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Comparison of Various Adaptive Filtering Algorithm Techniques for Removal of PLI Noise from an ECG Signal – A Case Study

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Abstract— *ECG Electrocardiogram signal is the most commonly known recognized and used biomedical signal for medical examination of heart. The ECG signal is very sensitive in nature, and even if small noise mixed with original signal, the various characteristics of the signal changes, Data corrupted with noise must either filtered or discarded, filtering is important issue for design consideration of real time heart monitoring systems.Various filters used for removing the noise from ECG signals, most commonly used filters are Notch Filters, FIR filters, IIR filters, Wiener filter, Adaptive filters etc. Performance analysis shows that the best result is obtained by using Adaptive filter to remove various noises from ECG signal and get significant SNR and MSE results. Also various types of Adaptive Filters have been studied based on Least Mean Squared (LMS) algorithm, these are LMS, Signed Regressive LMS (SRLMS), Sign LMS (SLMS) and Sign-Sign LMS (SSLMS). The comparison has been shown on basis of signal to noise ratio and mean squared error. The proposal is to implement various algorithms and to make comparison between them based on several parameter.*

Keywords— *Adaptive filter, Least Mean Square (LMS), Normalized LMS (NLMS),Sign LMS (SLMS), Sign-Sign LMS (SSLMS), Signed Regressor LMS (SRLMS),Power line interference (PLI).*

1. INTRODUCTION

ECG signal plays an important role in the primary diagnosis, prognosis an survival analysis of heart diseases. The electrocardiogram (ECG) provides a physician with a view of the heart's activity through electrical signals generated during the cardiac cycle, and measured with external electrodes. Its clinical importance in cardiology is well established, being used for example to determine heart rate, investigate abnormal heart rhythms, and causes of chest pain. As shown in Figure 1, the most important ECG signal features in a single cardiac cycle are labeled (along with the physiological cause of that feature).

- *"P" wave*— due to depolarization of the atria
- *"Q" wave*— due to activation of the anterioseptal region of the ventricular myocardium
- *"R" wave*— due to depolarization of the ventricular myocardium
- *"S" wave*— due to activation of the posteriobasal portion of the ventricles
- *"T" wave*— due to rapid ventricular repolarization

The extraction of high resolution ECG signals from noisy measurements is among the most tempting open problems of biomedical signal processing. In order to support clinical decision making, reasoning tool to the ECG signal must be clearly represented and filtered, to remove out all noises and artifacts from the signal. ECG signal is one of the bio signals that is considered as a non-stationary signal and needs a hard work to denoising.

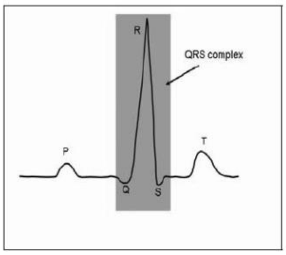

Fig. 1: An "ideal" ECG signal from a healthy subject Key features,including the QRS complex, are identified.

In this approach noise due to power line interference is considered which is of 50Hz.

A.Bhavanishankar et al [7] in their paper compared various Adaptive filtering algorithm and concluded that SRLMS performance is better as compared to LMS and other Adaptive filtering algorithm. Mbachu et al.[3] has given a suppressive mechanism for power line interference in ECG using adaptive digital filter. The filter has been designed using LMS algorithm and it has proved that the Adaptive filter is most stable and has Linear Phase.

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Soumya I. et al. [4] have shown respiration wander removal from cardiac signals using optimized adaptive noise canceller. Here they gave optimum step size least mean square (OSSLMS) algorithm. Yatindra et al [5] have given performance analysis of different filter for power line interference reduction in ECG signal and hence conclude that Adaptive filter after tuning to some optimum value gives the best result. Rahman et al.[6] have compared various adaptive filter algorithm for noise cancellation in ECG signal and concluded that SRLMS algorithm performs better than LMS in both SNR improvement and computational complexity.

2. VARIOUS ADAPTIVE FILTERING ALGORITHMS

2.1 LMS Algorithm

The LMS algorithm is a method to estimate gradient vector with instantaneous value. It changes the filter tap weights so that e (n) is minimized in the mean-square sense. The conventional LMS algorithm is a stochastic implementation of the steepest descent algorithm. It simply replaces the cost function ξ (n) = E [e2 (n)] by its instantaneous coarse estimate.

The error estimation e(n) is

$$e(n) = d(n) - w(n)X(n) \quad (1)$$

Coefficient updating equation is

$$w(n+1) = w(n) + \mu x(n) e(n), \quad (2)$$

Where μ is an step size chosen as $0 < \mu < 0.2$ for the convergence of the algorithm. The larger step sizes make the coefficients to fluctuate wildly and eventually become unstable. The most important members of simplified LMS algorithms are:

2.2 Signed-Regressor Algorithm (SRLMS)

The signed regressor algorithm is obtained from the conventional LMS recursion by replacing the tap-input vector x (n) with the vector sgn{x(n)}.Consider a signed regressor LMS based adaptive filter that processes an input signal x(n) and generates the output y(n) as per the following:

$$y(n) = wt(n)x(n) \quad (3)$$

where, w(n) = [w0(n), w1(n), …, wL-1(n)]t is a L-th order adaptive filter. The adaptive filter coefficients are updated by the Signed-regressor LMS algorithm as,

$$w(n+1) = w(n) + \mu\, sgn\{x(n)\} e(n) \quad (4)$$

Because of the replacement of x(n) by its sign, implementation of this recursion may be cheaper than the conventional LMS recursion, especially in high speed applications such as biotelemetry these types of recursions may be necessary.

