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DETECTION OF SMALL VARIATIONS OF ECG FEATURES USING WAVELET

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ABSTRACT

ECG contains very important clinical information about the cardiac activities of heart. The features of small variations in ECG signal with time-varying morphological characteristics needs to be extracted by signal processing method because there are not visible of graphical ECG signal. Small variations of simulated normal and noise corrupted ECG signal have been extracted using FFT and wavelet. The wavelet found to be more precise over conventional FFT in finding the small abnormalities in ECG signal.

Keywords: ECG, wavelet, FFT, Holter, cardiac, abnormality, feature extraction, statistical parameters.

1. INTRODUCTION

Electrocardiogram (ECG) is a graphical record of the electrical activity that is generated by depolarization and repolarization of the atria and ventricles. It is well suited for analysis by joint time-frequency and time-scale distributions. ECG signal has a very time-varying morphology characteristic, identified as the P-QRS-T complex. The signal frequencies are distributed (1) low frequency - P and T waves, (2) mid to high frequency-QRS complex [1, 2]. When the heart muscle becomes ischemic or infarcted, characteristic changes are seen in the form of elevation or depression of the ST-segment. Ischemia also causes changes in conduction velocity and action potential duration, which results in fragmentation in the depolarization front and appearance of low-amplitude notches and slurs in the body surface ECG signals [3]. The statistical properties of ECG wave are generally changed over time tending to be quasi-stationary. A Holter monitor is an ECG recording done over a period of 24 or more hours. An automatic algorithm and software is needed to analyze this huge amount of 24 hours Holter ECG signals. A major problem is the proper detection of the ECG signal and extraction important features from it.

Recently wavelets have been used in a large number of biomedical applications. The wavelet packet method is a generalization of wavelet decomposition that offers a rich range of possibilities for signal analysis. The multi-resolution framework makes wavelets into a very powerful compression [4] and filter tool [5], and the time and frequency localization of wavelets makes it into a powerful tool for feature extraction [6]. There is some works on precise detection of ECG using FFT and wavelet [7-16]. Karel *et al*. proposed the performance criteria to measure the quality of a wavelet, based on the principle of maximization of variance [7]. Mahmoodabadi *et al*. developed and evaluated an electrocardiogram (ECG) feature extraction system based on the multi-resolution wavelet transform [8]. David *et al*. presented a method to reduce the baseline wandering of an electrocardiogram signal [9]. Shantha *et al*. discussed the design of good wavelet for cardiac signal from the perspective of orthogonal filter banks [12]. Nikolaev and Gotchev proposed a two-stage algorithm for electrocardiographic (EGG) signal denoising with Wiener filtering in the translation-invariant wavelet domain [13]. Most of the works focused on the large size abnormalities with respect to extreme noisy channel using conventional FFT and wavelet method. Most of the clinically useful information in the ECG is found in the intervals and amplitudes defined by its features (characteristic wave peaks, frequency components, and time duration). In this paper, FFT and wavelet methods are developed for the extraction of small variations of the ECG signal. Wavelet method of signal processing is found to be superior to the conventional FFT method in finding the small abnormalities in ECG signals.

2. MATERIALS AND METHODS

ECG signals both standard and noise corrupted have been generated using Matlab. These signals are analyzed by the wavelet method (Matlab wavelet Tool). Continuous wavelet transform (CWT) is defined as the sum over all time of the signal multiplied by scaled, shifted versions of the wavelet function ψ

$$C(scale, position) = \int_{-\infty}^{\infty} f(t)\psi(scale, position, t)dt$$

The results of the CWT are many wavelet coefficients C, which are a function of scale and position. Multiplying each coefficient by the appropriately scaled and shifted wavelet yields the constituent wavelets of the original signal.

For many signals, the low-frequency content is the most important part. It is what gives the signal its identity. The high-frequency content, on the other hand, imparts flavor or nuance. To gain a better appreciation of this process, it is performed a one-stage discrete wavelet transform of a signal. The decomposition process can be iterated, with successive approximations being decomposed in turn, so that one signal is broken down into many lower resolution components. This is called the wavelet decomposition tree.

