Denoising ECG Signal using Empirical Wavelet Transform

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Abstract

Denoising signals has been achieved as one of the greatest application in the field of Signal processing.In biomedical signal processing the main challenge is the noise embedded within the physiological signals.ECG signal denoising process in an embedded platform it is a challenge to deal with several issues.The analysis of the ECG signal has a great importance in the detection of cardiac abnormalities.The electrocardiograph signals are often affected by noise.The noises that commonly affect are power line interference ,instrumentation noise ,external electromagnetic field interference.The noises are classified according to the frequency content present in the signal.It is essential to reduce the disturbances in ECG signal to improve the accuracy and the reliability.Different types of the denoising methods have been adopted to remove the noise.In this paper a denoising technique for ECG signal based on the Empirical Wavelet Transform has been adopted.By using this technique an adaptive decomposition of the fourier spectrum is carried out.Spectrum is segmented depending on the information present in the signal.The proposed technique has been computed with different values of noise levels. The result shows that as the percentage of the noise level increases the SNR decreases gradually. The SNR has reached almost value of about 30 it shows better performance while denoising with EWT.

Keywords

Empirical wavelet transform (EWT), Signal to Noise ratio (SNR),Electro Cardiogram (ECG), Additive White Gaussian Noise (AWGN), Empirical Mode Decomposition (EMD),Intrinsic Mode Functions (IMF), Signal to Noise Ratio (SNR).

1. Introduction

Signal processing is used for ECG analysis and interpretation.In many situations the ECG signal has been corrupted by different types of noise, Noise reduction represents another important objective of ECG signal processing.ECG defines the electrical activity of the heart .Achieved by placing electrodes on the skin.Any change in the heart rhythm caused by cardiac arrhythmias will reflect person's ECG also.In this paper an adaptive approach has been opted to denoise the signal.

To analyze the signal, adaptive method is used to find the sparse representation. Rigid methods such as fourier transform uses some prescribed subdivision or basis to process the signal.EWT is one of the adaptive method used where the basis are found depending on the information content in the signal.The method has a great advantage to separate the stationary and non stationary components from a signal.Here the mode is represented as AM -FM components .The fourier spectrum has been segmented and some filtering action has been given for the detected support.The orthonormal basis are formed based on the information present in the signal.

ECG shows the electrical activity of the heart. It provides the following information regarding the position of the heart and size of the chambers ,origin of the impulse and its propagation ,Heart rhythm, Heart rate and disturbances in conduction ,Variations in electrolyte concentrations etc.

The Fig.1 depicts ECG wave pattern it mainly consist of the following waves

- P wave

It indicates the depolarization of the atria. It is the first wave which has small amplitude of approximately 1mV

- QRS complex

Mainly consist of three peaks Q and S are the negative peaks and R is the positive peak. It indicates the depolarization of the ventricles

- PR segment

The electrical impulses travel from the atria to the ventricles through the AV node

- T wave

Soon after the QRS complex which indicates the positive deflection is called as T wave which indicates the repolarization of the ventricles

- ST segment

It aligns with the isoelectric line and occurs between the depolarization and repolarization of the ventricles

- U wave

It follows the T wave and represents the repolarization of the purkinje Fibres. The Fig.1 shows the ECG waveform pattern plotted with different segments.

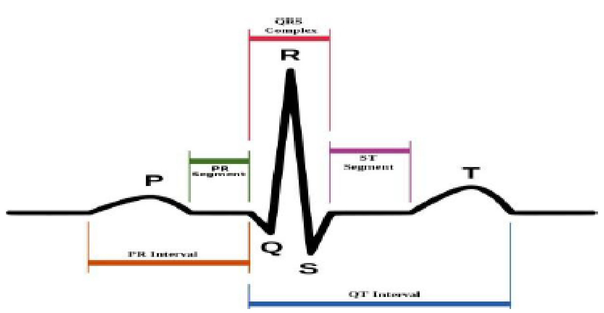

Fig .1 ECG Wave Pattern

2. System Model

An adaptive method to denoise the ECG signal has been proposed over here .The noises mainly present are the baseline wander noise and the AWGN noise in the ECG signal. Different authors has been proposed different denoising techniques for the ECG signal .But all of those methods uses a prescribed subdivision and in those cases it forms an orthonormal basis function independent of the signal.In the proposed method an adaptive signal processesing method is opted.It shows better performance to find the sparse representation .A well known approach is to build the basis pursuit approach. The adaptive method can be used to separate the signal as AM-FM components, It combines both the strength of wavelet formalism and EMD's adaptability .At first the noisy imf's are obtained which has undergone filtering action to produce the denoised ECG signal. With this method at different percentage of noise levels the SNR of the signal has been computed.It has been found out that as the Percentage of the noise level increases the SNR decreases gradually.The SNR defines the ratio of the signal power to the noise power.

