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Noise Analysis and Different Denoising Techniques of ECG Signal - A Survey

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Abstract : *ECG signal is a biomedical signal that gives information about the electrical activities of the heart. ECG signal is corrupted by different noises of high frequencies and low frequencies and that may lead wrong interpretations, therefore in this study different noises like power line interference, channel noise, baseline wander, Electromyogram (EMG) Noise, electrode contact noise, and motion artifacts are analyzed. This paper also focuses on certain techniques for denoising of ECG signal.*

Keywords- *Electrocardiogram (ECG), Denoising techniques, Empirical mode decomposition (EMD), DWT, Filtering Techniques, Filtered Residue method, Signal to Error Ratio (SER), Signal to Noise Ratio (SNR).*

I. INTRODUCTION

The ECG records the electrical activity of the heart, where each heart beat is displayed as a series of electrical waves. ECG signal conveys information about structure and function of heart. Normally, the frequency range of an ECG signal is of 0.05–100 Hz and its dynamic range of 1–10 mV. The ECG signal is characterized by five peaks and valleys labelled by the letters P, Q, R, S, T. There is a U wave in ECG signal which is having a very low amplitude or even more often is absent. Mainly an ECG tracing is a repeating cycle of three electrical entities: a P wave (atrial depolarization), a QRS complex (ventricular depolarization) and a T wave (ventricular repolarization).

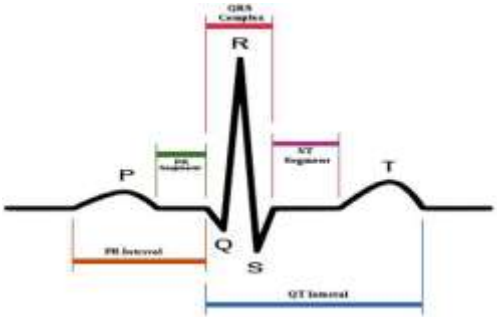

Figure1.1 An ECG signal representation[1]

Different noises are affected by the ECG signal during its acquisition and transmission. Mainly two types of noises are present in the ECG signal. Noises with high frequency include Electromyogram noise, Additive white Gaussian noise, and power line interference. Noises with low frequency include baseline wandering. The noises contaminated in the ECG signal may lead wrong interpretation. There are different denoising techniques are available in the literature.

In this paper some of the noises are analyzed and some of the denoising techniques are discussed. The rest of the paper is organized as follows. Different noises in ECG signals are presented in section II. Different ECG signal denoising techniques are presented in Section III, and section IV concludes the paper.

II. DIFFERENT NOISES IN ECG SIGNAL

2.1 Power line interference

It consist of 50/60Hz pickup and harmonics. The interference is mainly caused by Electromagnetic interference by power line, Electromagnetic field (EMF) by the nearby machines, Stray effect of the alternating current fields due to loops in the cables, Improper grounding of patient or the ECG machine ,The electrical equipments induce 50 Hz signals in the input circuits of the ECG machine. Example, air conditioner, elevators and X-ray units which draw heavy power line current[1]

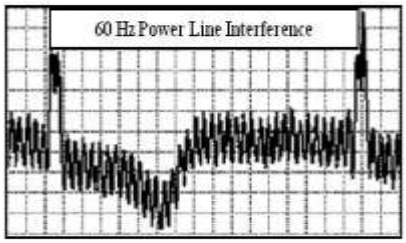

Figure 1.2 60 Hz Power Line Interference[1]

2.2 Electromyogram (EMG) Noise

The Electromyogram (EMG) noise is generated from electrical activity of the muscle. EMG consist of maximum frequency of 10 KHz. Sections of ECG may be interfered and corrupted by surface EMG which causes difficulties in data processing and analysis[2]

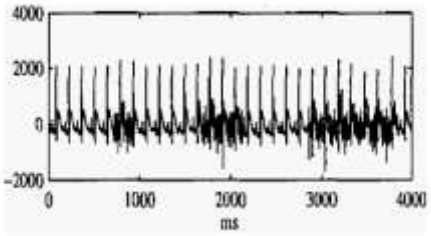

Figure 1.3 ECG signal which contains EMG noise [2]

2.3 Baseline Wander

Baseline wander is a low-frequency noise component present in the ECG signal. This is mainly due to respiration, and body movement. Baseline wander have frequency greater than 1Hz. This low frequency noise, Baseline wander causes problem in detection and analysis of peak.