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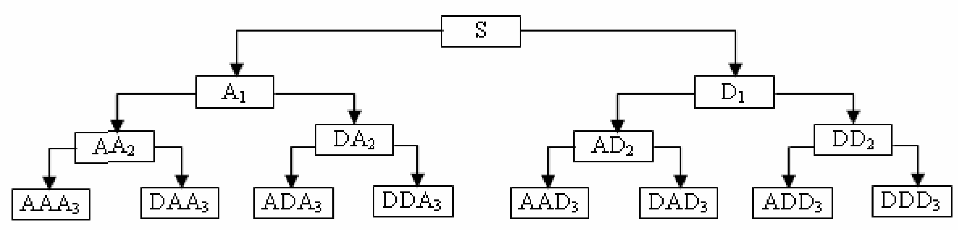

Figure-1. Wavelet packet decomposition tree.

The wavelet packet method is a generalization of wavelet decomposition that offers a richer range of possibilities for signal analysis. In wavelet analysis, a signal is split into an approximation and a detail. The approximation is then itself split into a second-level approximation and detail, and the process is repeated. The wavelet packet decomposition tree has been shown in Figure-1.

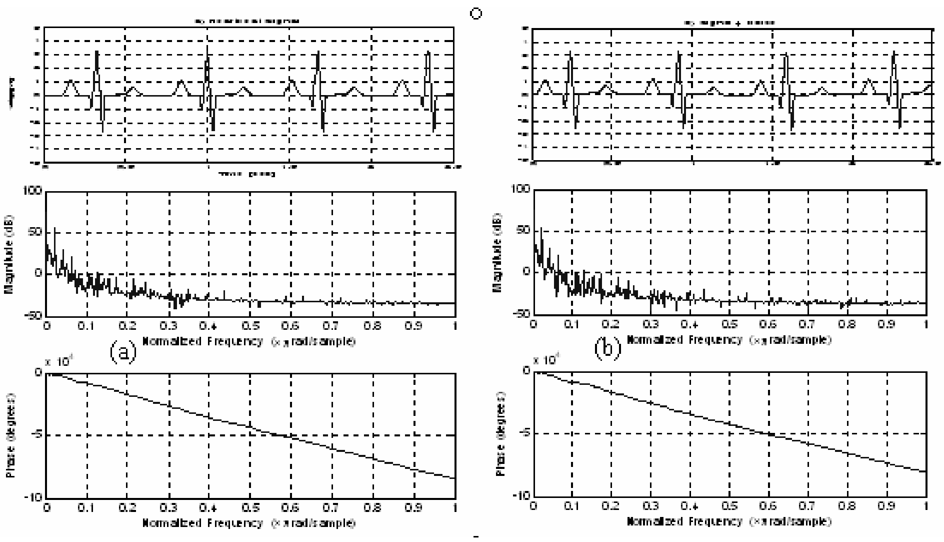

Figure-2. Response using FFT of simulated normal (a) and noise corrupted (b) ECG signals.

The wavelet decomposition tree is a part of this complete binary tree. For instance, wavelet packet analysis allows the signal S to be represented as A1 + AAD3 + DAD3 + DD2. This is an example of a representation that is not possible with ordinary wavelet analysis. Whereas the process of Fourier analysis is represented by the Fourier transform. The sum over all time of the signals is multiplied by a complex exponential. A complex exponential can be broken down into real and imaginary sinusoidal components. The results of the transform are the Fourier coefficients, which multiplied by a sinusoid of frequency yield the constituent sinusoidal components of the original signal. From the principle of FFT, it does not have possibilities to detect the little change of the signals.

3. RESULTS AND DISCUSSIONS

The simulated standard ECG signals as well as the simulated noise corrupted signal have been implemented using FFT and wavelet for proper feature extraction. From the human body, sudden pain of any parts may occur the continuous sinusoidal signal with very low frequency with approximately 0.5/1 Hz cause the small abnormalities of the cardiac activities of heart. Signals have been generated with different parameters using the following steps:

Step 1: Generation of standard ECG pattern having amplitude of 3.5mV and pulse repetition rate of 75 per minute. This signal is shown in Figure-2(a).
Step 2: Generation of a noisy signal having frequency of 0.5/1 and amplitude of 0.1 mV which is 2.85 percent of the standard ECG signal. This signal is shown in Figure-2(b).
Step 3: Generate the response of the signal using FFT method.
Step 4: Generate the response of the signal using wavelet method.

From the Figure-2, it can not be identified the abnormalities using conventional FFT method. These dissimilarities are needed to record long time for proper diagnosis. Figure-3 shows the wavelet output of normal ECG signal and noise corrupted ECG signal. In Figure-3, the dissimilarities are identified by the statistical parameters of wavelet properties (Table-1).