3. Previous Work

There are many techniques used for denoising the ECG signals.One of them is the EMD to decompose a signal into different modes.It is one of the adaptive technique used which does not use any prescribed subdivision scheme for segmentation.It seperates both the stationary and non stationary components from the signal.But the method has certain disadvantages .It lacks the mathematical theory and due to its non linearity it is very difficult to model,moreover it is one of the algorithmic approach.Another approach is the Ensemble EMD technique .Where several decompositions of the original signal with different noises are computed.The final EMD is the average of each EMD.The technique increases the computational cost .Malvar Wilson wavelets build an adaptive method by segmenting the temporal signal itself but the task is very difficult to perform.
In this paper we present an adaptive method of segmenting the signal has been used.It doesn't use any prescribed subdivision scheme. This denoising technique overcomes all the above drawbacks. The orthonormal basis are developed depending upon the information contained within the signal.The noisy imfs are filtered to get the denoised output.

4. Proposed Methodology

Adaptive denoising of signals plays a major role in denoising of biological signals. Since the biological signals are non-stationary signals and periodic in nature. The remaining wavelet denoising techniques adopt a prescribed subdivision scheme. The keen feature of the adaptive wavelets are they are capable to separate the AM and FM components of a signal. They have a compact support Fourier transforms. Segment the Fourier spectrum by applying some filtering operation. By examine the Fourier supports the set of functions which form an orthonormal basis functions are formed. Based on it the EWT is applied and the inverse of it to analyze the signal. The EWT is able to separate both the approximation and detail coefficients .It is based on apriori filtering and has a strong mathematical background.

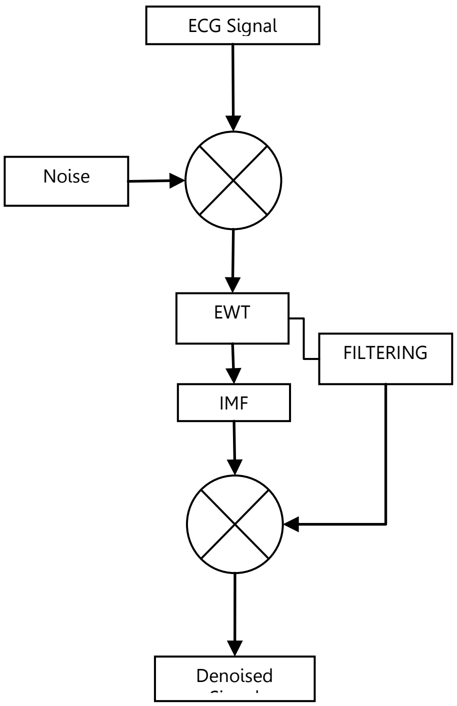

Fig .2 Block diagram of ECG signal denoising using EWT

As an application oriented EWT denoising technique has been used in the case of biological signals since it is a non-stationary signal. At first the Fourier spectrum of the ECG signal is determined and then divides into different segments .Find the maximum or highest peak point within the signal. Along the midpoints of the two maximas consider the middle point .Design the filter in such bands. Here the filter output is convoluted with the original ECG signal to get the IMF components. To undergo the EWT the algorithm has the following steps. The algorithm is as follows,

1 Find the Fourier transform of the signal
2 Compute the local maxima of the transformed signal w_n
3 Choose $\gamma < min_n \left(\frac{w_{n+1}-w_n}{w_{n+1}+w_n}\right)$
4 Build the filter bank
5 Filter the signal to get each component.

5. Segmentation of the Fourier spectrum

It is one of the important step to provide adaptability with respect to the signal. The different modes of the signal are extracted specified around a specific frequency .Need to find N+1 boundaries .To find those boundaries find the local maxima in the spectrum and sort in decreasing order.

6. Framing

Framing is done to obtain a tight frame .In order to avoid the loss of information. It should satisfy the following condition $\gamma < min_n \left(\frac{w_{n+1}-w_n}{w_{n+1}+w_n}\right)$.

