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Wavelet Technique and Function for Noise Removal from ECG Signal

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Abstract: Electrocardiogram (ECG) signal analysis is important for diagnosing cardiac disease, which is the leading cause of mortality in developed countries. Electrophysiological activity of the cardiac can be measured using an electrocardiograph device. Using the ECG signal, it can be determined which area of the cardiac has a disorder and lesion. Therefore, we first examine the effect of various diseases on the cardiac in general. Then we reconstruct the ECG heartbeat signal using MATLAB software. Always these types of signals are accompanied by noise that interfere with signal processing. To know the arrhythmias of the cardiac, parameters of the time of occurrence, amplitude, duration and rhythm of each signal wave, especially the P and QRS waves, are used. One of the algorithms for detecting arrhythmias in the cardiac is based on time-frequency analysis, which is used less than the partial signal features, such as the location of the start and end location. Wavelet conversion is a useful technique for time-signal analysis that can accurately predict the rapid changes in the signal. This ability can be effective in isolating the different parts of the ECG signal from strong noise. In this paper, we use the Wavelet functions to remove the ECG signal from the cardiac, which makes the amplitude of the peak of the signal (peak) close to the natural amplitude of the signal, because maintaining the main signal characteristics is necessary when noise is eliminated and filtered.

Keywords: Electrocardiogram Signal, Wavelet Function, Cardiac, Noise, MATLAB Software, ECG Viewer

1. Introduction

The cardiac is a vital part of the body that continuously and continuously pumps blood to various parts of the body and the muscle center is the force generation that is inside the fibrous pericardium. The cardiac consists of grooves, surfaces, faces, bases, vertices, 4 holes and 4 valves, coronary arteries, veins and nerves [1]. In terms of electrocardiography, cardiac cells are three types of pacemakers, electrical conductors, and myocardium [2]. The myocardium consists of a variety of cells that together lead to a regular contraction of the cardiac. The specialized cells form the electrical system of the cardiac that produces electrical impulses and they transmit these impulses to myocytes and myocytes also cause mechanical contraction. The cardiac rate consists of two separate stages, the systole and diastole the systole is the contraction phase and the diastolic phase of the resting phase of the cardiac. In the course of depolarization, the muscle cells of the cardiac get constricted and during repolarization, the muscle cells of the cardiac expand. The most important electrical event occurring inside the cardiac is depolarization [3]. Electric impulses are released throughout the cardiac and cause depolarization and repolarization and ultimately Makes blood flow throughout the body [4]. The ECG signal contains P wave, Complex QRS and wave T (Figure 1).

