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NOISE CANCELLATION IN ECG SIGNAL USING COMPUTATIONALLY SIMPLIFIED ADAPTIVE TECHNIQUES

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***Abstract*— The main aim of our paper is to give a way to cancel noise in biomedical signals like ECG which are non-stationary.ECG is the recording of electric conductivity of heart and is used in investigation of many heart diseases.In the recording process the noise through various sources takes account in the corruption of ECG signal. Main sources of noise are motion artifacts, muscle contraction, respiration, electrode contact and power line interference. Noise generated by these sources is non-stationary. Since doctors are interested in the peaks of the ECG but because of the non-stationary noise they face hindrance in getting the information signal. An appropriate filtering technique is required to extract the information signal from a noisy environment. Fixed coefficient FIR filters cannot be used in this case because the statistics of the signal are not known. Adaptive filtration is the best possible solution. It's a simple but the powerful filtering technique that works on recursive algorithm. The algorithms are used to update the filter coefficients in such a way that the noise is cancelled out from the signal and a noise free signal is recovered.**

Key words: Adaptive filters,Adaptive algorithms,LMS,NLMS,RLS, ECG

I. Introduction

The electrocardiogram (ECG or EKG) is a phenomenon in which the electrical activity of heart is judged. It is done by positioning the leads on the body on specific positions. The leads are attached to the body and the patient lies flat on the table for Ecg. A small amount of gel is basically applied on the body, so that the electric impulses of the heart should be transmitted easily to the leads of the Ecg leads as shown in the figure 1. The patient lay straight and the ecg I recorded.

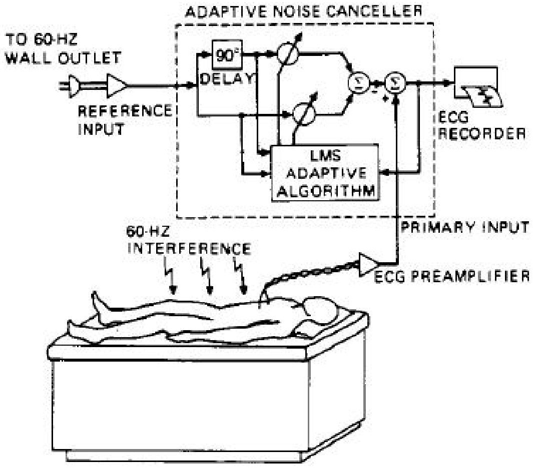

Figure1. ECG process

Then the desired information about the heart's activity is gathered and the information about it is displayed and then further printed for use.The Ecg tells us about the information like the rhythm mechanism of heart, how it beats, about the position of heart i-e how it is placed in a chest cavity, about the variation in heart muscle, also about the cardiac disturbances as shown in figure 2.

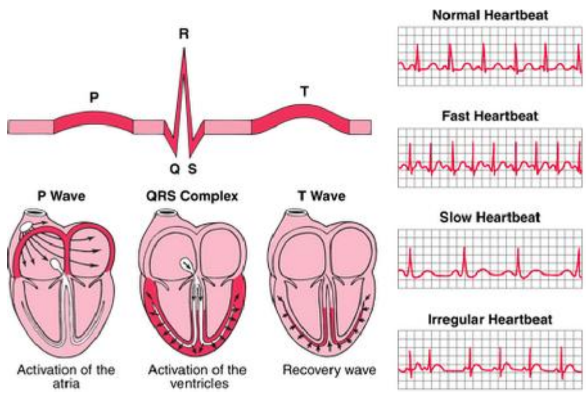

Figure 2. Results obtained from ECG

An Ecg signal consist of P wave, QRS complex wave and T wave. The description is shown in figure.

