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A COMPARITIVE ANALYSIS OF WAVELET BASED METHOD FOR DENOISING OF ECG SIGNAL

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Abstract- Signal acquisition or transmission is often contaminated with noise. Denoising is an issue that must be resolved before further analysis of the signal. Denoise plays a major role in the analysis of biological signals. The electrocardiogram (ECG) is a common technique of recording bioelectric currents generated by the heart used for diagnosing cardiac diseases. Since ECG signal is a non-stationary signal, wavelet based analytical method presents best results in the case of irregularity measurements which makes it more convenient for ECG data analysis. Moreover, wavelet transform is a successful tool for analysis of biological signal because of its good localization properties in time and frequency domain. In this paper, wavelet based denoising of ECG signal is considered and the performance is evaluated by measuring SNR improvements. The results are compared using different wavelet transforms and finally a wavelet transform is proposed for optimal denoising of ECG signal.

Keywords- ECG, QRS complex, Denoising, Thresholding, Signal to Noise Ratio.

I. INTRODUCTION

An electrocardiogram (ECG) is a recording of the electrical activity of the heart which is used in diagnose many cardiac diseases such as arrhythmia, conduction abnormalities. The electrocardiogram (ECG) signal as shown in fig.1 is interfere by the different noise while gathering and recording. The most troublesome noise sources are muscle contraction noise, instability of electrode skin contact, patient movement, power line interference,and baseline wandering due to respiration and many others. Hence denoising of ECG signal is very important in the clinical environment. In such cases signal noise reduction is only possible with wavelet denoising methods.

Power line interference signals have frequency of 50Hz.Hence it is easily recognizable. The instability of the electrode skin contact is due to either loose contact or the dirty electrodes. When the machine or patient is not properly grounded, power line interference may be the part of the ECG waveform. Electrical equipment and power system induce extremely rapid pulse as the spike in the trace. Care should be taken to suppress these transients. The base line wandering can be eliminated by the selection of proper electrode material and the proper attachment of electrodes.

Wavelet based methods present best performance as irregularity measures and makes them suitable for ECG data analysis. As wavelet transform plays an important role in signal processing, because of its advantages of getting large output signal to noise ratio. This paper presented performance evaluation of different wavelet transform in terms of signal to noise ratio and finally a wavelet transform is proposed for optimal denoising of ECG signal.

A. Morphology

The morphology of the electrocardiogram is widely used in cardiology for the diagnosis of cardiovascular diseases because of its simple,non invasive, effective and low cost procedure.The standard clinical ECG consists of 12 views of the electrical impulse generated by the heart.The 6 views on the left half of ECG (called I, II, II, aVR, aVL and aVF) are generated by the electrodes on the arms and legs.The 6 views on the right half (V1through V6) are generated by the electrodes on the chest. From the 12 views, various cardiac abnormalities can be detected to specific areas of the heart.

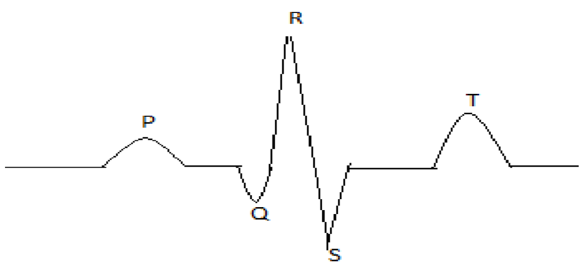

fig.1.

Each heart beat generates a "complex"consists of three parts. The ECG trace is essentially a periodic waveform as shown in fig.1.One period of the ECG waveform represents one cycle of the blood transform process form the heart of arteries. One cardiac cycle in ECG consists of P-QRS-T waves. P-wave is a low voltage deflection away from the baseline caused by depolarization of the atria.Abnormalities of the P wave therefore reflect abnormalities of the right and left atrium. QRS complex is the largest amplitude portion of the ECG caused by vertical depolarization thereby the cardiac muscle is prepared for the next cycle of the ECG.Anormalities of QRS reflect prior myocardial infarction(heart attack). The T wave represents the recovery period of the ventricular muscle after it has been stimulated.Most of the clinically useful information of the electrocardiogram (ECG) is found in the intervals and amplitude defined by its features.

