# Noise elimination and ECG R peak detection using wavelet transform

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# Noise Elimination and ECG R peak detection using wavelet transform

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*Abstract*-**In this paper a brief study of Electrocardiogram has been done. Then for feature extraction purpose only initial step i.e. R-peak detection has been done. Also R peak localization points are collected. For this purpose wavelet transform has been used. But before detection of R peak the original signals are passed through IIR low pass filter to remove high frequency noise in it. Power line interference has been reduced using comb filter. At last sensitivity and positive predictivity of the signals are calculated. Analysis is carried out in MATLAB simulation environment and BIH-DB [Boston's Beth Israel Hospital Database], PTB-DB [Physikalisch Technical Bundesanstalt Database] and fantasia-db database is used for analysis. R peaks are detected with an average sensitivity and predictivity of 99.98% and 99.68% over 120 different ECG data records considered.**

***Keywords-Electrocardiogram, Wavelet transform, Low pass filter, localization, threshold, sensitivity, predictivity.***

## I. Introduction

Nowadays heart diseases become one of the biggest threats in our world, which can be controlled by easy and early diagnosis of different clinically significant ECG features.

ECG is a diagnosis tool, which is the electrical exposition of contractile intercourse of the heart. This is a non-invasive technique that is the procedure does not involve with break the skin or physically enter into the body [4]. Due to de-polarization and re-polarization of the atria and ventricles the electrical dynamism is generated records as graphical measure which indicates direction i.e. time information in second by the x-axis and magnitude i.e. voltage in mV by the y-axis.

In normal condition cardiac cells are in electrically polarization i.e. cell's inner sides are negatively charged relative to its outer side. In depolarization the cardiac cells miss out their negativity and gain a wave by spreading depolarization from cell to cell which produce electric current flow and detected from the surface of the body by several electrode. After completion of depolarization the cells are again come to its previous normal polarization condition and it also detected by electrode [3][9][10]. The electrocardiogram contains several peaks named as P, Q, R, S, T and U and those are shown in Fig.1, is an ideal waveform of ECG [14][12]. P wave depicts atrial depolarization and ventricular depolarization is depicted by QRS complex. Where T wave depicts ventricular repolarization [15][16][17][19]. Clinically U wave is very small in magnitude not an important one and interestingly it is inconspicuous of 70% people. The human electrocardiogram has frequency range of 0.05Hz-150Hz but useful information present in 0.05Hz to 45Hz [5][6][7][8][9]. Among these peaks R peak is the most dominant one. So by detection of R-peak localization we can extract the feature of electrocardiogram. But with ECG signal various noises like baseline drift, motion artifacts, EMG from the chest wall, instrumentation noise, muscle noise, electrosurgical noise, disturbances due to power supply variations in the device, interference of RF signal etc. also present [3][1][2][13].So at first it is very much necessary to remove the disturbances with appropriate filtering without any effect with original ECG signal. Clinically significant ecg features are polarity, height and duration of different ECG component wave peaks and the time interval between different fiducial points. R peak is the most prominent among the ECG component wave peaks. QRS complex contain high deflection voltage 10-20mV and age and gender has also effect on it [18]. R peak detection can be considered as the starting point of analysing an ECG signal. With respect to detected R peak positions, other ECG component wave peaks localization and their features can be detected. From the detected successive R peak locations, heart rate can be estimated. Slower heart rate (i.e. less than 60 beats per second) may lead to bradycardia, whereas faster heart rate (greater than 100 beats per second) may lead to tachycardia. In this paper an effort is made to detect

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R peak localizations from a single lead ECG data by analyzing the signal in frequency domain.

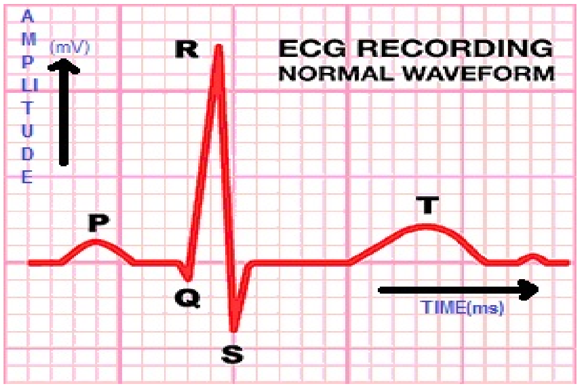



Fig. 1 Normal ECG waveform

In Fourier transform though we get good frequency resolution but we lost time information completely. If we think about Short Time Fourier transform (STFT) then we able to get time and frequency information both but this is not an optimal tool for ECG analysis. In STFT window size is fixed and hence not suitable for analyzing a non-stationary signal like ECG. So we move with wavelet tool as window size is not fixed here and it provide time and frequency information both better than other mentioned[11].