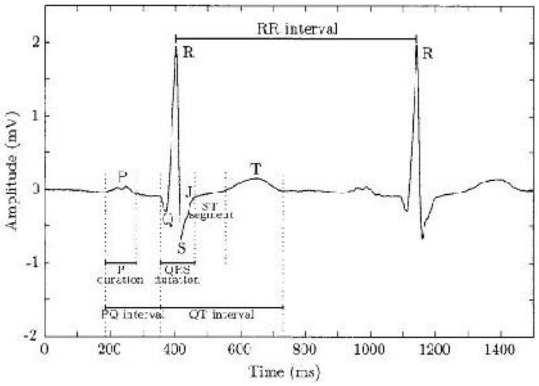

Figure 3. ECG signal

The PQRST waves have the following functionality.

- P wave: it is the sequential activation (depolarization) of the right and left atria
- QRS comples: right and left ventricular depolarization
- T wave: ventricular repolarization

The electrical changes on the skin that are caused when heart muscle depolarizes are detected and amplified. When the body is at rest, each heart muscle cell has a negative charge across its outer wall. The increase in this negative charge to zero is known as depolarization, which then causes it to contract. During each heartbeat, the heart will have an orderly succession of a wave of depolarization that is activated by the cells in the sinoatrial node, spreads out through the atrium, and then it passes through "intrinsic conduction pathways" and then spreads all over the ventricles. The two electrodes which are placed on both sides of the heart are used to detect this rise and fall in voltage, which is then displayed on the screen or printed out on the paper. This output from the ECG device is then used to get further information about the behavior of heart. Now as this information is so important for the doctor to examine the patient, so it needs to be error free. It should provide the actual reading and information to the doctor.

There are many factors of noise like power line interface, baseline wandering, muscle artifacts, motion artifacts due to which ECG signal can be effected [1]. The noise because of power line is sinusoidal noise of 50Hz superimposed on the desired signal with its harmonics. EMG (electromyogram) type signal generated because of muscle contraction process and get mixed with the ECG signal. The amplitude of the EMG noise is non-stationary and can be modeled in simulation as zero mean Gaussian function [2]. There are certain other sources of noise like variable contact between the electrodes and skin, respiration of the patient and the coupling of noise from other electronic devices. Removal of power line interference and random noise suppression is one of the common problems.Processes to remove this unwanted interference are common and come in many renditions. The technique of adaptive filtering is one medium by which signal enhancement or noise reduction is accomplished [3].

Therefore we tried to minimize these factors of noise for which we use different filtering techniques, among which the adaptive filtering is best to denigrate different noise sources. The reason to prefer these filters over fixed coefficient filters is that we do not have priory information about the signal because human behavior is not exactly known[4]. These are the cases where signal conditions and system parameters are slowly changing and the filters except adaptive are not suitable for this variation[5].

II. METHADOLOGY

An adaptive filter is a filter that self-designs its transfer function according to algorithm. It uses feedback to refresh its coefficient and its frequency response [3]. As the adaptive filters do not know about any information of the noise, it estimates a noise signal. This signal is in general called a desired or reference signal, whose choice is normally a tricky task that depends on the application [6].

Adaptive algorithms have been studied and used frequently during last many years and they covered a wide area in many of the applications like biomedical, image processing, communication signal processing and many other applications [10]. The two of the main adaptive algorithms are least mean square (LMS) and recursive mean square (RLS). Their performance depends directly on the signal condition and the filtering order given to them. LMS algorithm was introduced by Widrow and Hoff in 1959. It estimates the gradient vector from the given data. LMS algorithm uses iterative technique that updates the weight vector in the negative direction of gradient vector which minimizes the mean square error. The performance of the LMS algorithm depends upon the convergence parameters too. As compared to the other algorithms, LMS is relatively simpler and because of its simplicity, it is widely used in adaption techniques.

Adaptive Filter uses the filter parameters of previous moment to automatically adjust the filter parameters of the present Moment, to adapt to the statistical properties of the signal and unknown random noise, in order to achieve optimal Filter [7].

