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DIFFERENT DE-NOISING METHODS AND PROCEDURES FOR ECG SIGNAL: A REVIEW

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A B S T R A C T

Electrocardiogram signal is one of the biomedical signals, which reflects electrical activity of the heart. ECG signals are widely studied and applied in clinic. The ECG signal is time varying signal, includes the valuable information related to heart diseases, but frequently this valuable information is corrupted by various noises. As noise corrupts the ECG signal it is very important as well as difficult task to suppress noises from ECG signal. So de-noising is the method of estimating the unknown signal from available noisy data. The empirical mode decomposition provides description of signal, decomposing it at different time-frequency resolution. Empirical mode decomposition is well suited tool for analysis of non-stationary signals like ECG. At first step, the signal is decomposed into transform domain where filtering procedures are applied. The noise free signal is then obtained by inverse transform. The basic idea behind this paper is the estimation of the uncorrupted ECG signal from the corrupted or noisy signal, and is also referred to as signal denoising.

Keywords*: RMSE: root means square error, SNR: signal to noise ratio, ECG: Electrocardiogram, AWGN: Additive White Gaussian Noise, LMS: Least Mean Square*

1. INTRODUCTION

The ECG is nothing but the recording of the heart's electrical activity. The deviations in the normal electrical patterns indicate various cardiac disorders. Cardiac cells, in the normal state are electrically polarized. Their inner sides are negatively charged relative to their outer sides. These cardiac cells can lose their normal negativity in a process called depolarization, which is the fundamental electrical activity of the heart. This depolarization is propagated from cell to cell, producing a wave of depolarization that can be transmitted across the entire heart. This wave of depolarization produces a flow of electric current and it can be detected by keeping the electrodes on the surface of the body.

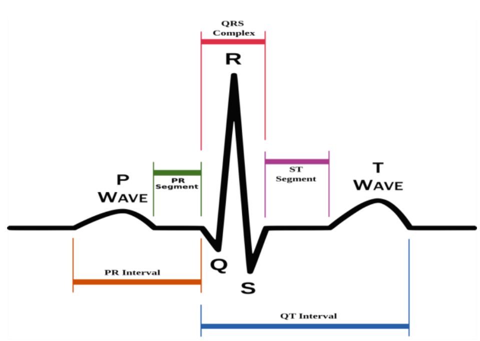

Figure 1: Representative Signal Cycle of an ECG signal [2]

Thresholding can be also used in ECG signal filtering selection of threshold value plays an important role in denoising of ECG signal. The parameters of this shrinkage function were optimized by comparing denoised results of the simulative ECG signal at different contaminating levels. The choice of threshold and shrinkage function is the most important step for wavelet denoising. In order to obtain the best denoising results, a new shrinkage function which would be used in ECG signals denoising was proposed here, expressed as formula

$$\hat{Y} = \begin{cases} 0 & |Y| \leq T_L \\ \operatorname{sgn}(Y)\left[\frac{|Y - T_L|^{\gamma} . T_H}{|T_H - T_L|^{\gamma}}\right] & T_L < |Y| \leq T_H \\ Y & |Y| > T_H \end{cases}$$

Where γ, TH, TL are alterable. This Formula is equal to formula of hard threshold when TL=TH; this formula is equal to formula of firm when γ=1, TL=2/3TH; and the same formula is equal to formula of Yasser when γ=3, TL=0.

General method: There are various methods to help restore ECG from noisy signal corrupted by various noises. Flow diagram of required work for ECG signal filtering is explained below.