2.3 Sign Algorithm (SLMS)

This algorithm is obtained from conventional LMS recursion by replacing e(n) by its sign. This leads to the following recursion:

$$w(n+1) = w(n) + \mu x(n)\, sgn\{e(n)\} \quad (5)$$

2.4 Sign – Sign Algorithm (SSLMS)

This can be obtained by combining signed-regressor and sign recursions, resulting in the following recursion:

$$w(n+1) = w(n) + \mu\, sgn\{x(n)\}\, sgn\{e(n)\}, \quad (6)$$

Where sgn{. } is well known signum function, e(n) = d(n) – y(n) is the error signal. The sequence d (n) is the so-called desired response available during initial training period. However the sign and sign – sign algorithms are both slower than the LMS algorithm. Their convergence behavior is also rather peculiar. They converge very slowly at the beginning, but speed up as the MSE level drops.

2.1 Sample Adaptive filtering for PLI noise cancellation & Comparison of various Adaptive filtering algorithm based on Mean Square Error & Computational Complexity

The Figures 2,3,4 and 5 shows an example of Implementation in MATLAB of Adaptive LMS filter for removal of Power line Interference noise removal with following specification Length = 40 Step Size =0.05

In the Table 1 various Adaptive filtering algorithm has been compared on the basis of MSE and Convergence factor as proposed by A.Bhavanishankar et al [7]. The convergence speed for μ =0.02 is faster than μ=0.004. But MSE performance is comparatively better for μ=0.004 than μ=0.02. Convergence rate of LMS algorithm is better when μ=0.02 and low MSE value when μ=0.004. It is also inferred that the MSE performance of Sign Regressor LMS (SRLMS) at the step size of 0.02 is better when compared to other algorithms. But there is always tradeoff between convergence rate and mean Squared error.

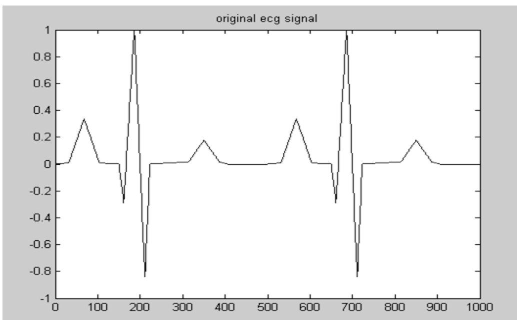

Fig. 2: Original Simulated ECG signal

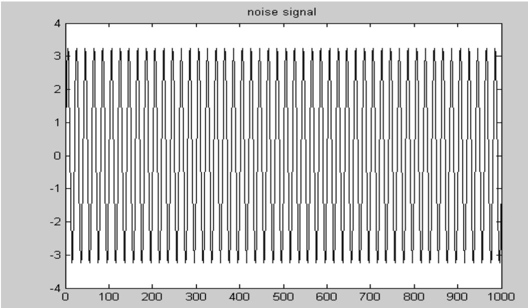

Fig. 3: Generated 50 Hz Noise Signal

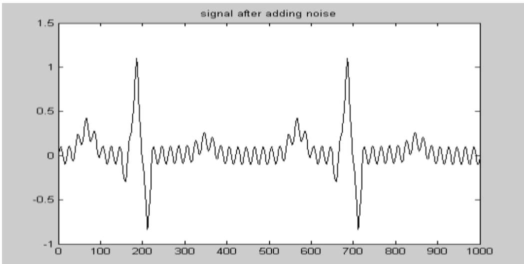

Fig. 4: ECG in addition with noise

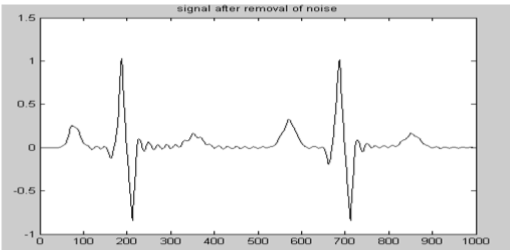

Fig. 5: Filtered ECG signal

Table 1: Comparison of various adaptive filtering Algorithm on the basis of Mean Square Error & Convergence Rate (C)

Algorithm	*μ=0.02*		*μ=0.004*	
	MSE	*C*	*MSE*	*C*
LMS	2.837e-004	100	5.4907e-005	250
SRLMS	8.5993e-006	100	5.303e-004	550
SIGN LMS	1.3406e-004	100	4.9436e-005	550
SIGN SIGN LMS	4.951e-004	200	8.7072e-004	550

Table 2: Comparison of various adaptive filtering Algorithm on the basis of computational complexity.

Algorithm	*Multiplications*	*Additions*	*Shifts*
LMS	L+1	L+1	Nil
SRLMS	1	L+1	Nil
SLMS	Nil	L+1	L
SSLMS	Nil	L+1	Nil

L= Length of Filter

The various algorithms has been compared on the basis of computational complexity as proposed by Rahman et al.[6].

From Table 2 it is clear that SSLMS adaptive filtering algorithm will be simplest one in terms of computational complexity whereas LMS algorithm will be the complex one.

3. CONCLUSION

The study has revealed useful properties of various Adaptive filtering algorithms. The object is to minimize MSE to improve the quality of eliminating PLI. It has also observed from the study that performance depends on various factors like step size, number of samples taken for consideration. Choosing an algorithm depends on the parameter on which system is more concern..So the work includes implementation of various algorithms, Further a novel adaptive filter is to be implemented to improve SNR and to remove the computational complexity.

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