ECG SIGNAL DE-NOISING USING DIGITAL FILTER TECHNIQUES

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Abstract - *The function of the heart is analysed by the Electrocardiogram(ECG) signal. But the ECG electrodes recorded ECG signal cannot be used directly for further processing. Several kinds of noises may corrupt the ECG signal in recording process. Usually the ECG signals are contaminated by the baseline wander noise (BLW), muscle noises (EMG) and moving electrode artifact (MA). Therefore, to enhance the ECG signal appropriate digital filtering techniques are used. In this study, discrete wavelet transforms (DWT) and low pass filter (LPF) methods are used to de-noise the ECG signal. Further moving mean method, linear regression method and savitzky-golay smoothing techniques are applied for ECG signal enhancement. Mean square error (MSE) and signal to noise ratio (SNR) parameters are evaluated to assess the noise removing capability of the methods. From the results it is observed that the LPF with moving mean smoothing method show superior performance in ECG De-noising.*

Key Words: ECG signal, BLW noise, EMG noise, moving artefact, DWT, low pass filter, moving mean, linear regression, savitzky-golay.

1.INTRODUCTION

The ECG signal is shown in the figure 1. To understand the function of heart first has to analyses the PQRST wave. The P wave that indicates the polarization of the arteries, QRS complex that indicates the polarization of ventricles and depolarization of arteries, T wave that indicates the repolarizing of the ventricles. Usually the ECG signal is small at range from 0.1mV to 20mV and frequency range of 0.05 Hz to 100 Hz.

Generally, the cardiac function is represented by the ECG signal. To record the ECG signal multiple ECG electrodes are placed on the skin in an Einthoven structure. The recorded ECG signal is corrupted by the different types of noise, such as BLW noise, motion artifact, EMG noise, power line interference noise (PLI), electrode noise and high frequency noise can taint the raw ECG signal. Among these noise BLW noise, EMG noise and MA noise are more pervasive in process. Past research stated that the advancement in ECG signal de-noising, feature extraction, event detection and classification play crucial role in medical diagnosis and clinical applications.

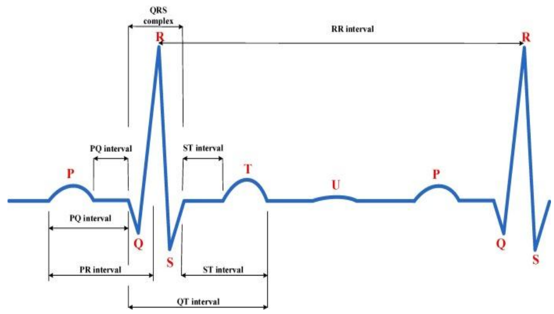

Fig-1: ECG signal

The ECG signal cannot be directly altered or processed using conventional procedures when it has been tampered with different types of noise. In general, digital filters are the best choice for reducing noise in ECG signals. P.C. Bhaskara and M. D. Uplaneb suggested a low pass FIR filter with different windowing techniques that can cancels the high-frequency noise effectively from the ECG signals [7]. Excellent noise reduction services were offered by Kaiser Window. Chaudhary M. and Narwaria R. P. compared the performance of different digital filters IIR, Butterworth, Chebyshev Type-I and Type-II in terms of the signal to noise ratio and average power. Concerned work results demonstrated that a low pass Butterworth filter might reduce noise more effectively than the alternatives. Mahawar et al. developed a FIR low pass filter with strong attenuation using the windowing approach, Kaiser and Dolph-Chebyshev (DC), and DC. Based on some of the performance metrics Sharma M. and Dalal H. reported that FIR and IIR digital filters can remove the low-frequency baseline drift from the ECG signal [4]. In order to de-noise the Baseline Wander interferences, Rastogi, N. and Mehra, R. developed an integrated strategy that combines Daubechies wavelet decomposition with a variety of thresholding techniques and the IIR digital Chebyshev or Butterworth filter [4].

