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Extraction of Unwanted Noise in Electrocardiogram (ECG) Signals Using Discrete Wavelet Transformation

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ABSTRACT-The electrocardiogram (ECG) is an invaluable tool for diagnosis of heart diseases. Electrocardiogram is used to measure the rate and regularity of heartbeats to detect any irregularity to the heart. The spectral distribution of energy varies between normal ECGs and those from patients post infarct or with ventricular hypertrophies. This suggests that discriminating between normal and abnormal conditions may be possible on the basis of differences in the distribution of spectral energy. The electrocardiogram signal contains an important amount of information that can be exploited in different manners. For the purpose of quality diagnosis, the ECG signal must be clearly de-noised to remove all noises. Major interest of this recent paper presents a method for De-noising the noisy real ECG signal using wavelet transform. The determination of the wavelet transform and the choice of Thresholding parameters are considered.

Keywords: Discrete Wavelet Transform, Denoising, ECG signal, Thresholding.

I. INTRODUCTION

All sciences contribute to the maintenance of human health and the practice of medicine. Medical physicists and biomedical engineers are the professionals who develop and support the effective utilization of this medical science and technology as their responsibilities to enhance human health care with the new development of the medical tools such as electrocardiogram (ECG). The electrocardiogram (ECG) is a noninvasive and the record of variation of the biopotential signal of the human heartbeats. The noninvasive technique meaning that this signal can be measured without entering the body at all. An Electrocardiogram (ECG) describes the electrical activity of the heart recorded by electrodes placed on the body surface using a galvanometer. It is used for the primary diagnosis of Heart abnormalities like the Heart Attack, Acute Coronary Syndrome, Aortic, Ischemia, myocardial infarction, conduction defects, and Arrhythmia. The ECG detection which shows the information of the heart and cardiovascular condition is essential to enhance the patient living quality and appropriate treatment.

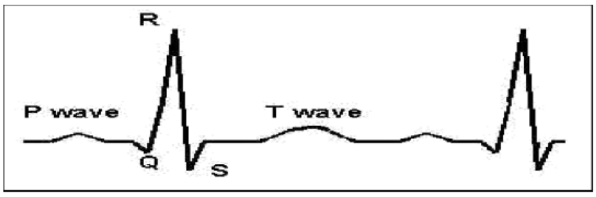

Fig.1 An example of a Normal ECG trace

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All of the ECG waveforms pattern and variability must be determine accurately to get the better diagnostic result that will shown the correct heart disease of the patient. Figure 1 shows the normal ECG traces which consist of P wave, QRS complex and T wave. The P wave is the electrical signature of the current that causes atrial contraction, the QRS complex corresponds to the current that causes contraction of the left and right ventricles and the T wave represents the repolarization of the ventricles.

The most difficult problem faced by an automatic ECG analysis is the large variation in the morphologies of ECG waveforms, it happens not only for different patients or patient groups but also within the same patient. Noise contamination of the ECG such as baseline wander, power line interference and muscle activities can pollute the ECG and reduce the clinical value of an ECG signal. Thus, filtering of the ECG signal is a necessary preprocessing step to conserve the useful information and to remove such noise.

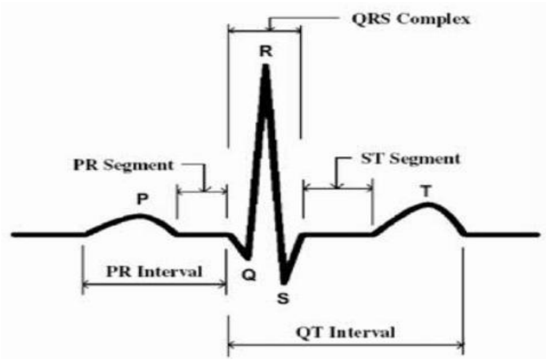

Fig.2. An ECG Signal

All of the ECG waveforms pattern and variability must be determine accurately to get the better diagnostic result that will shown the correct heart disease of the patient. Figure 1 shows the normal ECG traces which consist of P wave, QRS complex and T wave. The P wave is the electrical signature of the current that causes a trial contraction, the QRS complex corresponds to the current that causes contraction of the left and right ventricles and the T wave represents the repolarization of the ventricles.

ECG signal is one of the biosignals that is considered as a non-stationary signal and needs a hard work to Denoising. An efficient technique for such a non-stationary signal processing is the wavelet transform. The wavelet transform can be used as a decomposition of a signal in the time frequency scale plane.

This paper mainly aimed to extract important parameters from the ECG signal through the DWT technique. There are many application areas of wavelet transform like as sub-band coding data compression, characteristic points detection and noise reduction.

II. WAVELET TRANSFORM:

Discrete Wavelet transform is an emerging tool for the de-noising of non-stationary signals like ECG. There are number of wavelet families like Haar, Daubechies (Db), Symlet etc for analysis and synthesis of signal. Proper selection of wavelet basis function plays a vital role in Denoising.

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The Wavelet transform is a two-dimensional timescale processing method for non-stationary signals with adequate scale values and shifting in time. 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 wavelet transform is capable of representing signals in different resolutions by dilating and compressing its basis functions. The ECG signals which consisting of many data points, can be compressed into a few features by performing spectral analysis of the signals with the WT. These features characterize the behavior of the ECG signals. Using a smaller number of features to represent the ECG signals is particularly important for recognition and diagnostic purposes

The ECG signals were decomposed into time-frequency representations using Discrete Wavelet Transform (DWT). The DWT technique has been widely used in signal processing tasks in recent years. The major advantage of the DWT is that it provides good time resolution. Good resolution at high frequency and good frequency resolution at low frequency.

