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Electrocardiogram Preprocessing Using Weiner Filter & Least Mean Square Algorithm.

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Abstract: Electrocardiogram (ECG) is a method of measuring the electrical activities of heart. Every portion of ECG is very essential for the diagnosis of different cardiac problems. But the amplitude and duration of ECG signal is usually corrupted by different noises like Power Line Interference (PLI) & Baseline Wander. In this paper pre processing stage is performed by denoising these two types of noise involved with real ECG signal. Two methods such as Weiner Filter , least-mean-square (LMS) are applied to remove the noises. For better clarification simulation results are compared in terms of different performance parameters such as, power spectral density (PSD) & SNR. Signal Processing Toolbox built in MATLAB® is used for simulation of performance parameter.

Keywords: Include at least 4 keywords or phrases.

I. INTRODUCTION

A. ECG Basics

Electrocardiogram (ECG) is widely used for diagnosing many cardiac diseases, which are one of the prime causes of mortality all over the world. The origin of ECG is the electrical activation of heart muscle cell causing sequence of depolarization and repolarization of its membrane. The electrical pulses generated due to this electrical activation are propagated along the cell fiber and transmitted to adjoining cells. The result is generation of electrical impulses, which travels through the cardiac surface. These electrical impulses can be detected by surface electrodes, amplified and displayed as the ECG. From electrical point of view, the heart is situated at the center of the electrical field it generates. The intensity of its electric field diminishes with the distance from its origin. A 12-lead electrode system is used for ECG recording, exploring an overall view of the heart's electrical activity. ECG waveform consists of five different component waves, namely P, Q, R, S and T wave followed by a conditional U wave. A typical ECG beat is shown in Figure 1. The durations and intervals of the constituent waves and amplitudes of the wave peaks reveal clinically significant information to the cardiologists for diagnosis

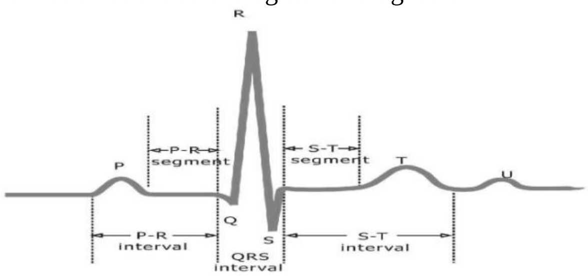

Figure 1.Normal ECG Signal with Various Components [5]

The impulses of the heart are recorded as waves called P-QRS-T deflections. The following is the description and significance of each deflection and segment.

P wave indicates atrial depolarization (and contraction).
PR Interval measures time during which a depolarization wave travels from the atria to the ventricles.

QRS Interval includes three deflections following P wave which indicates ventricular depolarization (and contraction). Q wave is the first negative deflection while R wave is the first positive deflection. S wave indicates the first negative deflection after R wave. ST Segment measures the time between ventricular depolarization and beginning of repolarization.

T wave represents ventricular repolarization.
QT Interval represents total ventricular activity

B. Problem Formulation

Removal of unwanted noise components (Preprocessing) in ECG Signal *Preprocessing Stage* consist of following Noise Removal

1) Baseline Wander
2) Powerline Interference

Algorithm used

1) Weiner Filter Technique
2) Least Mean Square (LMS)

C. Literature Survey

Baseline Wander

Baseline wander elimination is often one of the first steps required in the processing of the electrocardiogram (ECG). Baseline wander makes manual and automatic analysis of ECG records difficult, especially in the detection of ST-segment deviations[1]. This segment is very important and has the information related to heart attack. Since the spectrum of baseline wander and low frequency component of ECG signal usually overlaps, removing of baseline wander may cause distortion of important clinical information. Baseline noise occurs due to respiratory

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signal and body movements. Respiratory signal wanders between 0.15Hz and 0.8Hz frequencies[2]. One of the most common methods used was High Pass Filtering. Digital Filters IIR & FIR filters where used for Baseline Noise removal [3]

Powerline Interference

Powerline noise interference consists of 50Hz or 60Hz (depending on Signal) twined with ECG signal. Digital FIR Equiripple filter was designed to remove this noise.
The minimum order of the filter selected was 580 and the sampling frequency of 1000Hz. Complete design was performed with FDA tool in the Matlab[4].The notch equiripple filter designed was having higher order which increasing the computational complexity. It shows that with increase in order of the filter the computational complexity was increased and it adds delay in response.