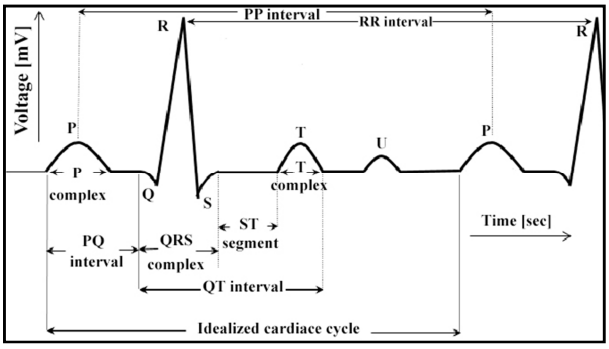

Figure 1. *Normal ECG signal.*

These waves are the result of cardiac electrophysiological function. The ECG receives the depolarization and contraction of the atrium with electrodes on the surface of the body and records a wave of this action which indicates the expansion of intra-myocardial atrium expansion, from beginning to end, which is the same P wave. After completion of the depolarization of the atrium, the ECG signal becomes smooth again. Then due to the depolarization and contraction of the ventricles, a wave called the complex QRS after the wave P is created. Because the size of the ventricles is much larger than the atrium. The QRS height is greater than the P wave height and the pathways for ventricular depolarization are complex which makes the QRS complex more sophisticated and more variable than P wave. In the ECG signal, the wave T represents Ventricles repolarization [5]. When these waves out of their natural state, they can be detected by the ECG signal and found heart disease [6]. Heart hypertrophy is a type of heart condition that increases the muscle mass of the heart which is associated with cardiomyopathy the enlargement of the heart causes a particular cavity to expand. The hypertrophy occurs due to overpressure when the heart is forced to pump blood against a high resistance and due to volume overload, enlargement occurs when the cavity is opened to accommodate more blood volume [7]. Enlargement is seen in valve diseases such as aortic failure (left ventricular enlargement) and mitral failure (enlargement of the left atrium). Three conditions for a wave in the ECG occur due to hypertrophy and enlargement of the heart, which include: increase in ECG wave, Increase wave height and the possibility of changing the direction of the ECG signal's electrical axis [8]. Any disorder in the speed, order, place of production and conduction of the electrical pulse of the heart is called arrhythmia the reduction of cardiac output is a sign of arrhythmias. By examining the rhythm of the heart over a longer period of time, several complexes that are characterized by 12 ECG regularities can be diagnosed with arrhythmias in electrocardiogram [9]. The four heart valves (mitral, aortic, triplet and pulmonary) are fully open and closed with each heartbeat, so that blood flow can be done correctly but when a valve does not completely open, an impairment in the movement of the front of the blood and a complication called a valve stenosis occurs due to thickening or even tangle of valves and when the valve is not closed, allowing the blood to flow back, a regurgitation occurs [10]. Echocardiography is very useful in determining the cause and severity of aortic valve obstruction [11]. The abnormal accumulation of fluid in the pericardium makes the QRS complex voltage low, which is another heart disease that is visible with the ECG signal [12]. In general, recorded heart signals always contain noise, which should be filtered to use the useful information of these signals. Factors such as the volatile recording environment, the disturbance of nearby equipment signals, weak electrodes, and electromagnetic noise generate noise in the ECG signal. Due to the very low amplitude of latency and signal-to-noise ratio (SNR), it is very difficult to use conventional denoise methods to eliminate noise from the ECG signal [13]. Therefore, a valid signal processing technique is required to extract useful clinical information from an ECG signal with noise. So, in this article, a more effective noise cancellation method will be presented, which we will discuss later.

2. Methods

In this article, we used the ECG signal simulation software MATLAB v2009 for the database of Microsoft Access, as well as for the filtration of the ECG Viewer. To filter the ECG in the ECG Viewer, there are two types of filters available, Fast smooth and Wavelet. The first type filter uses two mid-moving filters and the second type filter uses the Wavelet toolbox, MATLAB. In the ECG Viewer, the IBI filter is used to represent IBI outliers. Due to the non-static ECG signal, we use Wavelets to eliminate noise and analyze these signals. Among the time-frequency methods for signal processing, the Wavelet-based technique is preferred because it has more precision in detecting and maintains vital information for signal diagnosis. The Wavelet transform combines two low pass filter and high pass filter. In the transformation of a discrete wavelet, the signal decomposes into an approximation signal and a detailed signal, and the signal of the approximation can be broken down again using the wavelet transform into two parts, and this process continues for the number of steps required. Wavelet has the ability to segment signals and noise. Using a discrete wavelet transform, we can establish a relationship between Wavelet in mathematics and Wavelet application. By using the Wavelet conversion function used by the $\{h_k\}$ filter coefficients, we can estimate the signal by equation (1).

$$W_L(\mathrm{n,j}) = \sum_m W_L(\mathrm{m,j-1})\,\mathrm{h(m-2n)} \qquad (1)$$

The high-pass output is expressed by equation (2).

$$W_H(\mathrm{n,j}) = \sum_m W_L(\mathrm{m,j-1})\,g(\mathrm{m-2n}) \qquad (2)$$

Here W_L (p,q) is the p^{th} scaling function in the q^{th} step and W_H (p,q) is the Wavelet Function Coefficient p^{th} in the q^{th} step. h (n) and g (n) are the filter coefficients according to the scaling function (low pass filter) and the Wavelet function (high pass filter) separately. In this area it is assumed that the smooth functions provide a better wavelet. The Wavelet threshold will result in the maintenance of the coefficients according to the desired signal. There are two types of diagnostic methods in the ECG Viewer GUI, which include Template Matching and Self Template that in the Self Template, 60,000 first-generation ECGs are used to detect QRS complexes. The SNR is the ratio of signal strength to noise power and is a measure of noise reduction. The higher the number, the better the noise reduction performance, the noise elimination method in this article has a high SNR. The relation SNR is the equation (3).

$$SNR_{imp}\left[dB\right]=10\log_{10}\frac{\sum_{n=1}^{N}\left|x\left[n\right]\right|^{2}}{\sum_{n=1}^{N}\left|\hat{x}\left[n\right]-\left|x\left[n\right]\right|\right|^{2}} \quad (3)$$

A beat-correlation Template Matching algorithm is used to detect a pulse, and the correlation coefficient between two longitudinal pieces of N from x and y is calculated by following equation:

$$r_{xy}=\frac{\sum_{N=1}^{N}[(x(n)-\bar{x})(y(n)-\bar{y})]}{\sqrt{\sum_{N=1}^{N}[(x(n)-\bar{x})]^{2}\sum_{N=1}^{N}[(y(n)-\bar{y})]^{2}}} \quad (4)$$

The beat is defined as the highest peak r_{xy} between each flag and up flag event.