2.4 Channel Noise

Channel noise introduces when ECG signal is transmitted through channels. This is due to the Poor channel conditions. It is mainly like white Gaussian noise which contains all frequency components [1]. E.g. AWGN

2.5 Electrode Contact Noise

Electrode contact noise is caused by the loss of contact between the electrode and the skin, which effectively disconnects the measurement system from the subject. The noise is of duration 1s. [3]

2.6 Motion artifacts

Motion artifacts are transient base line changes caused by changes in the electrode-skin impedance with electrode motion. As this impedance changes, the ECG amplifier sees a different source impedance which forms a voltage divider with the amplifier input impedance therefore the amplifier input voltage depends upon the source impedance which changes as the electrode position changes[3].

III. DIFFERENT ECG SIGNAL DENOISING TECHNIQUES

3.1 Filtering Techniques – To Remove power line interference (PLI)

3.1.1 IIR Notch filter

IIR filter is a simple filter. The stationary power line interference can be removed using a notch filter. If a notch filter has higher attenuation level, it will be able to remove PLI noise to a greater extent from ECG signal [1].But practically it eliminates power line interference at 50Hz frequency.

3.1.2 FIR Filtering

FIR filters are simple and stable filters. Window method is the simplest FIR filter design method. Here all frequencies below the cut off frequency are passed with unity amplitude and others are blocked. The different windows used are Rectangular Window, Hanning window, Hamming window, and Blackman window. Using these windows High pass filter and Low pass filters are designed with cut off frequency 3Hz and 100Hz respectively. Then the noisy ECG signal is passed through these filters to remove noises

3.1.3 Adaptive filter

The adaptive filter reduces the mean squared error between primary input (ECG signal) and the reference input (noise with ECG signal) [1]. An adaptive noise canceller is an efficient method to denoise noisy ECG signal .The algorithm used is Recursive least squares (RLS) [4].

Advantages of adaptive filter method are:

- Filtering response is fast
- Residual errors are small
- When working in time varying environment it has excellent performance

Drawback of adaptive filter method is:

- This method requires reference signal (either signal or noise characteristics) information for the effective filtering process.[1]
- When RLS algorithm is used it has high computational complexity and stability problems

3.2 Discrete Wavelet Transform (DWT)

Wavelet transform (WT) is a powerful method for analyzing non stationary signals. ECG signals are time varying and non-stationary signals so WT is suitable for analyzing ECG signal. Wavelets allow both time and frequency analysis of signals. Discrete Wavelet Transform (DWT) analyze and a signal as a linear combination of the sum of the product of the wavelet coefficients and mother wavelet.

Generally 3 procedures are done in DWT

- DWT is applied to the Noisy ECG signal to produce noisy wavelet coefficients
- Thresholding of the DWT coefficients
- Inverse wavelet transform of the thresholded wavelet coefficients to obtain denoised ECG signal

3.3 Bionic Wavelet Transform (BWT)

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[5] .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[5], For higher input SNR more improvement is obtained.

3.4 Filtered Residue (FR) Method

In this method the residue of the noisy ECG signal is calculated. The residue is given as the difference between the input ECG signal and the corresponding signal average at every point. This residue is then given to the Low pass FIR filter, thus we get a filtered residue .To reconstruct the final output this filtered residue should be added with the signal average.