II. PROPOSED METHODOLOGY

A. *Weiner Filter*

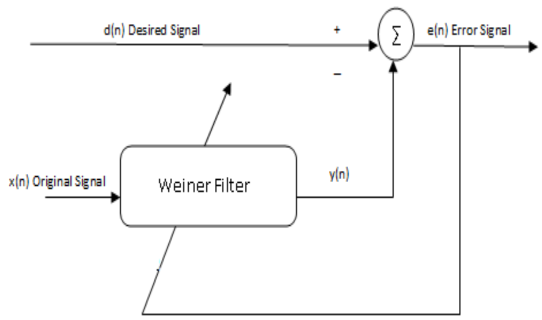

Figure 2 Principle of Weiner Filter Denoising

An M Tap discrete time Wiener Filter is of form

$$y[n] = \sum_{m=0}^{M-1} w_m \, x[n-m] \quad (1)$$

Where the w_m are referred to as filter weights

The quality of filtered signal y(n) is determined from error sequence e(n) = d(n) – y(n)
The weights w_m are chosen such that

$$E\{e^2[n]\} = E\{(d[n] - y[n])^2\} \quad (2)$$

Is minimized, that is we obtain the minimum mean squared error. This results in a filter that is optimum in sense of minimum mean square error.

The Resulting system of equations

$$\sum_{m=0}^{M-1} w_m \, E\{x[n-k]x[n-m]\} = E\{x[n-k](d[n])\} \quad (3)$$

$$\sum_{k=0}^{M-1} w_m \, \emptyset_{xx}[m-k] = \emptyset_{xd}[-k] \quad (4)$$

For k = 0,1,….., M-1 are known as *Wiener- Hopf equations*

Here Φ_{xx} [k] is the autocorrelation function of x [n] and Φ_{xd} [k] is cross correlation function between x [n] and d [n]

B. *Least Mean Square (LMS)*

The original ECG signal is taken from the MIT-BIH arrhythmia database .The noisy ECG signal is pass through adaptive filter algorithms LMS. However, the basic block diagram for understanding the overall adaptive filtering process is depicted in Fig.3

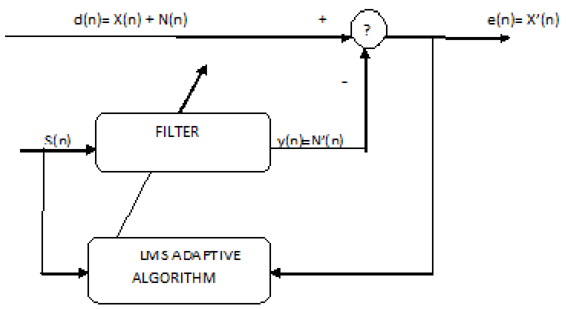

Figure 3 Principle of LMS Adaptive Filter Denoising

The block diagram indicates that, if the value of N(n) is known, then after subtracting this from the mixed signal d(n), the original signal X(n) is obtained. But it is difficult due to the harmonics of noise signal. For this reason an estimated noise signal N´(n) is calculated through some filters and measureable noise source S(n). If N´(n) is more close to N(n), then the estimated desired signal is X´(n) more close to the original signal X(n).
Mathematically the output is given by

$$e = X + N - y \quad (1)$$

The power or energy of this signal is computed by squaring

$$e^2 = X^2 + (N-y)^2 + 2X(N-y) \quad (2)$$

Takingexpectations of both sides results

$$E(e^2) = E(X^2) + E(N-y)^2 + 2EX(N-y) \quad (3)$$

$$E(e^2) = E(X^2) + E(N-y)^2 \quad (4)$$

Adapting the filter to minimize the error energy will not affect the signal energy. Therefore the minimum error energy is

