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A Review for Removal of Baseline Wander Noise in ECG Using Various Techniques

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Abstract— The electrocardiogram (ECG) is the powerful non-invasive tool used for diagnosis of a large number of heart related problems. The electrocardiogram signals are usually contaminated by different noises from the large number of sources. The baseline noise is low frequency noise from various noises of ECG that is generated by the little movement of patient. There are different techniques using filters used for noise removal of that low frequency signals. The different techniques using digital filters for removal of baseline wander noise are reviewed in this paper.

Keywords— ***ECG signal, baseline wander noise, Filtration, Wavelet Approximation, Moving Average Approach, Polynomial Fitting.***

I. INTRODUCTION

The ECG is a bioelectric signal that records the electrical activity of the heart. An extracellular electric behaviour of the tissue of cardiac muscle is represented by ECG. In this, the different electrical phases of cardiac cycle are explained and a summation in the time and in space of the potentials are described which are generated by millions of cardiac cells. The many number of ECGs are taken for diagnosis of different classes of patients where ECG can provide lot of the information about the abnormality in the patient. The signals of different patients are analysed by the physicians and these signals are interpreted depending upon their experience. ECG signal pre-processing is first step for the classification of the heart diseases. This classification depends on the P, QRS, ST waves or the combination of these waves. The different parameters known as amplitude and duration of the P-QRS-T-U wave contains the useful information about nature of the disease related to the heart [1].

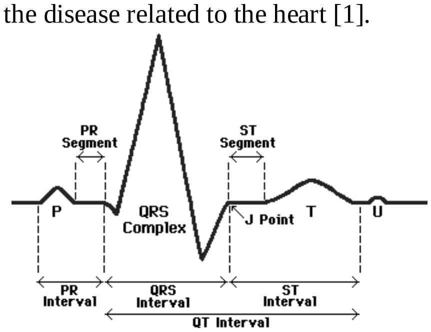

Fig.1. Normal Cardiac Cycle of the ECG signal

The noise reduction is an important factor in the ECG since the signal must be accurately represented for the further analysis. The decision to choose the type of the filter for the de-noising depends on the various factors like extraction of type of the waves, time required for the pre-processing, complexity involved, and reconstruction of the signal. This signal can be analyzed and processed in the two domains time and frequency. ECG signal is one of the signal from human body signals which can be analyzed and worked in these two domains. The different noises affect the ECG signals which can cause problems in analysing the ECG. Therefore, different signal processing schemes are applied to remove all those interferences. ECG signal is normally corrupted by different noises which are generated by the biological and environmental resources such as muscle contraction or electromyography (EMG) interference, baseline drift, motion artifacts caused by changes in electrode-skin impedance with the electrode motion, power line interference, electrode contact noise and instrumentation noise.[2]

Baseline Wandering is the noise of low frequency which is caused by the loose connection of electrode and skin. When the patient breathes, there is a relative motion between the skin and the electrode resulting in the shift in baseline. Baseline noise makes the manual and automatic analysis of the ECG records difficult in the detection of ST segment deviations in the signal. Therefore, the removal of baseline wandering noise in ECG is an important issue to get better results. Therefore, it is necessary to remove this type of noise for the correct evaluation of ECG. This paper presents the review of different approaches to remove the baseline wander

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noise from ECG signal. Different techniques are IIR filtering, FIR filtering, wavelet approximation, moving average approach, Savitzky-Golay Filtering, Polynomial Fitting. The paper is organised as follows. Section II describes the different approaches to remove the baseline wander noise from signal. The literature review of different approaches is illustrated in Section III. Finally, the conclusions are provided in Section IV.

II. DIFFERENT APPROACHES

A. FIR Filtering

In digital signal processing, FIR (finite impulse response) filter is the filter whose impulse response is of the finite duration, because it settles to zero in the finite time. The windowing method is the most commonly used method for the designing of FIR filters. The basic principle for the window design method is to truncate or trim the ideal response with the finite length window. In the filters which are designed using windows like Rectangular, Bartlett, Hamming and Blackman . The trade off exists between the main lobe width and the side lobe amplitude. The Nth order of the filter width is inversely proportional to main lobe. When there is an increase in the window length, the transition band of the filter decreases. For minimum stop band attenuation and the pass band ripple, the designer has to find a window with an appropriate side lobe level and then choose an order to achieve the prescribed transition width. In this process, the designer has to settle down for a window with an undesirable design specifications. To overcome this problem, another window known as Kaiser has chosen a class of windows that are based on the portable Speriodal functions. The equation for Kaiser Window is given by:

$$w[n] = \begin{cases} \dfrac{I_0\left(\pi\alpha\sqrt{1-\left(\frac{2n}{N-1}-1\right)^2}\right)}{I_0(\pi\alpha)}, & 0 \le n \le N-1 \\ 0 & \text{otherwise}, \end{cases} \quad \text{.....................................} \ (1)$$

Where N is length of the sequence, I0 is the zero order Modified Bessel function of first kind and α is an arbitrary, non-negative real number used to find the shape of window.