3. Results

Due to the presence of noise that accompanies the majority of signals, vital signals, such as the heart signal, should be filtered prior to analysis to eliminate the noise from the original signal. In this paper we use the Wavelet functions to remove signal noises. The reason for choosing the processing in the Wavelet domain for the ECG signal is due to the characteristics of the non-static signal and the widespread noise that restricts the use of ordinary linear filters. Wavelet's advantages in signal processing include features of the Wavelet compression coefficient, noise reduction in the Wavelet field, and noise elimination. The Wavelet transform combines two low-pass and high-pass filters, which apply at each step on a signal that low-frequency scores represent high-frequencies and high scales representing low frequencies. Wavelet conversion is large scale to compress and retrieve medical information. The ability to compress data by Wavelet is useful in ECG because ECG data requires a lot of storage space. In this paper, we simulated the ECG signal using MATLAB software, and then, in the ECG Viewer environment, we cleared the signal from the noise. First, in the ECG Viewer, turn on ECG Filtering on the fast smooth mode, take the Beat Detection section to Self Template mode and the IBI Filtering section on the standard deviation filter (SD) and on the above thresh, which represents the high threshold filter. As shown in (Figure 2), in this case the red circles representing the outlier are much larger than the green circles representing the beats. This means that the number of beats is much lower than the number of areas where the distance is above the threshold defined by the user. But in the next step, the ECG Filtering section is on the Wavelet mode and the Beat Detection section on Template Matching mode and we set the IBI Filtering section just to SD.

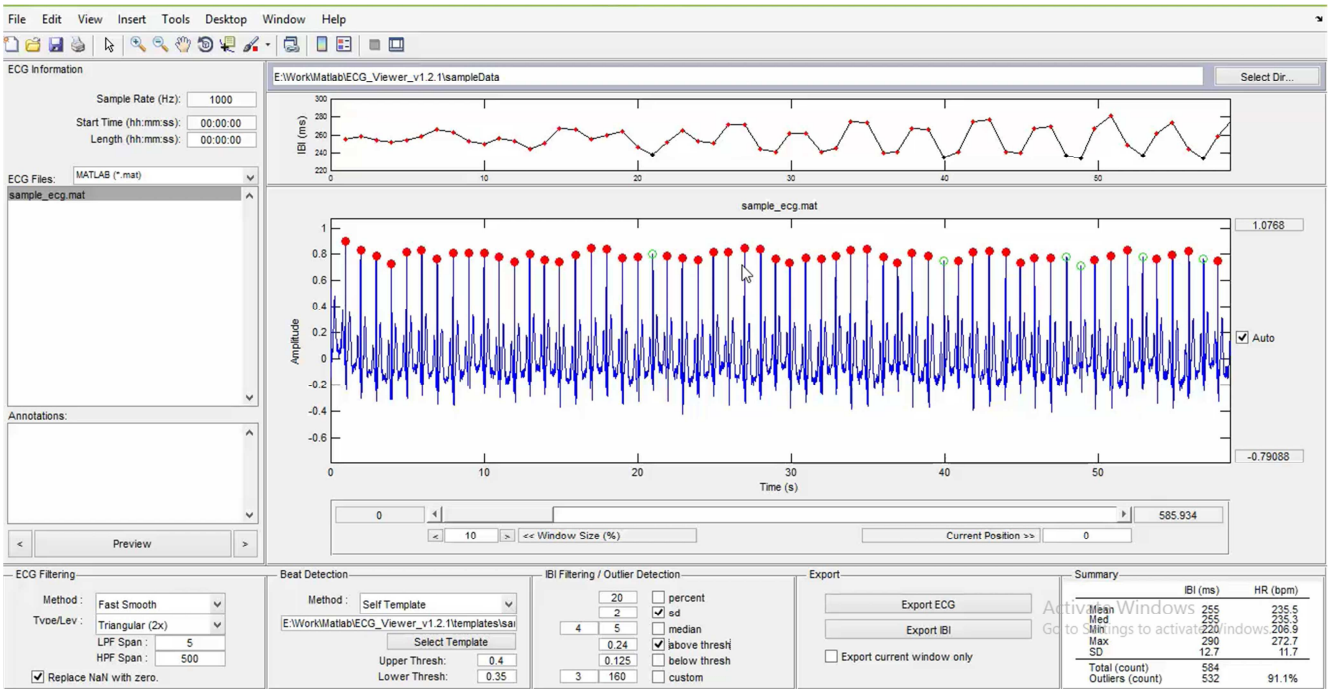

Figure 2. *The first signal, the number of outliers is higher than the number of beats.*

