Study of ECG Signal Denoising and Peak Detection Techniques

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Abstract – ECG signal is a biomedical signal that gives electrical activity of heart. This ECG signal may corrupted by different noises like channel noise, power line interference (PLI), baseline wandering, muscle artifacts etc. So denoising and smoothening is done before peak detection. In this paper study of different ECG denoising and peak detection techniques are presented.

Index Terms – ECG signal, Denoising, Peak detection, Sensitivity

1. INTRODUCTION

Electrocardiogram (ECG) signals are important biomedical signals, which are reflective of an electric activity of the heart. ECG measurements may be corrupted by many sorts of noise: EMG (electromyogram) signal, power line interference,AWGN etc. The corrupted noise prevents the proper analysis of ECG signal. As a result, it becomes necessary to separate signal from interference. The main features of an ECG signal are P,Q,R,S and T points. These points gives information about cardiac health of a person. So QRS detection and RR- interval detection are done for preliminary analysis of ECG signal. There are different denoising and peak detection techniques available in the literature. In this paper some of these techniques are mentioned.

The rest of the paper is organized as follows. Different ECG signal denoising techniques are presented in Section II. Different peak detection methods are discussed in section III. Section IV concludes this paper.

2. DIFFERENT ECG DENOISING TECHNIQUES

An ECG signal recorded from a human body may contain different types of interferences. Proper denoising of ECG signal is thus necessary to separate signal from noise. Adaptive filters are used to reduce the low frequency ECG signal noises like Power line interference and Base Line Interference. Mainly here an Adaptive Noise canceller is used to denoise the ECG signals and the algorithm used here is Recursive least squares(RLS) .PLI may severely affect the ECG signal .An advantage of this technique is that it has fast convergence even when the Eigen value spread of the input signal correlation matrix is large [1]..When working in time varying environment, the RLS algorithm has very good performance

The use of discrete time wavelet transform (WT) can be effective for suppressing wideband EMG noise compared to linear filtering. In this method reduction of broadband myo potenials (EMG) in ECG signals using wavelet wiener filtering is done. The Wiener filter requires an estimate of a noise-free signal, which is necessary to calculate the correction factor for the adjustment of transform coefficients [2]. Here the main aim is to find the most appropriate filter banks and to choose other parameters (decomposition depth of input signal, threshold size and thresholding method used for estimating noise free signal) of wiener filter with respect to SNR obtained. Selection of appropriate values of the parameters was performed to maximize the average resulting signal-to-noise ratio (SNR) for all the signals tested [2]. Testing is performed by loading ECG signal from standard CSE database and artificial addition of noise to it. Filtering performance was improved by adapting parameters of wiener filter according to the level of interference in the input signal. The proposed AWWF (Adaptive Wavelet Wiener Filter) algorithm provides better filtering results by showing an average SNR improvement of 10.6dB.

The main goal of ECG denoising is to recover valid ECG from undesired artifacts with minimum distortion. Optimal denoising algorithm for the ECG based on Stationary Wavelet Transform (SWT), including the selection of the optimal wavelet basis, appropriate thresholding method and decomposition depth, also called level or scale [3] is an effective method. The studies highlighted three main steps in WT denoising procedure.

1) Decomposition of noisy signal at level N using a wavelet basis for obtaining approximate and detailed coefficients.

2) Shrinkage of coefficients of each level by a thresholding method, along with shrinkage function and threshold.

3) Reconstruction of denoised signal using shrunk coefficients.

Results of denoising procedure are evaluated by means of SNR and visual inspection. The tests concluded that for processing ECG signals, symlets are the better wavelet bases because their near symmetry characteristics, orthogonal, compact support and scaling function is similar to that of ECG signal. Test results also summarized that highest SNR can be achieved using SWT thereby decomposing noisy ECG signal at level 5, employing sym4 wavelet basis and hard shrinkage function with EBayes threshold.

Another method used for the denoising of ECG signal is the use of bionic wavelet transform (BWT). The most distinguishing characteristics of BWT is that its resolution in the time – frequency domain can be adaptively adjusted not only by the signal frequency but also by the signal instantaneous amplitude and its first-order differential[4] .In denoising first the BWT is optimized and then the BWT coefficients are calculated after that hard thresholding and soft thresholding is done. This algorithm has many advantages like the signal denoised by BWT is a smoothed version, Single artifacts do no longer exist, Interference removal is achieved by properly adjusting the center frequency of mother function and the number of decomposition levels[4], For higher input SNR more improvement is obtained.