The main advantages of this algorithm are simple to implement, stable, output is an accurate reconstruction of the actual signal, it preserves high frequency components, and it is fast. The main limitation of the filtered residue algorithm is that the misalignment of the beats has a blurring effect on the output and the FR algorithm is not iterative that is if it is applied to a signal, the measurement of the activation time in the output is not improved [6]

3.5 Empirical Mode Decomposition (EMD)

In this method the noisy ECG signal is decomposed in to different intrinsic mode functions (IMFs) .Then we must find the width of the QRS complex, to preserve it. Therefore sum of first 3 IMFs were taken and their sum is calculated. With the help of this and R point location QRS width is calculated. Then an adaptive window (Tapered cosine window) of size equal to width of the QRS complex is designed to preserve the QRS complex from the noisy IMFs. Mainly lower order IMFs are noisy. Then the signal can be reconstructed by adding these windowed IMFs and the remaining IMFs [7]

An enhancement to this method can be done by using a moving average filter for the smoothening of windowed IMFs. Thus we have to increase the QRS complex quality. Here residue got after empirical mode decomposition is also considered. EMD is an adaptive and data driven technique, thus suitable for any non stationary signal [8].And the denoised ECG signal is very much similar to the original clean ECG signal. The ECG signal with high frequency Additive white Gaussian noise can be reduced using this technique.

SNR Vs SER	**ECG Record 100**	**ECG Record 103**	**ECG Record 105**	**ECG Record 119**	**ECG Record 213**
SNR (dB)	**SER (dB)**	**SER (dB)**	**SER (dB)**	**SER (dB)**	**SER (dB)**
8	27.71	23.52	20.56	21.97	17.86
10	29.94	28.21	23.48	22.46	20.65
12	33.16	30.23	24.67	23.47	22.93
18	37.85	37.02	29.63	26.76	30.61

Table1. Signal to Error Ratio for different ECG records from MIT/BIH database [8]

Table 1 shows signal to error ratio for different ECG records from MIT/BIH database using Empirical mode decomposition and moving average filter [8].

IV. CONCLUSION

The survey includes the works and findings done by various researchers on ECG signal denoising techniques, various types of noises such as power line interference, baseline wander, electrode contact noise, Electromyogram (EMG) noise and motion artifacts. Adaptive filtering is the best choice if the input signal has low frequency SNR. But Filtered Residue algorithm provides better output if the amount of noise is moderate. Wavelet denoising methods can be used for ECG signals with large beat to beat variation.EMD and moving average filter is an effective technique to remove high frequency Additive white Gaussian noise.

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REFERENCES

[1] Snehal Thalkar, Prof. Dhananjay Upasani " Various Techniques for Removal of Power Line Interference From ECG Signal" International Journal of Scientific & Engineering Research, Volume 4, Issue 12, December-2013 12 ISSN 2229-5518.
[2] P. Raphisak, S.C. Schuckers, A.J. Curry, An algorithm for EMG noise detection in large ECG data, Comput. Cardiol, 31 (2004) 369–372.
[3] Gary M,Friesen Thomas C. Jannett, Manal Afify Jadallah,Standford L. Yates, Stephen R.Quint, H.Troy N Nagle,1990,"A Comparision of the Noise Sensitivity of Nine QRS Detection Algorithms", IEEE Transactions on Biomedical Engineering,Vol,37, No. 1, March 1990.
[4] Chinmay Chandrakar, M.K. Kowar, "DENOISING ECG SIGNALS USING ADAPTIVE FILTER ALGORITHM", International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-2,Issue-1, March 2012
[5] Omid Sayadi , Mohammad Bagher Shamsollahi, "ECG Denoising with Adaptive Bionic Wavelet Transform" , in Proceedings of the 28th IEEE EMBS Annual International Conference New York City, USA, Aug 30- Sept 3, 2006

[6] S. Iravanian, L. Tung, A novel algorithm for cardiac biosignal filtering based on filtered residue method, IEEE Trans. Biomed. Eng. 49 (11) (2002) 1310–1317.
[7] B. Weng, M. B. Velasco, and K. E. Barner, "ECG denoising based on the empirical mode decomposition," in Proceedings of the 28th IEEE EMBS Annual International Conference New York City, USA, Sept.2006, pp. 1–4.
[8] Sonali, Omkar Singh, Ramesh Kumar Sunkaria- ECG Signal Denoising Based on Empirical Mode Decomposition and Moving Average Filter, 2013 IEEE
[9] www.Google.com
[10] The MIT-BIH noise stress test database. [Online]. Available: http: //www.physionet.org/physiobank/database/nstdb/.