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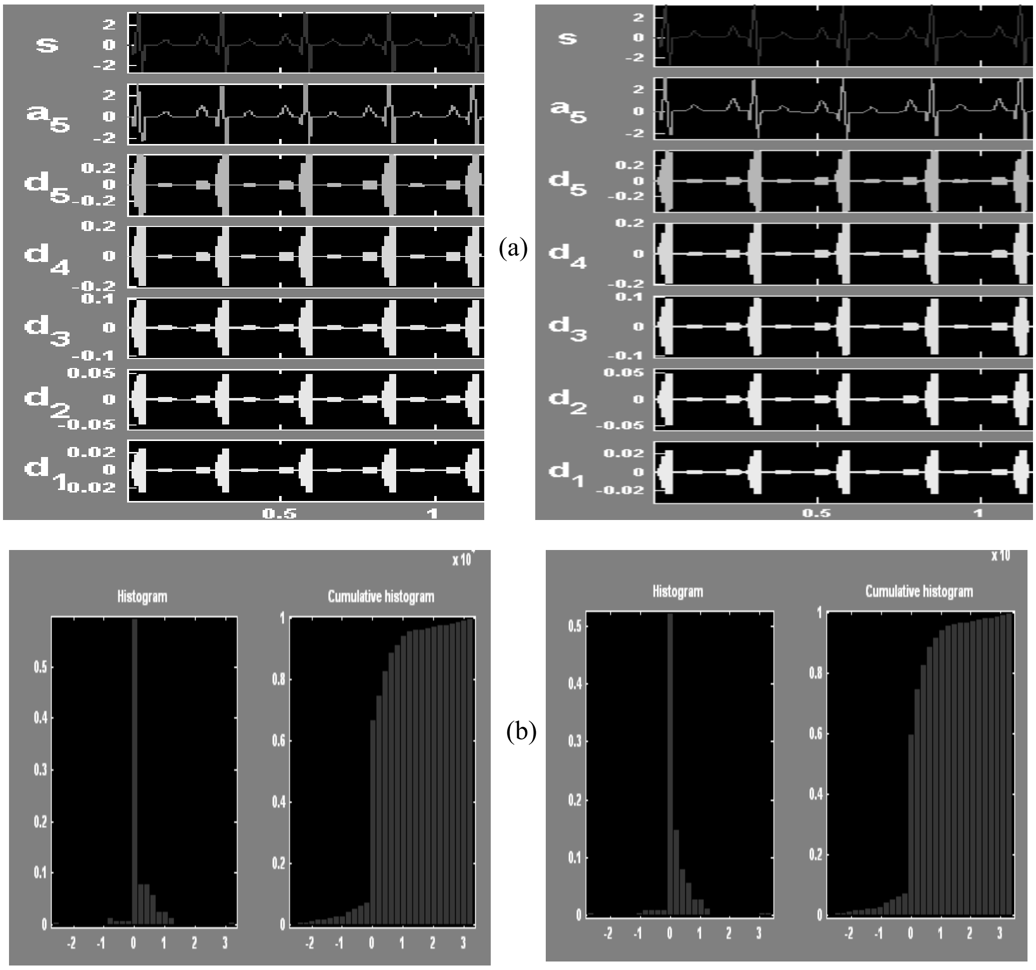

Figure-3. Decomposition a) and histogram b) of simulated normal and noise corrupted (b) ECG signals using wavelet.

Table-1. Results of the different parameters.

	Mean	Median	Mode	Maximum	Minimum	Range	Standard deviation	Median absolute deviation	Mean absolute deviation
Simulated standard signal	0.1763	0.02555	0.004261	3.294	-2.688	5.982	0.6779	0.02555	0.3826
Simulated noise corrupted Signal	0.1805	0.07863	-0.00625	3.385	-2.774	6.158	0.6821	0.1336	0.3857

The statistical parameters of simulated standard and noise corrupted signal are mean, median, mode, maxima, minima, range, standard deviation, median absolute deviation, mean absolute deviation. There are some differences between the parameters of simulated standard and noise corrupted signal which diagnosis the proper treatment for the patient.

4. CONCLUSIONS

In this paper, simulated normal and noise corrupted ECG signal conditions have been analyzed using conventional FFT and wavelet. Features of Holter ECG signal have been extracted to detect the small variations. The variations are evaluated using some statistical parameters. Wavelet is found to be superior to the conventional FFT method in finding the small abnormalities in ECG signals.

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