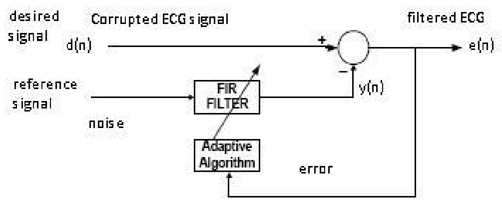

Figure 3:Adaptive Noise Canceller (ANC)

In figure 3 the desired inputd(n) in this case is the corrupted ECG signal. The reference signalx(n) is the source of noise. The filter estimates the noise (provided in the reference signal) updates its coefficients according to the noise and subtracts the estimated noise from the desired signal. Error signal e(n) is the filtered ECG signal where as the filter output y(n) is the purely estimated noise. Theadaptive algorithm is an iterative technique for minimizing the mean square error (MSE) between the primary input and the reference signal[8-9].

$$e(n) = d(n) - y(n) \quad (1)$$

$$= d(n) - w^T x \quad (2)$$

$$E[e^2(n)] = E[(d(n) - w^T x)^2] \quad (3)$$

$$= E[d^2(n)] - 2w^T E[xd(n)] + w^T E[xx^T]w \quad (4)$$

In LMS (Least Mean Square) algorithm case weights (w) are updated according to the equation 5.LMS filter weights are updated according to the squared value of error.

$$w_{n+1} = w_n + 2\mu\varepsilon_n x_n \quad (5)$$

The equation used for the NLMS(Normalized Least Mean Square) is:

$$w(n+1) = w(n) + \mu \frac{}{\|x(n)\|^2} x(n)e(n) \quad (6)$$

As we compute w(n+1), we see that the previous weight changes fractionally because of $\|x(n)\|^2$. So a lesser change means lesser disturbance in the system.

Another important characteristic of NLMS is that this algorithm exhibits a potentially faster rate of convergencethan that of LMS algorithm for both correlated and uncorrelated data.

In general, the NLMS algorithm is convergent in the mean square sense if the following condition for adaptation constant μ is satisfied:

$$0 < \mu < 2$$

Recursive least square (RLS) is most extensively used algorithm that is an extension of least square technique. In stationary environment the convergence rate or speed of RLS is faster than simple LMS. RLS is best for non-stationary environment with high convergence speed but at the cost of higher complexity. The RLS algorithms are known for their excellent performance when working in time varying environments but at the cost of an increased computational complexity and some stability problems. In the RLS Algorithm the estimate of previous samples of output signal, error signal and filter weight is required that leads to higher memory requirements.

III. Results and Discussion

Matlab based simulations are used because real-time corrupted ECG signal is not yet available. We have to model the noise as random noise.

Figure 2 shows the Matlab generated ECG signal of a normal man with a heartbeat of 72.The original ECG signal is contaminated with random noise because of different noise sources (as discussed earlier). In figure 3 the corrupted signal with random non-stationary white noise is modeled. In case of noise the useful information hidden in the peaks of the ECG signal cannot be gathered as shown in figure 2. This is the major problem faced in most biomedical processes. So a special treatment is required to extract the useful signal from the noise.

In the filtration process built-in functions are available for this purpose. Three main algorithms LMS, NLMS and RLS are used for filtration of distorted signal. In all the cases no of tabs N and the step size (μ) remains the same. N= 100, μ=0.01.

Number Of Tabs (N)	100
Step Size (μ)	0.01

Parameters Setting

In figure 4,5 and 6 the working of adaptive algorithms can be clearly seen. Initially the algorithm has no information about the noise gradually it updates its weight coefficients adapts the noise in the desired signal. The estimation of noise process is gradually processing process. Time taken by the algorithm to finally estimate the noise depends upon the rate of convergence, and further rate of convergence is dependent on the step size.

In figure 8 it is clearly seen that the signal has equally distributed power among all the frequencies, due to which it is impossible to make a distinction about the information signal. In figure 9,10 and 11 the spectrum of recovered signal is manipulated, if figure 9, 10 and 11 compare it with the spectrum of original signal in figure 7 then it is realized that the low frequency signal is extracted.