Based on the earlier survey concluded that ECG signal pre-processing and smoothing techniques are essential in ECG signal enhancement. Since the first and foremost step commence here is the reduction of noise and next is smoothing the de-noised ECG signal [2] using different digital filtering techniques.

2. METHODOLOGY

This work originated for noise reduction in ECG signals using two digital filtering methods such as discrete wavelet transform (DWT) and LPF. These filtering algorithms tested for de-noising of the ECG signal in BLW noise, MA noise and EMG noise. Also different smoothing techniques such as moving mean method, linear regression method and savitzky-golay smoothing techniques are applied for ECG signal processing.

DWT: A DWT method separates a given signal into several sets, each set consisting of a time series of coefficients that describe the signal's temporal history in the associated frequency band.

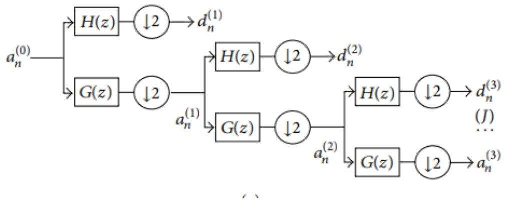

Fig 2.1: Decomposition of DWT

where,

$a(i)\ n = N-1 \sum k=0\ gka(i-1)\ 2n-k\ i = 1, 2, . ., J,$

$d(i)\ n = N-1 \sum k=0\ hka(i-1)\ 2n-k\ a(0)\ n \equiv x$�

LPF: A low-pass filter is a filter that retains the signals in higher frequency than a predetermined cut-off frequency while attenuating signals that are at lower in frequency.

Moving Mean: The de-noised ECG signal is typically smoothed using the moving mean method. These are smoothed based on short-term overshoots.

The ECG signal had the three different types of noise added to it. Using the DWT and LPF digital filtering techniques, the noise that was added to the signal is removed. These two approaches use various algorithms, such as the DWT algorithm, which is founded on decomposition stages. Here, the ECG signal has been de-noised using 8 decomposition levels. Similarly, the LPF is a unique approach that depends entirely on the cut-off frequency. The cut-off frequency is assumed to be 360 hertz.

The ECG signal's noise was subsequently removed in this manner. Following that, three distinct algorithms—moving mean, linear regression, and savitzky-golay—smoothens the filtered signal. The cut-off frequency used for these three approaches was 0.5 hertz.