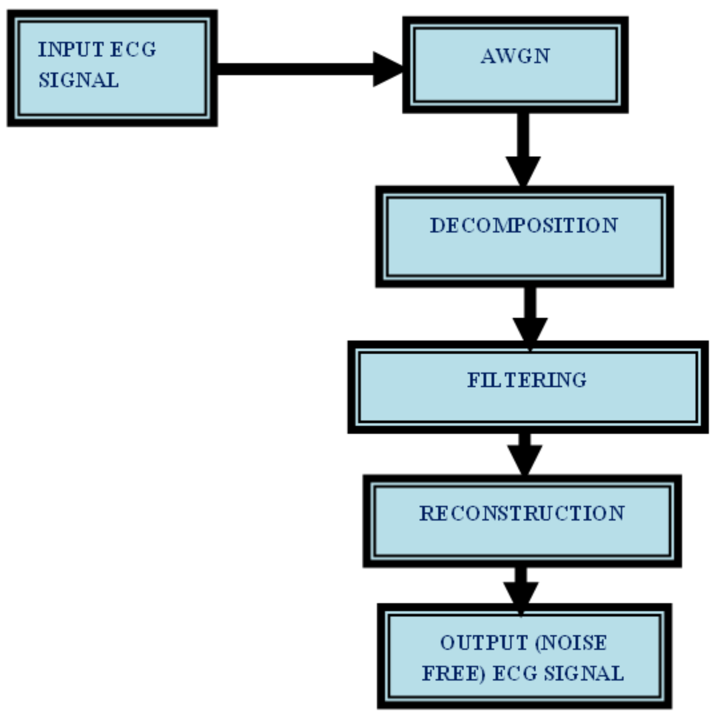

Figure 2 Flow graph of the methodology

While registering the ECG signal it may get contaminated by random noises uncorrelated with the ECG signal. These noises can be approximated by white Gaussian noise. Thresholding is used in wavelet domain to smooth out or to remove some coefficients of empirical mode decomposition of sub signals of the measured signal. This reduces the noise content of the signal under the non-stationary environment. The proposed method is implemented using following steps.

Step 1: ECG signal generation let x(n).

Step2: add random and adaptive white Gaussian noise with different quantity of noise to the ECG signal. White Gaussian noise with zero mean and constant variation is generated and added to the noise free ECG signal. Mathematically this may be written as

y(n) = x(n) + w(n)

Where, x(n) is the noise free ECG signal, w(n) is the white Gaussian noise and y(n) is the noisy ECG signal.

Step 4: Decomposition of the Signal into frequency.

Step 5: choose appropriate filter method and filter out the noise from the ECG signal.

Step 6: inverse transform and reconstruct the signal.

Step 7: Signal to Noise Ratio (SNR) & Root mean square error (RMSE) between original signal and estimated signal is computed.

EMD: The Hilbert–Huang transforms (HHT). The fundamental part of the HHT is the empirical mode decomposition (EMD) method. Breaking down signals into various components, EMD can be compared with other analysis methods such as Fourier transform and Wavelet transform. Using the EMD method, any complicated data set can be decomposed into a finite and often small number of components. The EMD method is a necessary step to reduce any given data into a collection of intrinsic mode functions (IMF) to which the Hilbert spectral analysis can be applied.

$$I(n) = \sum_{m=1}^{M} IMF_m(n) + Res_M(n)$$

where $I(n)$ is the multi-component signal? $IMF_m(n)$is the M_{th} Intrinsic Mode Function, and $Res_M(n)$ represents residue corresponding to M intrinsic modes.

2. LITRATURE REVIEW

Byeong hoon kim et al [3] developed a belt-type ECG measurement system with three-axis acceleration sensor for ECG signal measurement in daily life. Activity status is classified by using Fuzzy Classification. We use EMD-based filter to reduce motion artifact by adapting the activity status change. Chunyang Sha et al [2] novel vibration signal enhancement method based on empirical mode decomposition (EMD) and adaptive filtering is proposed to filter out Gaussian noise contained in raw vibration signal. The reference signal of the adaptive filter is produced by selective reconstruction of the decomposition results of EMD. Real vibration signals from the locomotive bearing are used to validate the performance of the proposed method. Conventional EMD and adaptive EMD are tested to compare the filtering performance. The results of simulation show that the vibration signal can be significantly enhanced by using the proposed method.

Manas Rakshit et al [1] in reality, pathological ECG signals are corrupted with several noises. In this work, empirical mode decomposition (EMD) along with adaptive switching mean filtering (ASMF) based ECG denoising technique has been proposed. Initially, an EMD based approach is utilized for eliminating high-frequency noises and enhancing QRS complexes in the ECG signal. Then, an ASMF operation is performed for further improvement of the signal quality. The validity of the performance of the described technique is evaluated on standard MIT-BIH arrhythmia database. Gaussian noises at different signal to noise ratio (SNR) levels are added to the original signals. A close study of the simulation and performance parameters indicate that the described technique outperforms the existing methods for denoising of real ECG signals.