Corrupted ECG Signal SNR	# Of Tabs (N)	Proposed Scheme SNR		
		LMS	NLMS	RLS
36.0136	32	35.6104	35.7753	35.8203
36.4268	64	36.0835	36.1535	36.2539
36.0000	100	35.7409	35.7619	35.8461

Table 1: SNR Improvement of Various Algorithms.

Table 1 shows the SNR comparison of different algorithms used.RLS gives highest improvement in SNR as compared to LMS and NLMS.As the filter tabs increases RLS give improved SNR values. Convergence rate of RLS is much faster than that of LMS and NLMS. Rate of convergence is not related to the spectrum of input signal [4-11].

IV. CONCLUSION

Various techniques have been used earlier for the filtration of ECG signals. In this paper we use different adaptive techniques LMS, NLMS, RLS and compare them in sense of computational time, complexity and performance. Among these adaptive techniques LMSis the most simplest algorithm, but the convergence rate of LMS is very low as compared to RLS and NLMS.Because of its simplicity it is most popular in adaptation techniques.NLMS is the modified form of LMS, but with a high convergence rate; computational time is low as compare to LMS and has a greater efficiency than LMS.On the other hand RLS has very high convergence rate as compared to LMS and NLMS. RLS also improves the signal to noise ratio of the contaminated signal but on the cost of complexity. Its each iteration is much greater than that of the other two algorithms. But in performance it is much better than LMS and NLMS.

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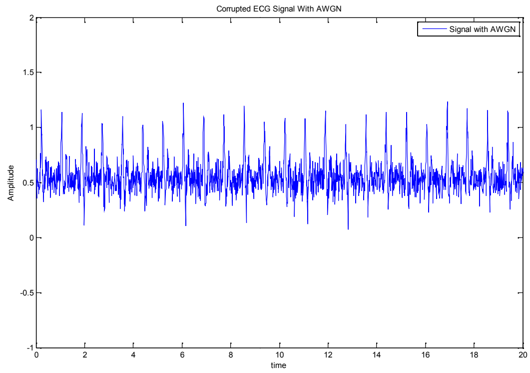

Figure 3: Corrupted ECG Signal

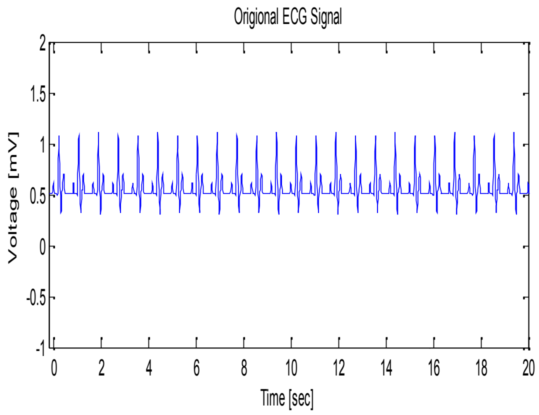

Figure 2: Original ECG Signal

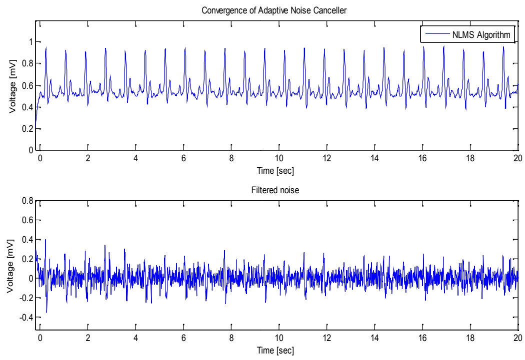

Figure 5: Convergence of Adaptive Noise Canceller (NLMS)

