ECG De-noising and Delineation Using Wavelet Transform and Slope Thresholding

M. Rekha, B. Rajapriya, M. Saranya, K. Shruthilaya and S. Ravindrakumar*
Senior Assistant Professor*
Department of Electronics and Communication Engineering
Chettinad College of Engineering and Technology, Karur, India

ABSTRACT

The electrocardiogram signal has been denoised and delineated. Both the simulated version and real-time version of the electrocardiogram signal was used for performing denoising and delineation operation. De-noising of electrocardiogram signal was done using various wavelet transforms such as daubechies, biorthogonal and haar wavelets. While experimenting with various wavelets it was evident that the Daubechies-3 wavelet proved more efficient in the removal of noise. The denoised signal was used to find the threshold value for obtaining the maximum point (R peak) in the electrocardiogram signal. Then with the help of the peak point (R peak) other waves (QRS complex and T wave) was detected. Hence the electrocardiogram was delineated to get the individual parameters (P, QRS complex and T wave) which can then be utilized for diagnosing various arrhythmias present in it.

1. INTRODUCTION

The ECG is a graphic recording of the electric potentials produced in association with the heartbeat. A twelve lead system is used for ECG recording purpose which gives information about heart’s activities. There are several methods for recording the electrical activity of the heart. One of the standard methods is twelve lead systems. The traditional twelve lead ECG can be extended in number of ways to improve the sensitivity for detecting various arrhythmias. It includes rV4 lead, Lewis lead or S5. In this paper the ECG signal recorded by the standard twelve lead system and those obtained by simulating it in MATLAB software is used.

One cardiac cycle in an ECG consist of P, Q, R, S and T waves. The analysis of the ECG is widely used for diagnosing many cardiac diseases. Since most of the clinically useful information in the ECG is found in characteristic wave peaks and boundaries, the development of accurate and Robust Algorithms for automatic detection of the major ECG characteristic waves (P wave, QRS complex, and T waves), the so-called ECG wave delineation is required. Several methods are available for the purpose of delineation such as the Pan and Tompkins algorithm, Kalman filter, Extended Kalman Filter and Hidden Markov model. The delineated parameters can be used to analyze various arrhythmias by comparing the delineated parameters of the test signal with the standard parameters.

2. LITERATURE REVIEW

ECG signal characteristics can be studied using several techniques such as Pan and Tompkins algorithm, Kalman filter, Extended Kalman filter, Wavelet transforms. The basic principles used here
for denoising is Wavelet transform. This method has the advantage of preserving both time and frequency information in the signal.

2.1 Wavelet Transform

A wavelet series is a representation of a square-integrable (real- or complex- valued) function by a certain orthonormal series generated by a wavelet. The integral wavelet transform is the integral transform defined as

\[ [W_f](a, b) = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{\infty} \frac{\psi(x-b)}{a} f(x) dx \]

As an alternative to the normal filtering techniques, which use different narrow-band filters to extract the frequency contents of the signal, the wavelet transform technique can be used. In wavelet transform technique, the signal is analyzed at different frequencies with different resolutions. It is called multi resolution analysis. The wavelet transform is a Time-frequency signal analysis method. It provides simultaneous interpretation of the signal in both time and frequency which allows local transient or intermittent components to be clearly available. In this paper the Wavelet transform was employed to de-noise the real time ECG signal. We have also used wavemenu in MATLAB to remove the noises and decompose the signal into different levels by using Haar, DB, SYM, Biorthogonal wavelets. The wavelet transform has become a useful computational tool for a variety of signal processing applications. For example, the wavelet transform is useful for the compression of digital image and important for storing images using less memory and for transmitting images faster and more reliably.

2.1.1 Daubechies Wavelet

Daubechies wavelets are widely used in solving a broad range of problems, e.g. self-similarity properties of a signal or fractal problems, signal discontinuities. The important property of the daubechies wavelet is vanishing moments.

\[ \int_{\mathbb{R}} x^k \psi(x) dx = 0, k = 0, ..., p - 1 \]

2.1.2 Haar Wavelet

Haar wavelet is a sequence of rescaled "square-shaped" functions. Haar Wavelet decomposes the signal into two sub-signals of half its length. The Haar scaling function is defined as

\[ \phi(x) = \begin{cases} 1, & \text{if } 0 \leq x \leq 1 \\ 0, & \text{elsewhere} \end{cases} \]

Haar mother wavelet is given by

\[ \psi(x) = \begin{cases} 1, & 0 \leq x \leq 1/2, \\ -1, & 1/2 \leq x \leq 1, \\ 0, & \text{otherwise} \end{cases} \]

The technical disadvantage of the Haar wavelet is that it is not continuous, and therefore not differentiable.
2.1.3 Biorthogonal Wavelet

A biorthogonal wavelet is a wavelet where the associated wavelet transform is invertible but not necessarily orthogonal. In Biorthogonal wavelets the scaling function $\phi$ and the mother wavelet $\psi$ are given by the recursive relations,

$$
\phi(x) = \sqrt{2} \sum_{k} h_k \phi(2x - k)
$$

$$
\psi(x) = \sqrt{2} \sum_{k} g_k \phi(2x - k)
$$

Designing biorthogonal wavelets allows more degrees of freedom than orthogonal wavelets. One additional degree of freedom is the possibility to construct symmetric wavelet functions.

3. METHODOLOGY

The ECG signal can either be obtained from real-time signal sources like ‘physionet.org’ in the internet or it can be simulated using the MATLAB software.

3.1 De-noising of ECG

This input ECG signal is denoised using convolution algorithm and wavelet transform (Daubechies, Biorthogonal, and Haar wavelets). The denoising was better observed in db3 (Daubechies-3) wavelet. In the denoised signal, the maximum point (R peak) is obtained. In this paper the Daubechies wavelet is adopted for de-noising the test ECG signal. Even though the Daubechies algorithm is conceptually more complex and its computation methods are complicated than the other methods. It is used here because of its ability to pick up minute detail that cannot be detected by other wavelet transforms such as Haar and Biorthogonal.

3.2 Delineation of ECG

Further, by employing the thresholding mechanism the slope of the R wave is identified to detect its onset. The following equation of slope thresholding is

$$
Z = (2^c)/16
$$
Where, \( c \) is maximum value of the slope 
\( Z \) is slope thresholding value.

Then, the QRS complex is extracted by employing the method of forward searching and reverses searching ten samples with respect to the identified peak point in the denoised signal. Then by employing same mechanism, other waves such as the P wave and T wave were also extracted separately from the denoised signal. The individual delineated signals (P wave, QRS complex, T wave) are then separately correlated with each of the various diseased ECG signals to obtain the maximum correlation value. Based on the correlation values the arrhythmia present in the test signal can be identified. Then the results can be compared with the physician’s annotations for accuracy.

4. RESULTS

4.1 Real Time Signal

4.2 Denoised Signal

4.3 Maximum Points

4.4 Delineation Output
4.5 Delineation Using Real Time Signal

5. CONCLUSION

ECG signal was de-noised using a program with different wavelets and the results were compared with those obtained through wavemenu. Delineation of the ECG signal was done by detecting the peaks of the P wave, R wave and T wave employing thresholding technique and by using those peaks to extract them separately from the test signal. These delineated waves can be used for the purpose of arrhythmia diagnosis.

REFERENCES

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