The ECG signal with high frequency Additive white Gaussian noise can be reduced using Empirical mode decomposition and moving average filter. Here at first the noisy ECG signal is decomposed in to various intrinsic mode functions (IMFs) of finite length. Then first 3 IMFs were taken and then width of the QRS complex calculated. Then an adaptive window (tapered cosine) is designed and it is applied to the noisy IMFs to preserve the QRS complex. After applying window to the noisy IMFs smoothening of QRS complex done using moving average filter with a span of 3.Thus finally we get the denoised ECG signal. EMD is an adaptive and data driven technique, thus suitable for any non-stationary signal [5].And the denoised ECG signal is very much similar to the original clean ECG signal.

3. DIFFERENT PEAK DETECTION TECHNIQUES

Wearable sensors are used to wirelessly transmit ECG signals of patients at remote locations to monitoring centers. In joint QRS detection and data compression technique, both operations are done together so that the complexity of the device gets reduced. ECG signals are collected from patient's body using electrodes, it is then processed. Adaptive linear filtering is used for ECG detection and data compression. The current ECG sample is predicted from actual sample and prediction error is calculated as the difference between actual and the predicted value. The prediction error is higher for steep amplitude signals. QRS portion of ECG signal is having steep amplitude. So prediction error marks the presence of QRS complex. A simple bit packaging scheme is used for error signal coding [6]. Usually ECG data are taken from MIT/BIH Arrhythmia Database for studies. It contains several recordings of ECG signals taken at different conditions. For the MIT-BIH Arrhythmia Database, a 48 half-hour excerpts of two-channel 24-hour are selected, ECG recordings obtained from 47 subjects (records 201 and 202 are from the same subject) studied by the BIH Arrhythmia Laboratory between 1975 and 1979. Of these, 23 (the "100 series") were chosen at random from a collection of over 4000 Holter tapes [7].

The original signal is retrieved from coded signal. It is smoothened using Savitzky-Golay filter to remove impulse noise. For detecting peak, the signal is enhanced and an initial threshold value is set. It is the 25% of the maximum amplitude sample in the signal. When any signal crosses the threshold value, it checks for three continuously rising values in the signal and waits for 100ms, again checks for three continuously falling points. If it is satisfied peak is detected otherwise discards it. When 4 peaks are detected average threshold is calculated. RR interval is also calculated. For every RR interval if QRS peak is not detected then average threshold is reduced to 75%. Sensitivity and Positive Prediction is calculated. Sensitivity is the measure of QRS peaks that are correctly detected. Predictivity shows the proportion of positive results in a test. The result shows a sensitivity of 99.81% and positive prediction of 99.64%.

Another peak detection method uses decision rules to discriminate the QRS complex from noise events. There is a pre-processor section which performs linear and nonlinear filtering of ECG signal. The decision rule is based on the output of the pre-processor. QRS complexes has steep amplitude, but simple peak detection algorithm falsely detects multiple peaks due to ripples in the wave. A simple local maxima peak detector is used here which can detect small- amplitude peaks. Both peaks results from same QRS complex, but one peak is classified as QRS complex and other as noise [8]. Low pass filtering helps to reduce the ripples and multiple peaks. Instead of using a filter, in this work, a peak detection algorithm is used. It will find peaks in final output of filtering stage and these peaks define an event. The algorithm stores maximum levels and new peak is defined only after half the maximum of that height is crossed.

MIT/BIH tapes are pre-processed and for each detected peaks a 2-dimension vector is defined. QRS detectors may be optimized with respect to false positives and negatives. Here the decision rules are optimized to minimize sum of false negative and false positive detections. Peak level estimator is used to predict next QRS peak from previous one. Here peak detection is done using mean, median and iterative prediction. Similarly RR interval is also calculated. The results shows that the detector produces 340 false negative detections and 248 false positive detections for a sensitivity of 99.69% and positive predictivity of 99.77%.

4. CONCLUSION

The survey includes the works and findings done by various researchers on ECG signal denoising and peak detection techniques. ECG signal suffer from serious noise problems. Many of the works pointed out that the use of discrete time wavelet transform can be an effective tool for suppressing EMG noise compared to linear filtering and for suppressing high frequency Additive white Gaussian noise EMD and moving average filter is an effective technique. Peak detection is done to locate QRS complex in the ECG signal. Studies shows that Sensitivity and positive predictivity is very high for ECG signals.

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