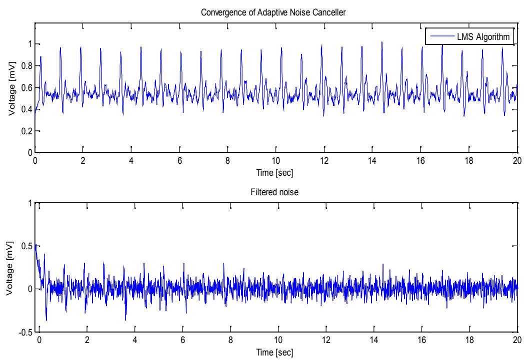

Figure 4: Convergence of Adaptive Noise Canceller (LMS)

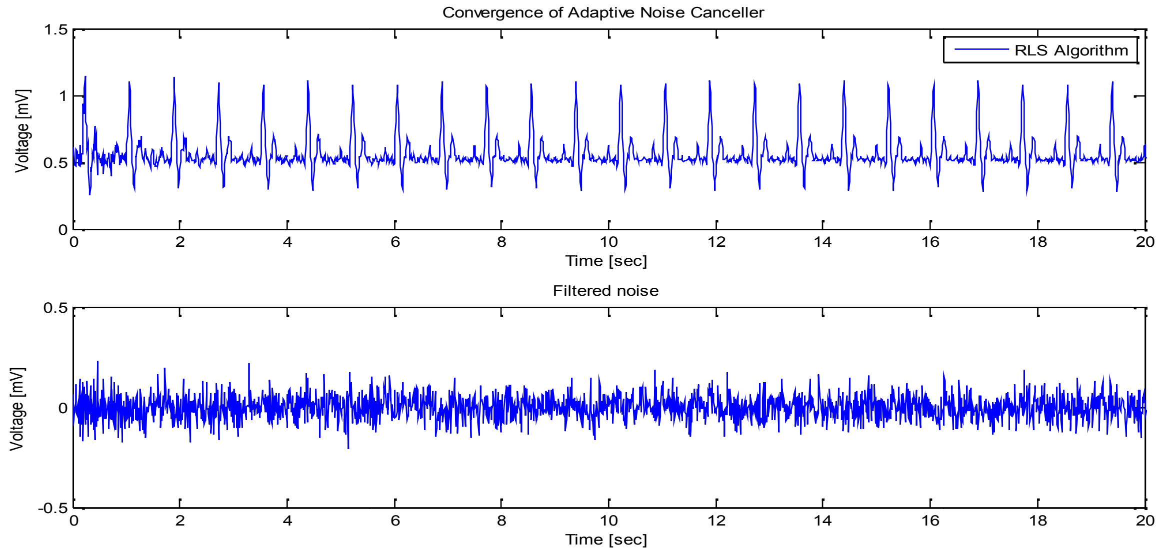

Figure 6: Convergence of Adaptive Noise Canceller (RLS)