Noise reduction in ECG signal is one of the main problems which appear during analysis of electrical activity of the heart. The most troublesome noise source contain frequency spectrum with in ECG spectrum, i.e, EMG and electrode skin contact. In addition to these, power line interference and baseline wandering are also ECG contaminants. In such signals, noise reduction is only possible with using more advanced signal processing method, as wavelet denoising technique.

The earlier method of ECG signal analysis was based on time domain method. But this is not always sufficient to study all the features of the ECG signal. So the frequency components of a signal are required. To accomplish this, Fast Fourier Transform (FFT) technique is applied. But the unavailable limitation of this FFT is that the technique failed to provide information regarding the exact location of frequency components. The immediate tool available for this purpose is the Short Term Fourier Transform (STFT), but the major drawback of this STFT is that its time-frequency precision is not optimal. Hence, we opt a more suitable technique to overcome this drawback. Among the various time-frequency transform, the wavelet transform is found to be simple and more valuable.

B. Wavelet Transform

A wavelet is a small wave-like oscillation with an amplitude that begins at zero, increases and then decreases back to zero. As a mathematical tool, wavelet can be used to extract information from many different kinds of data. Wavelet transform has the characteristics of multi-resolution and time-frequency analysis method of signal. It has the ability of presenting the character of signal in time field and frequency field. Wavelet transform can be modeled suitably by combining translations and dilations of a simple, oscillatory function of finite duration called wavelet. Recently, wavelet transform has been widely used in signal and image processing due to its time-frequency localisation characteristic. The wavelet transform is based on a set of analysis wavelet allowing the decomposition of ECG signal in a set coefficient. Each analysis wavelet has its own time duration, time location and frequency band. The wavelet coefficient resulting from the wavelet transform corresponds to a measurement of the ECG components in the time requirements and frequency band.

The theory of wavelet transform based on signal processing and developed from the Fourier transform basis. Wavelet transform of a function in real space as a linear combination of wavelet basis function. It performs the linear operation of the signal and the basis function (mother wavelet). A set of integral

$$x_{\omega}(a,b) = \int_{-\alpha}^{\alpha} x(t)\Psi\left(\frac{t-b}{a}\right)dt \qquad (1)$$

function is constructed by scaling and shifted the mother wavelet. The mother wavelet is scaled by a factor ‘a’ and translated by a factor ‘b’ to give

$$\Psi_{a,b}(t) = \frac{1}{\sqrt{a}}\Psi\left(\frac{t-b}{a}\right) \qquad (2)$$

Generally there are two types of wavelet transform continuous wavelet transform and discrete wavelet transform.

C Continuous wavelet transforms

Continuous Wavelet Transform (CWT) the signals are analysed using a set of basis function, which are related to each other by simple scaling and translation. CWT is a wavelet transform with a continuous mother wavelet, continuous dilation parameter and a discrete translation parameter.

A wavelet transform is a convolution of the wavelet function $\Psi(t)$ with the signal $x(t)$. Continuous wavelet transform (CWT) of a continuous square integrable function $x(t)$ at a scale a>o and b belongs to R is expressed by the following integral.

$$x_{\omega}(a,b) = 1\frac{1}{\sqrt{a}}1\int_{-\alpha}^{\alpha} x(t)\Psi^{*}\left(\frac{t-b}{a}\right)dt \qquad (3)$$

where $1/\sqrt{a}$ is the normalization factor and $\Psi^{*}\left(\frac{t-b}{a}\right)$ is the conjugate of the mother wavelet function[9,10,11]..

D. Discrete Wavelet Transform

Discrete Wavelet Transform (DWT) as a wavelet transform with a discrete-time mother wavelet, integer dilation parameter and a discrete translation parameter. The discrete wavelet transform, which is based on sub-band coding is found to yield a fast computation of wavelet transform. It is easy to implement and reduce the computation time. In the case of DWT, a time-scale representation of the digital signal is obtained using digital filtering techniques. The signal to be analysed is passed through filters with different cut off frequencies at different scales.

In DWT, the low and high frequency component x(n) passed through a series of low-pass and high-pass filter with different cut off frequencies. This results a set of approximation and detail DWT coefficients thereby helping in analysing it at different frequency band with different resolutions.