With regard to (Figure 3), it can be seen that the green circles are much larger than the red circles, that is, the number of beats more than those whose intervals are greater than the average IBI.

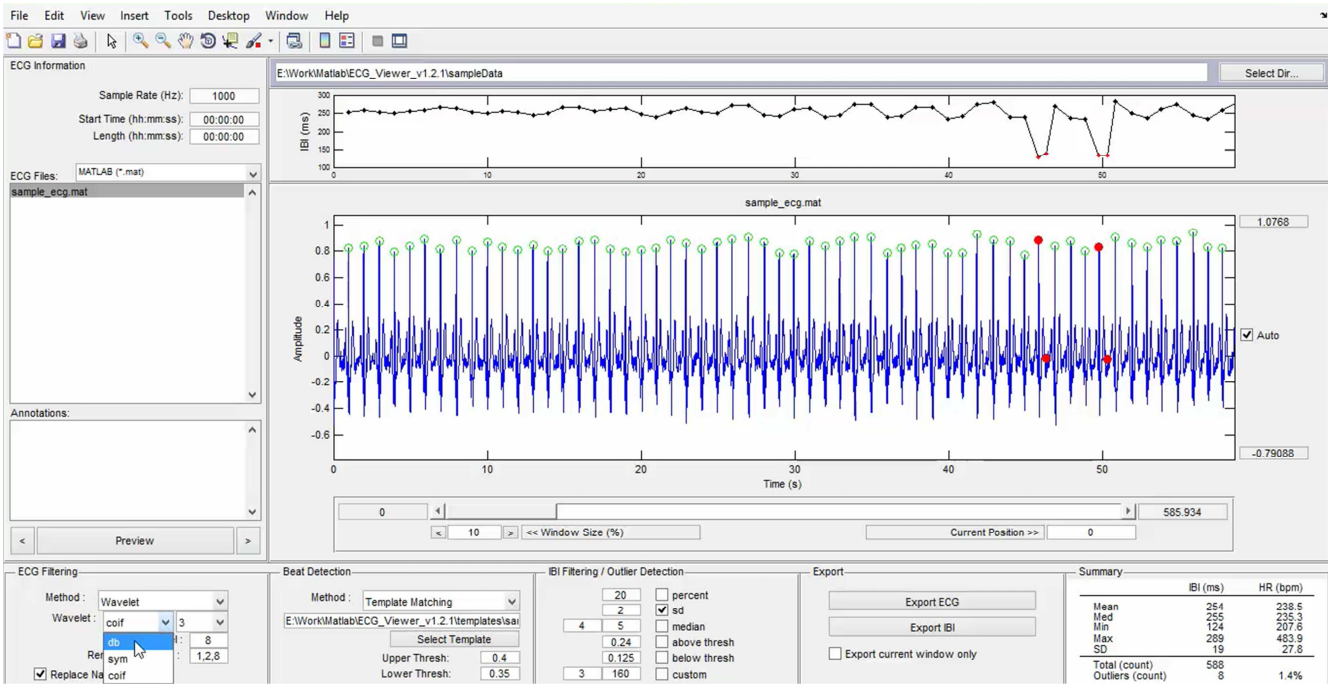

Figure 3. *The second signal, the number of outliers is less than the number of beats.*

4. Conclusion

Cardiac disease, including hypertrophy, heart enlargement, arrhythmias, and hinge problems affect the ECG signal and cause the signal to come out of its natural form. So, by examining the ECG signal, you can detect a variety of heart disease and try to cure these diseases. Therefore, studying the vital signal of the heart is of great importance, which should analyze this vital signal accurately. The correct analysis of this signal depends on the signal received and the inappropriate information. Our main goal in this paper was to eliminate the noise from the ECG signal and to test the applicability of the threshold based wavelet to eliminate the noise from the ECG signal. So, the ECG signal was simulated accurately and we removed it from the noise using the Wavelet functions and obtained a favorable signal for medical analysis.

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