Wavelel is a powerful multiresolution tool which analyzes a signal at different frequencies into different resolutions. It means that it represent same signal corresponding all different frequency band. Wavelet means a short wave, has an oscillation like wave containing amplitude starts from zero, increase and reduced back to zero.

According to J. Morlet, Wavelet is a colony of functions organized from translations and dilations of a function called the "Mother Wavelet" ψ(t). Another way we can say that "Mother Wavelet" is a prototype which generates other window functions which are finite in practice.

They are defined by,

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

and a,b are real.

Where 'a' is scale or scaling parameter which measures degree of compression and 'b 'is translation parameter which indicates the time location of the wavelet.

Case I: If |a|>1 then window function has large time-width in accordance with low frequency of the original signal.

Case II: |a|<1 then window function on compressed version in accordance with the high frequency of the signal.

In discrete wavelet we use different filters with different cut-off frequencies to measure the signal at different scale factor. Different high pass and low pass filters are used to analysis. The allotment of amount of details information for a signal is able to adjustment by filter operation. Scale is adjusted by up-sampling and down-sampling transference.

## II. METHODOLOGY

Prior to processing the signal, it was passed through a combination of two filters. A comb filter was designed to remove power line interference from the ECG signal. Actually comb filter is designed as a combination of two filters. Comb-1 is used to remove 50-60Hz noise with their odd harmonics and comb-2 for 100-110Hz with their odd harmonics. Comb filters are designed from low pass IIR Butterworth filter with sampling frequency 1 KHz. Then another order 4, low pass IIR Butterworth filter with 150 Hz cut off frequency used to remove high frequency noise. Transfer function of lpf_basic, Comb-1, Comb-2, lpf_final are given.

$$H(z)_{lpf\_basic} = \frac{0.278+1.105z^{-1}+1.683z^{-2}+1.105z^{-3}+0.278z^{-4}}{1+1.570z^{-1}+1.276z^{-2}+0.484z^{-3}+0.076z^{-4}} \qquad (2)$$

[From basic lpf comb filters are designed]

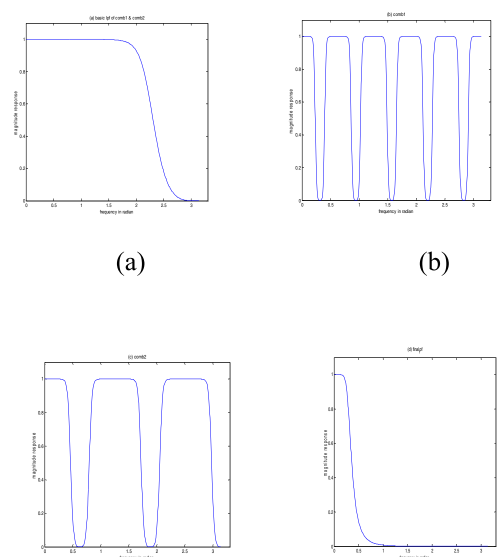
$$H(z)_{comb-1} = \frac{0.278+1.105z^{-10}+1.683z^{-20}+1.105z^{-30}+1.278z^{-40}}{1+1.570z^{-10}+1.276z^{-20}+0.484z^{-30}+0.076z^{-40}} \qquad (3)$$

$$H(z)_{comb-2} = \frac{0.278+1.105z^{-5}+1.683z^{-10}+1.105z^{-15}+0.278z^{-20}}{1+1.570z^{-5}+1.276z^{-10}+0.484z^{-15}+0.076z^{-20}} \qquad (4)$$

$$H(z)_{lp\ high\ frequency\ noise\ removal}$$

$$= \frac{0.0004+0.0014z^{-1}+0.0025z^{-2}+0.0017z^{-3}+0.0004z^{-4}}{1+3.1806z^{-1}+3.8612z^{-2}+2.1122z^{-3}+0.4383z^{-4}} \qquad (5)$$

Frequency response of lpf_basic, Comb-1, Comb-2, final lpf (for reducing high frequency noise) are given in Fig. 2(a-d).