A general equation for the DWT signal is written as

$$X[a,b] = \Sigma_{n=-\alpha}^{\alpha} x(n)\phi_{a,b}(n) \qquad (4)$$

where x(n) is the input signal to be transformed and

$$Ø_{a,b}(n) = \frac{1}{\sqrt{a}} \phi\left(\frac{n-b}{a}\right) \quad (5)$$

In DWT, the function ϕ(n) represents a window of finite length, where 'b' is a real number known as window translation parameter and 'a' is a positive real number named as dilation or contraction parameter. The following two conditions are to be maintained for mother wavelet. First the energy associated with ϕ(n) must be finite.

$$E = \sum_{n=-\alpha}^{\alpha} |\phi n|^2 < \alpha \quad (6)$$

Second the following admissibility condition must be zero

$$r = \sum_{k=0}^{\alpha} \frac{|\phi[k]|}{k} < \alpha \quad (7)$$

r is the admissibility constant with its value depends on the chosen wavelet and

$$\phi[k] = \sum\nolimits_{n=0}^{\alpha} \phi[n] e^{-J^{2\pi kn}|_k} \quad (8)$$

is the K point discrete Fourier transform (DFT) of Ø (n),

Since DWT satisfies the energy conservation law and original signal can be properly reconstructed via employing it, DWT popular in ECG denoising and feature extraction technique.

D. Wavelet Decomposition

By applying the wavelet transform, ECG signals were decomposed to the approximate (low frequency component) and detailed (high frequency component) information. Each stage consists of two digital filters and two down samplers by 2.The first filter, g [n] is the high pass filter and h[n] is the low pass filter. The down sampled output of first high pass filter is called detail coefficients (D1) and output of low pass filter1) is the approximation coefficients(A1).The first approximation (A1) is further decomposed and this process is continued. The process of starting with a sequence of approximation coefficients at some level of resolution and then generating the approximation and detail coefficients at coarser level through decimation is called decomposition or analysis of the sequence. The reverse process of combining the coarser approximation and detail coefficients to yield the approximation coefficients at a finer resolution is referred as reconstruction or synthesis[12].

II. SIGNAL DENOISING

The general wavelet based method for denoising estimation is to transform the data into wavelet domain, threshold the wavelet coefficients and invert the transform[13].It follows three steps:

(1) Decomposition: Choose a wavelet, and choose a level N.Compute the wavelet decomposition at level N.
(2) Thresholding: For each level from 1 to N, select a threshold and apply soft or hard thresholding to the detailed coefficients.
(3) Reconstruction:After decomposition thresholding is applied to detail coefficients and after that signal is reconstructed by using original approximate coefficients and modified detail coefficients.

Wavelet thresholding is a signal estimation technique that exploits the capabilities of wavelet transform for signal denoising. Threshold selection is very important in signal denoising. Selection of a small threshold value yield a result close to the input,but the result still may noisy.While a large threshold value produce a signal with a large number of coefficients.This leads to smooth signal. In wavelet denoising signal is decomposed into wavelet coefficients by using wavelet transform. After fixing the threshold using a thresholding rule, the coefficients are filtered by using thresholding filters (softand hard).

III. ANALYSIS METHOD

The first step in ECG signal processing is to obtain it form a data base.The data base used for the experiments is MIT-BIH Arrhythmia database, available online[14].Record number 100 from MIT-BIH database has been taken for the implementation. Different wavelets are applied for the purpose of comparison.To obtain wavelet analysis, use 'wavelet toolbox' form Matlab program. The performance evaluation can be determined in terms of the Signal to Noise Ratio (SNR).

Signal to Noise Ratio

Basically signal to noise ratio (SNR) is a term for the power ratio between a signal and noise. It is expressed in terms of the logarithmic decibel scale.

$$SNR = 10 \log_{10}\left(\frac{E_{signal}}{E_{noise}}\right)^2$$

Where E_{signal}- Root mean square amplitude of the signal

E_{noise} - Root mean square amplitude of the noise

IV. RESULTS AND DISCUSSION

The original ECG signal form 100 MIT-BIH data base and denoised signal is shown in figure.2. Result obtained by decomposition is shown in fig.3. The different wavelet transforms from daubechies, symlet, and biorthogonal families are used for the comparison .In order to investigate the performance of these wavelet transforms, compare it with SNRTable.1.. From the result it is observed that Sym 20 wavelet perform best SNR than other wavelets. The analysis proposed optimal wavelet for denoising of ECG signal is Sym 20 which is shown in figure.4.