7. Empirical Wavelet Transform

In this case the detail coefficients are given by inner products with the empirical wavelets

$$W_f^{\epsilon}(n,t) = \langle f, \varphi_n \rangle = \int f(\tau)\varphi_n(\tau - t)d\tau \qquad (1)$$

And approximation coefficients inner product with the scaling functions.

$$W_f^{\epsilon}(0,t) = \langle f, \varphi_1 \rangle = \int f(\tau)\varphi_1(\tau - t)d\tau \qquad (2)$$

And the inverse transform has been found to reconstruct the original signal

$$f(t) = W_f^{\epsilon}(0,t) * \varphi_1(t) + \sum_f^N W_f^{e}(n,t) * \varphi_n(t) \qquad (3)$$

8. Results/Simulations

For the proposed work, the simulation has been done in MATLAB 7. Signal has been obtained from MIT –BIH database. The SNR at different percentage of noise levels are computed. The SNR has been computed for 10,20,30,40 and 50 percentage of noise level. From the simulated result it is clear that denoising using EWT the SNR has reached a value of about 31.SNR above 21 shows better performance .So denoising using this technique is almost effective. The simulated graphs are shown Fig .3 shows the ECG signal added with Additive White Gaussian Noise which consist of all the frequency components and the Baseline Wander which is due to the variation in the isoelectric line.

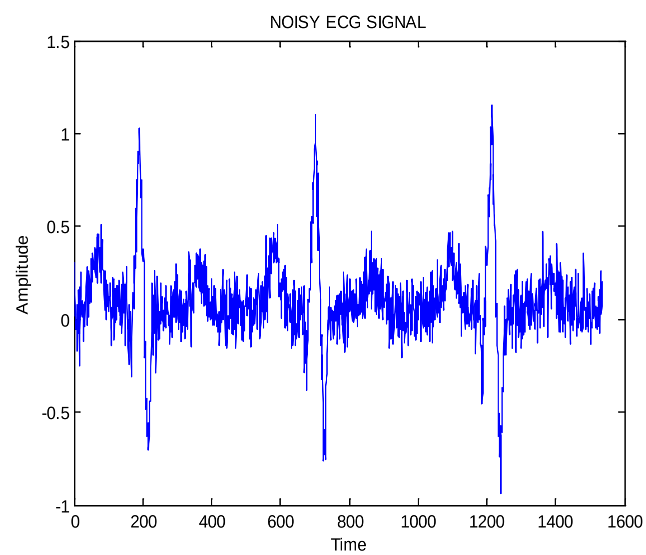

Fig.3 Noisy ECG signal taken as input

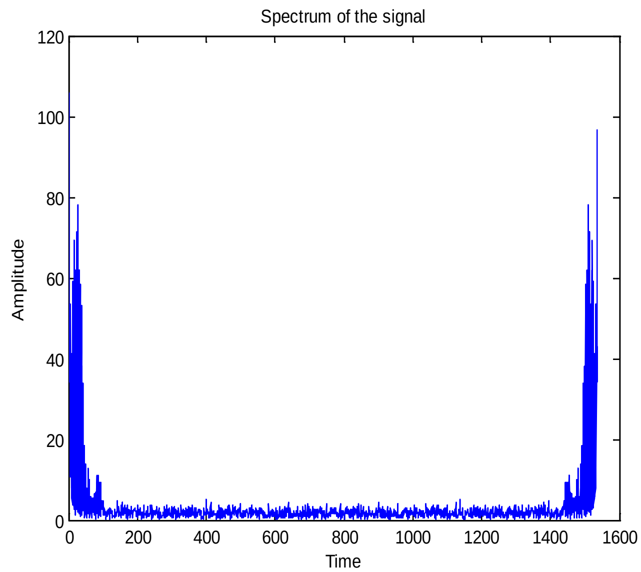

Fig.4 Fourier Spectrum of the signal computed

The Fig.4 shows the Fourier spectrum of the signal computed .The Fourier spectrum of the signal is divided into different segments. And from the segments the maximum peak point of the signal is found. Along the two middle peak points a filter has been designed.