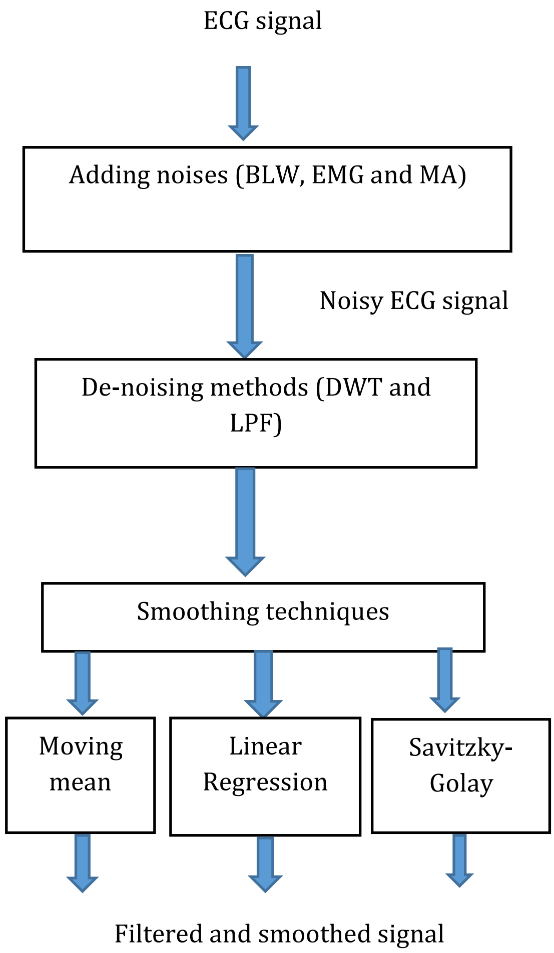

Fig- 2.2: Enhancement Flow

3. RESUTLS

The de-noising flow to remove the noise from the ECG signal is shown in the methodology. The MIT-BTH arrythmia database was used to download the ECG signal from the physio-bank ATM website. On the website, three different types of ECG signal were retrieved. Using the physio-bank ATM website, three noises were obtained from the MIT-BTH noise database.

The input healthy ECG signal and the filtered and smoothed signals performance measures were assessed. The two performance indicators considered are MSE and SNR. The filtered signal mean square error (MSE) will be lower than the input signal. Similar to this, SNR will rise, indicating that the ECG signal has less noise.

$$\mathrm{SNR} = 10 \log_{10} \frac{\sum_{i=0}^{N} (\mathrm{ECG_{raw}})^2}{\sum_{i=0}^{N} (\mathrm{ECG_{raw}} - \mathrm{ECG_{filtered}})^2}$$

$$\mathrm{MSE} = 10 \log_{10} \frac{\sum_{i=0}^{N} (\mathrm{ECG_{raw}} - \mathrm{ECG_{filtered}})^2}{\mathrm{N}}$$

Chart -1: ECG, Noisy and De-noised signal (a) Healthy ECG signal, (b) ECG signal corrupted with BLW noise, (c) De-noised by LPF, (d) Filtered signal smoothed by Moving-mean method

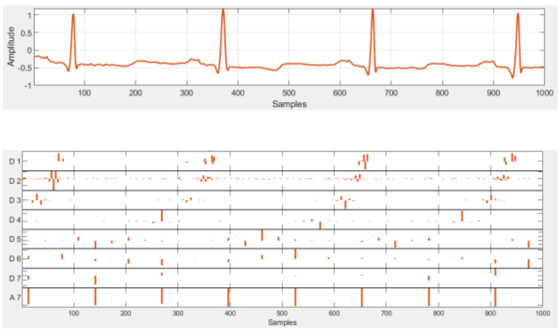

Chart -2: De-noised and Decompositions

(a) De-noised ECG signal, (b) DWT decompositions for the de-noised signal

Table 3.1: Performance metrics in BLW noise environment

BLW noise				
Filtering methods ➡	DWT		LPF	
Smoothing methods ⬇	MSE	SNR(dB)	MSE	SNR(dB)
Moving Mean	5.77E -01	12.45	3.77E -01	**15.35**
Linear Regression	9.51E -02	12.58	7.57E -01	12.39
Savitzky-Golay	8.09E -01	13.27	7.65E -02	12.35

Table 3.2: Performance metrics in EMG noise environment

EMG noise				
Filtering methods ➡	DWT		LPF	
Smoothing methods ⬇	MSE	SNR(dB)	MSE	SNR(dB)
Moving Mean	4.36E-01	10.55	**6.74E-02**	12.35
Linear Regression	3.57E-01	12.93	7.74E-02	12.35
Savitzky-Golay	6.45E-01	12.12	5.47E-02	13.35

Table 3.3: Performance metrics in MA noise environment

MA noise				
Filtering methods ➡	DWT		LPF	
Smoothing methods ⬇	MSE	SNR(dB)	MSE	SNR(dB)
Moving Mean	5.31E-01	15.24	3.76E-01	14.37
Linear Regression	4.67E-01	14.36	3.46E-01	13.47
Savitzky-Golay	3.67E-01	13.34	1.90E-01	13.46

The above tables- 3.1, 3.2 and 3.3 represents the evaluation of performance metrics by two digital de-noising methods and three smoothing techniques in various noise environments.