(a) (b)

(c) (d)

Fig. 2: Frequency response-(a) basic lpf, (b)comb-1, (c)comb-2, (d) final lpf.

As ECG records carry baseline drift with it is so it not possible to find all R peaks from the signal through detect the maximum peak value. Wavelet tool reduces the effect of baseline drift in detecting R peaks. The original ECG data array as obtained from mit-db and ptb-db data files is passed through the filters. Fig. 3 shows the performance of the filtering operation over an noisy ECG record. Wavelet transform is applied on the filtered ECG data. Wavelet coefficients are stored in a new data array. Then zero crossing points are captured on both sides of which opposite polarity dominant peaks exists as depicted in Fig 4.

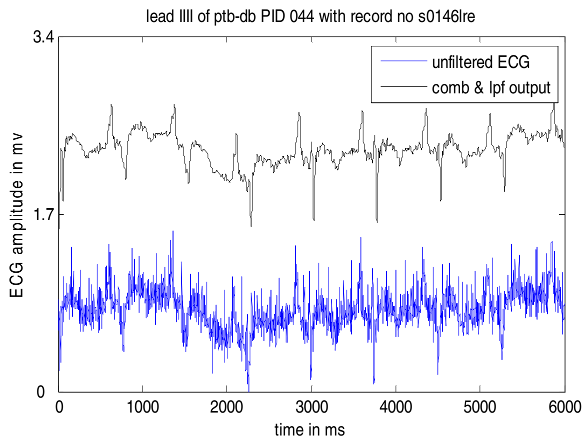
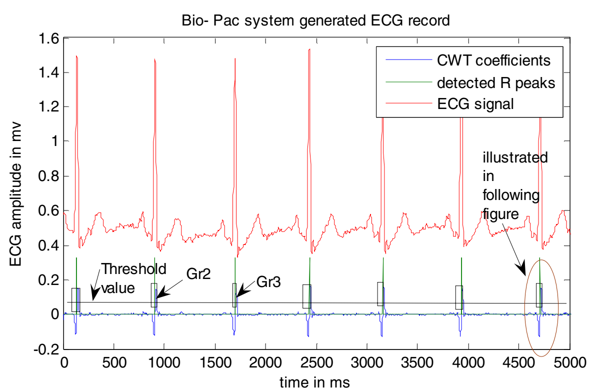
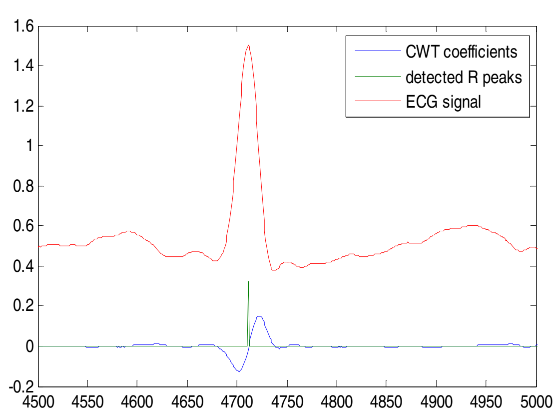


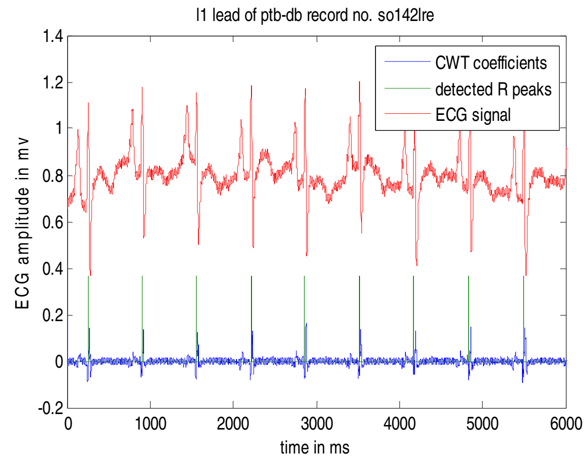

Fig. 3 Noise reduction using Filters




(a)




(b)




(c)

Fig. 4(a-c) R peak detection using locally generated maxima, minima and zero-crossing pt of wavelet coefficients.