B. IIR Filtering

Infinite impulse response (IIR) is the property applying to the many linear time-invariant systems. IIR filter techniques have an impulse response function that is non zero over an infinite length of time. IIR Filter can be implemented as either analog or digital filter. The equation for the transfer function of second-order Butterworth high-pass filter is given below:

$$H(s) = \frac{A_{hp} b s^2}{s^2 + \frac{a}{b} w_c s + \frac{w_c^2}{b}} \quad \text{..} \ (2)$$

Where A_{hp} is high pass gain.

C. Wavelet Approximation

A wavelet transform breaks down a signal into basis functions which are known as wavelets. Wavelet approximation for the various segments of the time-domain signal at different frequencies is calculated individually resulting in the Multi-resolution analysis (MRA). These wavelets are used by the type of results in this class. This technique attempts to determine the overall tendency of the ECG signal. The implementation of an MRA is the use of the Shensa's algorithm which corresponds to the computation of the Stationary Wavelet Transform (SWT). This method is used to determine the baseline noise and remove it. To determine the noise by using this method, the SWT for ECG signal is calculated with K decomposition levels. Then all the coefficients are met to zero and the new sequence is generated. The inverse SWT of the new generated sequence is calculated and then baseline estimation is obtained. This method gives good time resolution and poor frequency resolution at the high frequencies and good frequency resolution and poor time resolution at the low frequencies. The characteristics of this multi resolution analysis make it better for the signals having high frequency components for the short durations and low frequency components for the long duration.

D. Savitzky-Golay Filtering

Savitzky-Golay filtering can be thought of as the generalized moving average. The coefficients of the filter are derived by performing un-weighted linear least squares fit using the polynomial of an appropriate degree. The SG filter calculates smoothed value for each data point by estimating the local polynomial fit in the window. First of all, the ECG signal is low-pass filtered to remove most of the frequency components from the ECG signal. A symmetric FIR filter is used to avoid the distortion having the cut-off frequency of 0.8Hz. Then a SG filter is used to extract the baseline and the baseline is subtracted from the original signal which is delayed. The output is obtained having no baseline.

E. Moving Average Approach

A moving average filter smoothes data by replacing each data point with average of all other neighbouring data points that are defined within the span . The moving average filter can only pass low frequency signals. But the removal of baseline wander noise is the high-pass operation. If we subtract the signal obtained from the moving average filter and the recorded signal then we can obtain the wanted signal. A moving average filter is the special type of FIR filters. The transfer function of a moving average filter is given as:

$$H(z) = \frac{1}{N}\sum_{i=0}^{N-1} z^{-i} \qquad \text{.......... (3)}$$

The difference equation is:

$$y(N) = \frac{1}{N}\sum_{i=0}^{N-1} x(n-i) = \frac{1}{N}[x(n) + x(n-1) \dots\dots x(n-N+1) \qquad \text{.......... (4)}$$

Where x (n) is original ECG signal, y (n) is filtered ECG signal and N is power of two normally.

F. Polynomial Fitting

Polynomial fitting is the method for removal of baseline by fitting the polynomials to the representative points in the ECG signal. A representative sample is defined in each beat and it is known as knot. By increasing, the order of the polynomial and selecting one knot per beat through which baseline noise should pass is the method used to remove higher-frequency baseline noise and preserve only low frequency heart information which is used to get better results. The polynomial is fitted to the representative points in such a way that if one subtracted from the original signal then these knots have value of 0. The coefficients of the polynomial model can be easily reached by the means of least square error. If the order of equation is very low then the proper estimation of the baselines is not estimated. If the order of the model is higher than baseline's order then it partly tracks the ECG basic wave instead of the signal's trend.

III.LITERATURE SURVEY

Literature survey shows that various techniques for the removal of baseline wander are used from the ECG signal. Researchers have used different techniques on the basis of digital filters to get better results after the removal of noise.

Rinky Lakhwani, Shahanaz Ayub, J.P. Saini[2] explained that the heart diseases are one reason for the death from the several serious problems in this century and according to the latest survey, 60% of the patients die due to Heart problems. These diseases are diagnosed by ECG signals. ECG signals estimate the electrical potentials on the body surface via contact electrodes therefore it is very important signal in cardiology. There are different noises that affect the ECG signals due to which problems occur during analyzing the ECG. The various signal processing schemes are applied to remove such interferences. They are proposed a method for removal of low frequency interference which is known as baseline wandering in ECG signal and the digital filters are designed to remove it. The various digital FIR filters are designed with different windowing methods like Rectangular, Gaussian, Hamming and Kaiser. The results obtained are at a low order of the filters i.e. 56. The results for all FIR filters with different windows are compared by power spectrums of the original and filtered ECG signals. The filters using Kaiser Window give the best results.