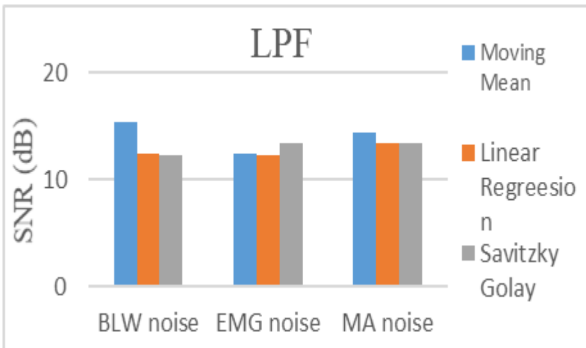

Chart-3: SNR result by LPF

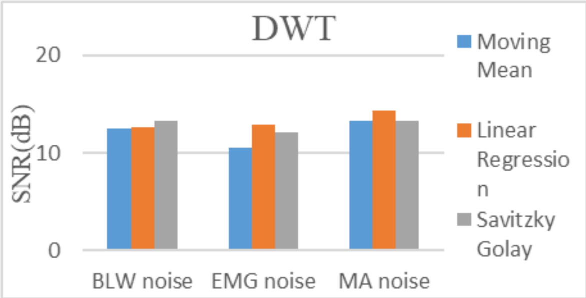

Chart-4: SNR result by DWT

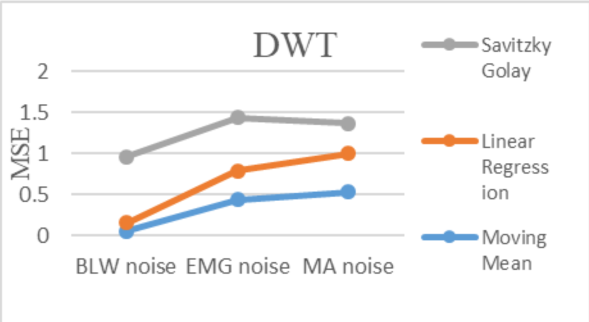

Chart-5: MSE result by DWT

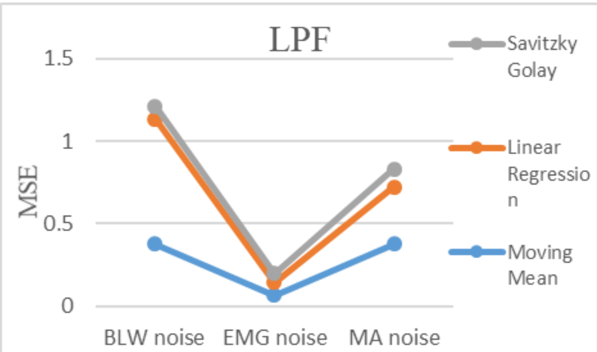

Chart-6: MSE result by LPF

The comparison of SNR values by three smoothing approaches is represented in the above figures 4.2 and 4.3. Similarly, the comparison of MSE by the three smoothing approaches is represented in the above figures 4.4 and 4.5.

The input SNR is considered as 10dB for all the noises.

The end findings demonstrate that both the Butterworth and Chebyshev algorithms performed noise reduction with about equal efficacy. The end findings demonstrate that both the Butterworth and Chebyshev algorithms performed noise reduction with about equal efficacy.

4. CONCLUSION

In order to de-noise the ECG signal, we will apply digital filtering techniques. The two methods that were utilised to eliminate noise from the ECG data are discussed in this paper.

So, we may conclude that the LPF has produced superior results than the DWT technique based on the comparison of MSE and SNR of the two digital filter techniques. Three different types of ECG signals were subjected to this methodology, which involved adding three different noises to each signal before de-noising it with two different procedures and smoothing it with three different smoothing techniques. The three signals MSE and SNR were assessed. On comparing the performance metrics by two techniques with three smoothing algorithms, the LPF with moving mean method performs better than the DWT technique. This kind of methodology can be used for any kind of bio-medical signal for eliminating the noise from it.

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