of a heart beat can be determined based on the R-R interval of ECG signal, it is difficult for physicians to manually detect R waves, as it is a time consuming process. Therefore the proposed algorithm can be used to automatically detect R-peaks number of beats in the sampled ECG signals. Which reduces the time and increases the accuracy. Thus the performance of the proposed system is increased.

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