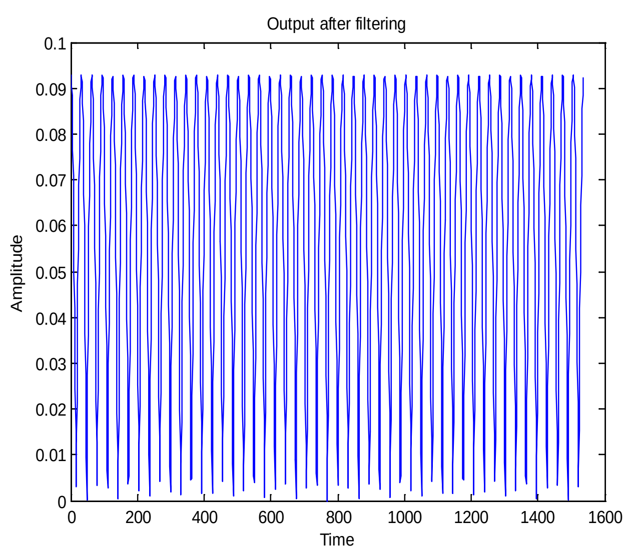

Fig.5 Output obtained after Filtering action

The Fig shows the output after filtering .The output consists of different imf components with noisy imfs within it. The imf components with the noise has been removed.

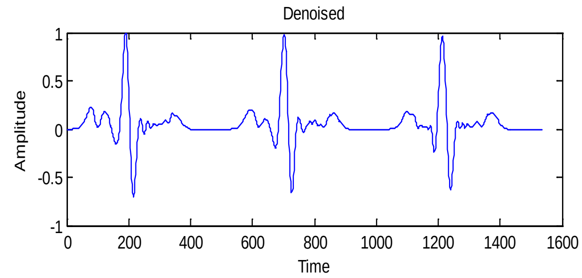

Fig.6 Denoised ECG signal using EWT

The Fig.6 shows the denoised Output of the ECG signal. All the noisy imf's are removed. By performing denoising with the Empirical wavelet transform.

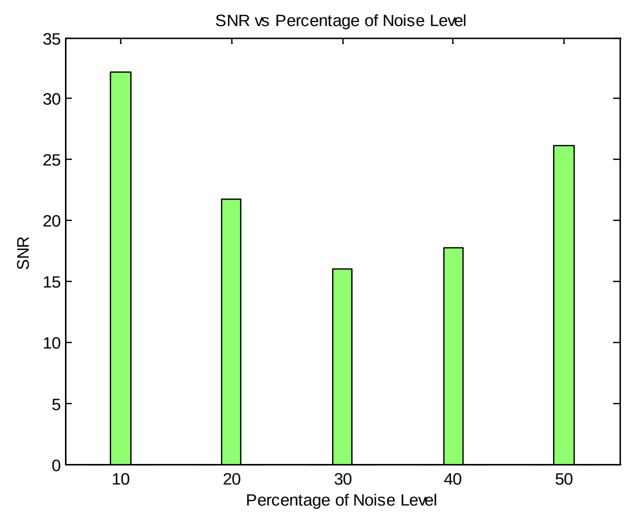

Fig .7 SNR vs Percentage of Noise Level for EWT

The Fig shows the SNR Vs Percentage of noise level computed. From the graph it is clear that at 10 percentage of noise level it shows the maximum SNR .Here, in the proposed work the SNR value is above 20 it shows better result while denoising. The below table shows the different SNR values computed for different Percentage of noise levels.

Table-1: SNR VS Percentage of Noise Level For EWT

PERCENTAGE OF NOISE LEVEL	SNR
10	32.1410
20	21.7550
30	15.9886
40	17.7127
50	26.1371

9. Conclusion

In this work, a new adaptive technique for denoising ECG signal has been developed. ECG is one of the non-stationary biological signal .Any noise added to the ECG signal will cause difficult to determine the cardiac diseases. In this paper Wavelets are build adapting to the signal. Dilation factors don't follow a prescribed subdivision scheme it is detected empirically. The main features include that it doesn't use any prescribed basis. Self-adapting according to the signal which is able to separate stationary and non stationary components from a signal.

7. Future Scopes

As future work, The EWT can be applied for denoising image .The 1D application can be extended to the 2D .The EWT can be explored for applications such as denoising and deconvolution. Different strategies can be used to segment the spectrum. Imf's are not orthogonal in case of EWT denoising technique to make it orthogonal different orthogonalisation procedures can be used such as Gram Schmidt orthogonalisation procedure.

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