Seema rani, Amanpreet Kaur, J S Ubhi[3] demonstrated that the function of a filter is to remove the unwanted parts of the signal that is random noise or to extract the useful parts of the signal that are the components lying within a certain frequency range. They have presented the comparisons of Digital FIR &IIR filter complexity and their performances to remove Baseline noises from the ECG signal. The order of filter is 2 used to estimate parameters and it is the recursive filter. Therefore, IIR filters have required less computation-power and their implementation is easier than FIR filters. The transition band of IIR filters is very narrow as compared to FIR filters and the phase delay is also approximately equal to zero. IIR filters have phase distortion which is caused by nonlinear phase response of IIR filters. If the order of filter is increased then infinite oscillations can get produced. They have compared the results which show that due to large order of FIR filter, there is a phase delay in FIR filtered waveforms and the computational complexity of FIR filter is far greater than IIR filters. It also increases the requirement for memory and power dissipation of the FIR filter. Therefore, IIR filters can gives better results for removal of Baseline noises.

Beatrice Arvinti, Dumitru Toader, Marius Costache, Alexandru Isar [4] has proposed a method based on stationary wavelet approximation of the whole signal to reduce the baseline wandering of an electrocardiogram signal. The objective of this method is to estimate the baseline wander and eliminate this noise by the subtraction from the acquired ECG. The removal of the noise is done by low-pass filtering. To perform this, the Stationary Wavelet Transform (SWT) of the acquired ECG is computed by using K decomposition levels. All the detail coefficients are met to value zero and a new sequence is obtained. Then the ISWT is computed and the baseline estimation is obtained for the new sequence. The method is a method which allows the process to be used in an automatic analysis of electrocardiograms.

Fakroul Ridzuan Hashim, John Soraghan Lykourgos Petropoulakis Sairul Izwan Safie[5] explains that the motion artifact noise in ECG processing is difficult to remove because its spectrum is known to overlap the ECG signal spectrum. The combination of wavelet based de-noising and high-pass/ low-pass filtering is demonstrated and it is shown to provide good motion artifact noise removal capabilities. This method of combination of a wavelet with the high-pass/low-pass filter is able to produce the better results compared to the other de-noising methods.

Ling Zheng, Carolyn Lall, Yu Chen [6] have presented a new method based on the Savitzky-Golay polynomial smoothing filter which is defined in the time domain. The results from this new method are compared with the cubic spline method and the heart rate adaptive high-pass filter. This new established method is simple that can preserve the ST segment and does not require extra knowledge about iso-electric points in ECG required by the cubic spline method or the heart rate required by the high-pass filter. The new method provides a low distortion baseline removal algorithm for ECG signals. The SG filter estimates the baseline noise from the ECG signal by performing the local polynomial fit in the data window and this noise is removed by subtracting the estimated baseline from the raw ECG signal.

Min Dai,Shi-Liu Liana[7] have purposed a modified moving average filter to selectively estimate the low-frequency baseline wander noise and remove it from the detected signals in order to get pure ECG. The interval sampling data is taken as important data when calculate the moving average to get useful ECG signals. The results of this method explain the improvement of the proposed moving average filter over the traditional one in removing baseline wander. This new approach is much successful in the online estimation and removal of the baseline wander because of their high processing speed.

Mohammadreza Ravanfar, Leila Azinfar, Riadh Arefin, Reza Fazel-Rezai[8] introduced a baseline drift cancellation algorithm using polynomial fitting based on empirical mode decomposition (EMD) which evaluates and then compare with two conventional methods that are EMD-based global slope minimization and moving average filtering. The use of this nonlinear signal processing method gives assistance to achieve more reliable outcomes. These methods are applied over 26 generated ECG baselines where the polynomial fitting showed more than 81% correlation with generated baselines. The comparative results of these methods are proved a remarkable robustness of the proposed algorithm against the baseline drifts.

IV. CONCLUSIONS

Scope of this review paper is focused on the removal of baseline wander in ECG signal using various techniques of filtering. The ECG waveform has been modified when filtered with different approaches. A number of de-noising algorithms have been designed but it is extremely difficult to make a comparison of these algorithms because these algorithms are applied on different samples of ECG .After applying all these different techniques using filtering give better results to removal of baseline wander.

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