At first to find out the opposite dominant peaks from the coefficient array the newly generated data array data are sorted as descending order of magnitude. The coefficients which are above some statistically determined threshold value are chalked out along with their indexes. Now a number of groups are formed from newly created data set based on the index point difference of the coefficients (chalked out), if exceed from threshold value. The local maxima are generated for each individual group. Local minima are also generated for each such groups formed from the neighborhood region of those groups, if found to be above some threshold value. Zero crossing points in between such maximum- minimum pairs are considered as probable R peaks.

## III. TESTING AND RESULTS

The R peak detection algorithm is tested using abnormal and normal data in MIT-PTB database and MIT-BIH and fantasia-db arrhythmia database. Biopac system generated ECG records (with1 KHz sampling) were also tested. PTB-DB and MIT-BIH data files contain ECG data with 1KHz and 360 Hz sampling respectively. MIT-BIH data files were upsampled to 1 KHz sampling to make it compatible with the algorithm, which is capable of processing the ECG samples with 1 KHz sampling. Evaluation criteria used for the mentioned R peak detection algorithm are mainly Sensitivity ($S_e$) and positive predictivity (P+) values expressed as

$$Se = \frac{Tp}{Tp+Fn} \tag{6}$$

$$P+ = \frac{Tp}{Tp+Fp} \tag{7}$$

Here Tp (True positive) represents correctly found wave peaks, Fp (False positive) represent an extra beat not present in data but algorithm detect it. Fn (False Negative) indicate a missed beat, present in ECG but not detected by algorithm.

TABLE I

| MIT-DB: %Sensitivity & %predictivity+ | | |
|---|---|---|
| **Patient-ID** | **%Se** | **%P+** |
| 100 | 100 | 100 |
| 101 | 99.85 | 99.92 |
| 103 | 100 | 100 |
| 108 | 100 | 99.86 |
| 104 | 100 | 100 |
| 106 | 100 | 99.97 |
| 112 | 99.98 | 100 |
| 113 | 100 | 85.09 |
| 200 | 99.96 | 99.98 |
| 221 | 99.86 | 99.91 |
| 222 | 100 | 100 |
| Average | 99.96 | 98.61 |

TABLE II

| Fantasia-db: %Sensitivity & %predictivity+ | | |
|---|---|---|
| **Record ID** | **%Se** | **%P+** |
| f1o01 | 100 | 100 |
| f1o04 | 100 | 100 |
| f2o01 | 100 | 100 |
| Average | 100 | 100 |

TABLE III

| PTB-DB:%Sensitivity & %predictivity+ | | | | | | |
|---|---|---|---|---|---|---|
| **Record Id in Physionet and patient id** | **Lead 1** | | **Lead 2** | | **V5** | |
| | **%Se** | **%P+** | **%Se** | **%P+** | **%Se** | **%P+** |
| S0301lre-Patient172 | 100 | 100 | 100 | 100 | 100 | 100 |
| S0311lre-patient121 | 100 | 100 | 100 | 100 | 100 | 100 |
| S0017lre-patient003 | 100 | 100 | 100 | 100 | 100 | 100 |
| S0168lre-patient046 | 100 | 100 | 100 | 100 | 100 | 100 |
| Average | 100 | 100 | 100 | 100 | 100 | 100 |

TABLE IV

**Avg. %Sensitivity and Avg. %Predictivity+ for different database(on tested data)**

| **Database** | Avg. %Sensitivity | Avg. %Predictivity+ |
|---|---|---|
| MIT-DB | 99.96 | 98.61 |
| PTB-DB | 100 | 100 |
| FANTASIA-DB | 100 | 100 |

## IV. CONCLUSION

This paper describes an approach ECG QRS detection using Wavelet transform. Before detecting the R peaks, ECG data are filtered. The algorithm is implemented with synthetic ECG data from ptb-db and mit-db database. Ptb-db and mit-db data contain noisy data. Scale 4 wavelet coefficient are found to be best choice for detecting r peaks from ECG data records. The sensitivity and predictivity values obtained are more than 99%, which shows appreciable detection rate as compared to another reported work [2], which shows 96.28% R peak detection rate MIT-BIH (mit-db) arrythmia database. The mentioned wavelet transform based approach is capable of detecting R-peaks even in the presence of baseline modulation.

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