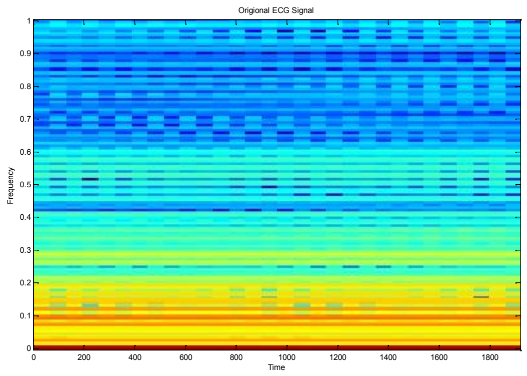

Figure 7: Spectrogram of Original ECG Signal

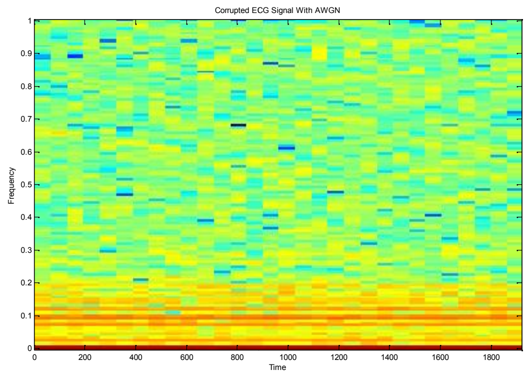

Figure 8: Spectrogram of Corrupted ECG Signal

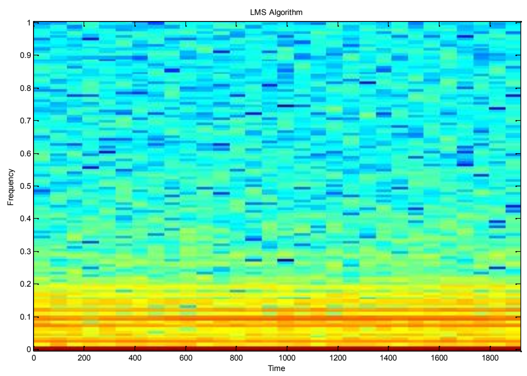

Figure 9: Spectrogram Adaptive Noise Canceller (LMS)

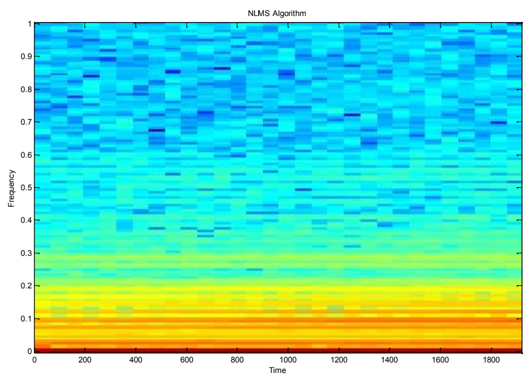

Figure 10: Spectrogram Adaptive Noise Canceller (NLMS)

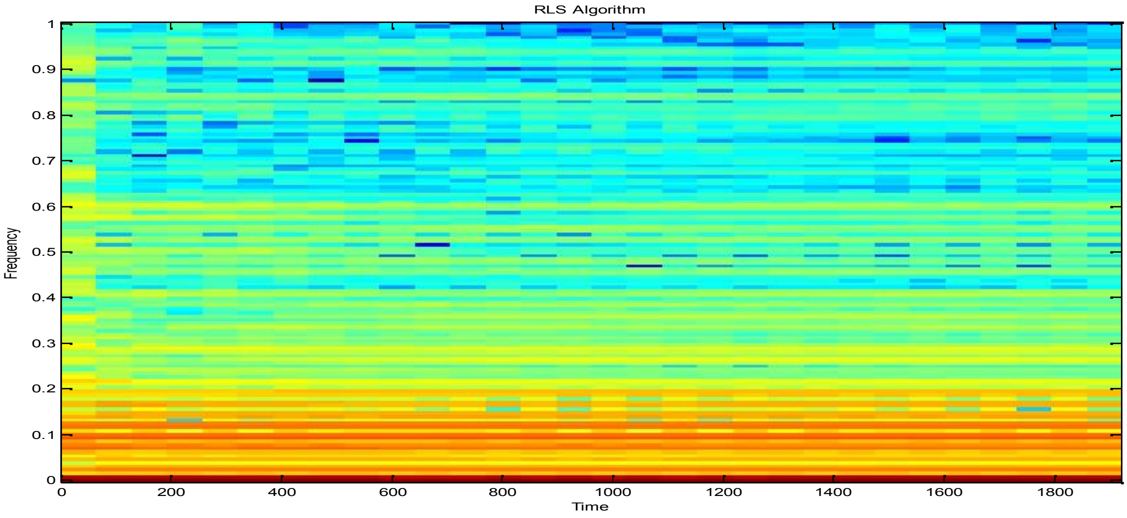

Figure 11: Spectrogram Adaptive Noise Canceller (RLS)