$$E(e^2)_{min} = E(x^2) + E(N - y)^2_{min} \quad (5)$$

$E(e-X)^2$ is also minimized since, (e – X) = (n – Y). Therefore, minimizing the total output energy is the same as minimizing the noise energy.
The LMS algorithm produces the least mean square of the error signal by changing the filter tap weight, whose coefficient updating equation is

$$W_{k+1} = W_k + 2\mu e_k X_k \quad (6)$$

Where μ is an appropriate step size to be chosen as $0 < \mu < 0.2$. The Larger step size make the coefficient to fluctuate widely.

III. TOOLS & MATERIALS

Here in this paper the ECG signal samples are extracted from MIT- BIH arrhythmia database. This Database is obtained from www.physionet.org. [10]

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Preprocessing stage for noise removal is done using MATLAB 2013R

IV. IMPLEMENTATION

A. Overview

Preprocessing which consists of noise removal is an important stage of this project.

Preprocessing is done using Matlab R2013 Workspace. Different Noise like PLI power line interference & Baseline Wander is attempted to remove using Weiner Filter Technique & LMS Least Mean Square algorithm.

Following Steps are used to for implementation of Noise Removal in ECG Signal

1) ECG Signal Samples are available in MIT-BIH database www.physionet.org, these sample ECG data has to be transferred (read in MATLAB workspace). rddata.m program is used for loading the sample signals to MATLAB.
2) The Signal consists of various noise which needs to be removed. One of the noise present in the signal is Baseline Wander, which causes drift in the baseline of the signal. This noise is present at 0.15Hz to 0.8Hz which needs to be filtered & another is PLI with 60 Hz noise is present. First Algorithm consists of weiner filter is used for removal of this noise & Second algorithm uses LMS. Designing of Filter is done through the FDA(Filter Design and Analysis) in MATLAB Toolbox
3) After Filter Design Run in MATLAB workspace the ECG Filtered Signal Along with PSD Graph is Displayed.

B. Weiner Filter Technique Algorithm

Step 1:- Estimate the Noise From Ideal ECG.
Step 2:- Workout Length to make FFT
Step 3:- Build Weiner Model by calculating Power of Ideal ECG, Power of Noise, Calculate FFT of Sample Signal.
Step 4:- Optimize the Filter by maximizing the ratio of Signal to Noise power
Step 5:- Obtain ECG Estimate by product of Optimum Filter parameter & FFT
Step 6:- Filtered ECG is obtained by IFFT to bring the signal back to time domain.

C. Least Mean Square (LMS) Algorithm

Step 1:- Initialize number of data sample, filter output vector, filter coefficient vector, error vector & filter coefficient matrix for coefficient history.
Step 2:- LMS algorithm aim to estimate the optimum filter coefficients that minimize MSE by utilizing the gradient of MSE at each step. ECG Estimate is done using previous filter coefficient.
Step 3:- Evaluate Error
Step 4:- Update the Filter coefficient using parameters filter length & step size until the Filtered ECG is obtained.

V. SIMULATION RESULTS

Various Sample ECG Signals are taken from MIT- BIH arrhythmia database [12]. To Demonstrate PLI & Baseline wander noise removal from ECG signal, Sample record number 100,101 &104,105 are used. In the simulation we provide the input ECG database number, Order of the filter, Step size, amplitude of the interference signal proportional to the intensity of the interference signal and initial phase angle of power line interference signal.

Results shown are Original Signal with noise, Filtered Signal, and Power Spectrum Density graph for original and filtered signal. Results consist of both Weiner filtered and Filtered Signal using LMS Algorithm.