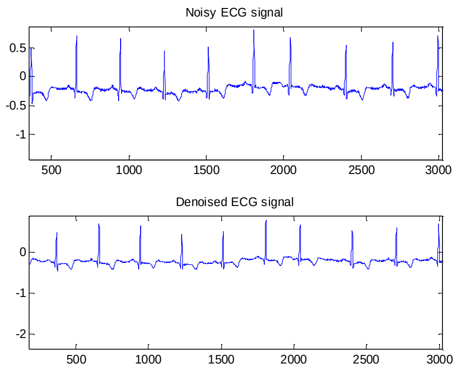

Fig.2. ECG signal obtained from 100.dat and denoised signal

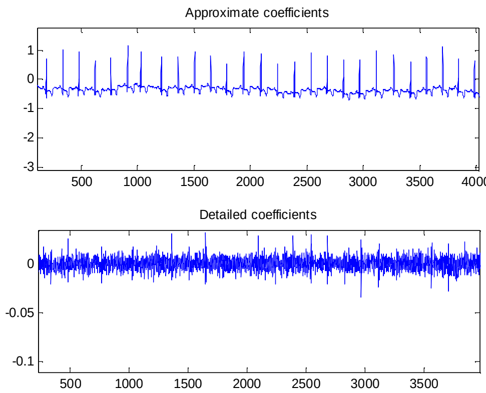

Fig.3.Signal decomposition using Sym 20 wavelet

Table.1. Different wavelet and SNR

Wavelet filter	SNR
Db3	31.7757
Db4	33.2822
Db5	34.3053
Db6	34.9311
Db10	35.8514
Sym5	34.1833
Sym10	36.0189
Sym20	36.4539
Bior1.1	23.8144
Bior2.4	31.6057
Bior3.7	34.4917
Coif1	29.68

CONCLUSION

Noise removal of electrocardiogram has always been a subject of wide research. Wavelet transform is most suitable for no stationary signal such as ECG. The wavelet method having great advantage in beat to beat analysis rather than averaging technique causing distortion in morphology of ECG signal. A wavelet filter for optimal denoising of ECG signal is proposed in this paper. The selected basis function has been found to optimal in terms of Signal to Noise Ratio(SNR) which is used for analysis purpose. The conclusion can be drawn from the study of test results of SNR have shown the best performance of Sym 20 wavelet compared to other wavelet methods.

REFERENCE

[1] Joseph j.Carr and Jon M.Brown," Introduction to biomedical Equipment technology",4th edition Pearson edition,Asia,2001.

[2] Willis J. Tompkins,"Biomedical Digital Signal Processing". Prentice hall Insia Pvt.Ltd.,2005.

[3] H.V Pipberger,R.A. Dunn, A.s. Berson," Computer Methods in Electroicardiography", Annual Reviw of BIo Physics and Bioengineering",June,1975,Vol.4,pp15-42.

[4] L.Cromwell,F.J.WEcbell,"Biomedical Instruments and Measurements",Prentice hall of India,New Delhi.

[5] GoldBerger A.L.,Amaral LAN,Glash, Physiobank, Physio Tool kitand physionet.

[6] V.Sukanya, C.Saritha, Y. Narasimha Murthy,"ECG signal analysis using wavelet transform",Bulg.J.Phys.35 (2008) pp 68-77.

[7] Wavelet,Continuous wavelet transform[online],available http://www.wikipdeia.com.

[8] Yun Yin, Yul ettu, Peizhi Liu,"The Research on denoising Using wavelet transform",IEEE 2011.

[9] E.D. Ubeyli.I,Guler,"Feature extraction from Doppler ultrasound signals for automated diagnostic systems, Comp.Biol.Med. 35(9) (2005),pp.735-764.

[10] I.Daubechies," The wavelet transform, time-frequency Localization and signal analysis, IEEE Trans. inform. Theory 36(5) (1990), pp961-1005.

[11] R.M.Rao, A.S.Bopardikar," Wavelet Transforms: Introduction to Theory and Applications, Addison-Weseley,Reading,M.A.1998.

[12] Raghuveer.M.Rao, Ajit.S.Bopardikar," Wavelet transform Introduction to Theory and applications", Proc.of the

[13] Pradnya B,Patil, Dr.Mahesh S.Chavan,"A Wavelet Based Method for Denosing of Biomedical Signal", Proc.of the Int.Con.on Pattern recognition,Informatics And Medical Engineering,March 21-23,2012.

[14] MIT-BIH Arrhythmia database,www.physionet.org.

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