TABLE 1: LITRATURE WORK METHODS

Author's	**Method**
Manas Rakshit et al [1]	Adaptive Switching Mean Filter and EMD for De-noising ECG
Chunyang Sha et al [2]	Adaptive EMD Filter remove noise in vibrating signals
Byeong-Hoon Kim el al [3]	Activity satatus of ECG and adaptive EMD filter
Ashish Kumar et al [4]	Wavlet transform and filter bank based ECG signal Denoising
Xiao Tan et al [5]	Low power ECG signal Noise removal using EMD decomposition.
Yingying Zheng et al [6]	EMD and ICA based pulse wave signal denoising

RMSE: root-mean-square error (RMSE) is a frequently used measure of the differences between values (sample and population values) predicted by a model or an estimator and the values actually observed. The RMSD represents the sample standard deviation of the differences between predicted values and observed values. Here x is the input signal y is the filtered output signal and z is the noisy signal.

$$RMSE = \frac{1}{N}\sqrt{\sum_{i=1}^{N}(x_i - y_i)^2}$$

SNR: SNR is defined as the ratio of signal power to the noise power, often expressed in decibels. SNR is the criteria which decide the amount of the noise in the signal, in filtering we expect High SNR value (low noise).

$$SNR = 10log_{10}\left(\frac{\sum_{i=1}^{N}(z_i - x_i)^2}{\sum_{i=1}^{N}(y_i - z_i)^2}\right)$$

PRD: percentage root mean square difference shows the RMSE changes between input and filtered signal.

$$PRD = \sqrt{\frac{\sum_{i=1}^{N}(x_i - y_i)^2}{\sum_{i=1}^{N}(x_i)^2}} X\ 100$$

TABLE 2 OUTCOMES OF MANAS RAKSHIT SNR, MSE AND PRD

Author	**Input Signal to noise ratio (SNR)**	**Output Signal to noise ratio (SNR)**	**root mean square error (RMSE)**	**percentage root mean square difference (*PRD*)**
Manas Rakshit et al [1]	20	6.8	0.021	4
	15	8.2	0.04	6
	10	8.9	0.08	11
	6	9	0.11	18

Inner race and outer race signal are the avarage of peaks with of x and –x. the SNR observe by [2] is shown in table 3.

TABLE 3 SNR OBTAIN FOR ECG OUTER RACE AND INER RACE SIGNALS

Auther	Signal to noise ratio (SNR) in Outer Race Signal	Signal to noise ratio (SNR) in inner Race Signal
Chunyang Sha et al [2]	4.4936	4.7236

From figure 1 we can observe that R-peaks are the part in ECG with maximum amplitude, in ECG signal we count number of ECG cycles with R-peaks counting. The standard deviation of a random variable, statistical population, data set, or probability distribution is the square root of its variance. The root-mean-square deviation (RMSD) represents the sample standard deviation of the differences between predicted values and observed values.

TABLE 4 STANDARD DEVIATION OBSERVE BY BYEONG-HOON

	R-peaks	Standard deviation
Byeong-Hoon Kim et al [3]	259	0.0786
	256	0.0528
	395	0.000271

PROBLEM STATEMENT

The ECG signal is time varying signal, includes the valuable information related to heart diseases, but frequently this valuable information is corrupted by various noises. As noise corrupts the ECG signal it is very important as well as difficult task to suppress noises from ECG signal. So de-noising is the method of estimating the unknown signal from available noisy data.

Problem with Byeong hoon kim et al [3] was that they never derive a new method they just analysis and select appropriate method from the available methods as per the input ECG signal their method is good if we use their method for research work but cannot guarantee to work accurate in practical conditions. Chunyang Sha et al [2] develop their own method for adaptive EMD filter and uses single stage filtering problem is that if the filtering done is not appropriate in one iteration of adaptive filter than inaccurate Threshold may also produce wrong results. Manas Rakshit et al [1] uses empirical mode decomposition (EMD) along with adaptive switching mean filtering (ASMF) based ECG denoising technique, their method was good but ASMF was time consuming process which further reduces the threshold. In near future we will develop a new modified adaptive EMD based ECG signal denosing method.

3. CONCLUSION

This paper work is study of EMD based ECG signal denoising and three research work have been studies and explained it's been observed that most of the available methods for ECG noise removal use EMD for ECG signal decomposition and later on different methods use different filters like [1] use switching mean filter [2] use adaptive filter and [3] monitor activity and normal FIR filter RMSE, SNR, PRD and standard deviation has been used for measurement of the results of the ECG signal filtering.

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