Because of its great time and frequency localization ability, the DWT can reveal the local characteristics of the input signal. The DWT represents a 1-Decompodition signal s(t) in terms of shifted versions of a low pass scaling function φ(t) and shifted and dilated versions of a prototype band pass wavelet function ψ(t).

$$\Psi_{j,k}(t) = 2^{(-j/2)}\,\psi\,(2^{-j}\,t - k) \qquad (1)$$

$$\varphi_{\,j,k}\,(t) = 2^{-j}\,\varphi\,(2^{-j}\,t - k) \qquad (2)$$

Where: j controls the dilation or translation

K denotes the position of the wavelet function

III. METHODOLOGY:

For wavelet analysis the Mat lab program, which contains a very good wavelet toolbox is used. The main steps of de noising algorithms based on Wavelet Transform and determining a threshold to find the value where minimum error is achieved between the detailed coefficients of thresholded noisy signal and the original.

The method can be divided into the following steps:

A. Noise Generation and addition:

A random noise is generated and added to the original signal. The process of adding noise to the original signal is mathematically shown as:

F (n) = X (n) + D (n), n = 1, 2, 3… N.
Where, *X* (*n*) is the original ECG signal,
D (*n*) is the 50/60 Hz PLI noise,
F (n) is the Noisy ECG signal.

B. Decomposing of the noisy and original signals using wavelet transform:

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The noisy and original signals are decomposed into five levels by discrete wavelet transform using the Daubechies wavelet (db4).

C. Choosing and applying threshold value:

For each level a threshold value is found through a loop, and it is applied for the detailed coefficients of the noisy and original signals. The optimum threshold is chosen by taking the minimum error between the detailed coefficients of noisy signal and those for original signal.

A Soft Thresholding is used to shrinkage the wavelet detailed coefficients of the noisy signal such that: the output wavelet transform coefficients after and T is the chosen threshold. For each level a loop is applied to find the threshold value that gives the minimum error between the detailed coefficients of the noisy signal and those of original signal.

D. Reconstruction:

The original signal is reconstructed using Inverse Discrete Wavelet Transform IDWR Thresholding of wavelet coefficients affects greatly the quality of ECG morphology thus, threshold determination is very essential issue in this case. Two concepts are presented in study to accomplish high quality ECG signal reconstruction, threshold determination using above method and the idea of not to threshold the approximation coefficients of ECG signal. The approximation coefficients contain the low frequency of the original signal where most energy exists.

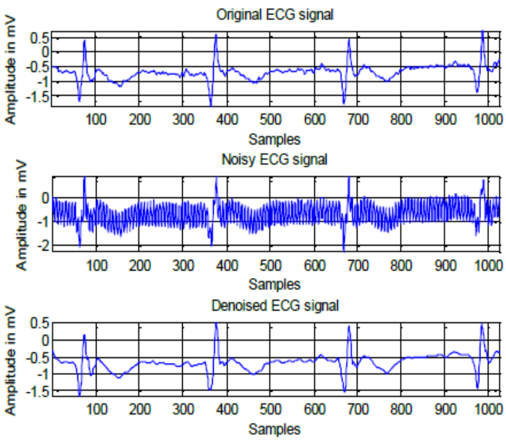

Fig.3. De-noising of ECG signal using Db4 wavelet Transform

IV. EVALUATION MEASURES:

De-noised ECG signal is compared with the original ECG signal based upon following evaluation criteria:

A. Estimation of Peak Signal to Noise ratio (PSNR):

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PSNR measures are used to measure the quality of the denoised image as well as visual quality of the images. PSNR is defined as the ratio of the variance of the noise-free signal to the mean-squared error between the noise-free signal and the Denoising signal. PSNR is computed as below:

$$\text{PSNR} = 10\log_{10}\left[\frac{R^2}{\text{MSE}}\right]$$

The higher the PSNR, the better is the quality of the compressed or reconstructed image.

B. Estimation of Mean Square Error (MSE):

It is estimated between the de-noised ECG signal and original ECG signal given by equation,

$$\text{MSE} = \frac{\sum_{M,N}[I_1(m,n) - I_2(m,n)]^2}{M*N}$$

where M and N, m and n are number of rows and columns in the input and output image respectively.

C. Estimation of Percentage Root Mean Square Difference (PRD):

The distortion resulting from the ECG processing is frequently measured by the percent Root-mean-square difference (*PRD*). In most ECG compression algorithms, the *PRD* measure is employed. However, the clinical acceptability of the reconstructed signal is desired to be as low as possible. Finally, the percentage root mean square difference (PRD) is calculated to verify the improvement in the reconstructed signal. It is defined as:

$$\text{PRD} = \sqrt{\frac{\sum_{n=0}^{N}(V(n) - V_R(n))^2}{\sum_{n=0}^{N}V^2(n)}} * 100\%$$

V (n): original ECG signal.
VR (n): reconstructed ECG signal.

V. CONCLUSION

The DWT characterization will delivers the stable features to the morphology variations of the ECG waveforms. This is possible by using the multi resolution decomposing into sub signals. This assists greatly to remove the noise in the certain pass band of frequency. The wavelet transform allows processing non stationary signals such as ECG signal. Filtering is an important step in the processing of the ECG signal. In this paper it shows the effect of the wavelet Thresholding on the quality reconstruction of an ECG signal.

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