Graphical Representation of Weiner Filter Denoising Result Sample 1 (Record 100)

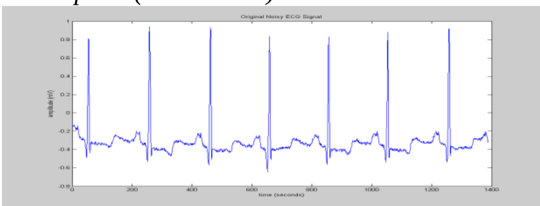

Fig. 4 (a)

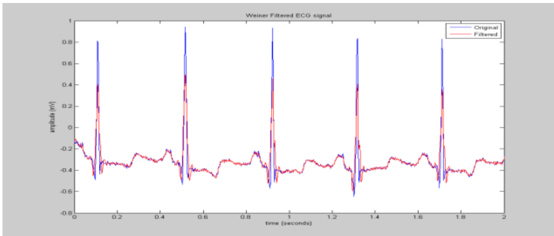

Fig. 4 (b)

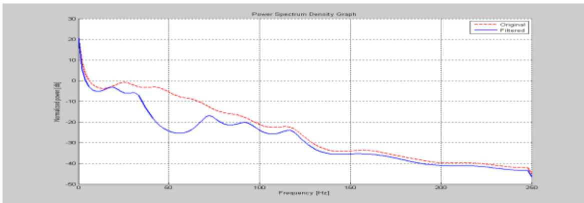

Fig. 4 (c)

Fig. 4 Weiner Filter Algorithm Results Sample 1 (a) Original Noisy Signal (b) Weiner Filtered Signal (c) Power Spectrum Density Graph

Graphical Representation of LMS Denoising Result Sample 1 (Record 104)

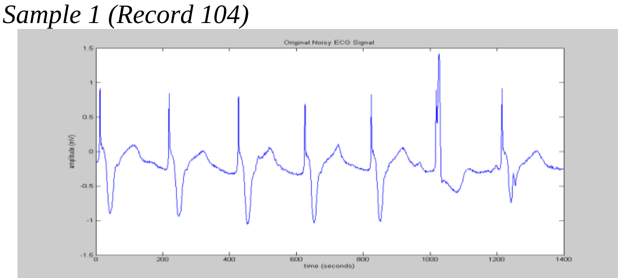

Fig. 5 (a)

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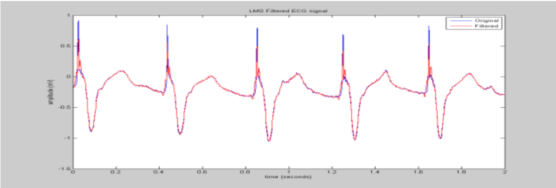

Fig. 5 (b)

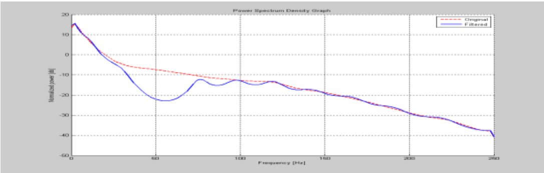

Fig. 5 (c)

Fig. 5 LMS Filter Algorithm Results Sample 1 (a) Original Noisy Signal (b) Weiner Filtered Signal (c) Power Spectrum Density Graph

Signal to Noise Ratio & Power Spectrum Density

a) *Weiner Filter*

Table1 Weiner Filter SNR & PSD Results

Sample (Record)	*SNR Filtered Signal*	*PSD of Original Signal*	*PSD of Filtered Signal*
100	4.36	-45.00 db	-46.00 db
101	7.20	-42.86 db	-44.20 db

b) LMS Algorithm

Table2 LMS Algorithm SNR & PSD Results

Sample	SNR Filtered Signal	PSD of Original Signal	PSD of Filtered Signal
104	14.62	-41.00 db	-43.79 db
105	16.39	-42.73 db	-42.80 db

VI. CONCLUSION

The proposed paper uses Adaptive Noise Cancellation method like weiner & LMS for noise removal like Baseline wander & Power line interference (PLI) which assists is replicating the denoised signal for better diagnosis. The performance analysis done using SNR & visual parameters like PSD confirms the denoising of PLI & Baseline wander nosie.

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