RESEARCH ARTICLE OPEN ACCESS

Adaptive Filter for Ecg Noise Reduction Using Rls Algorithm

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Abstract
Noise reduction in ECG signal is an important task of biomedical science.Adaptive filtering algorithms are evolving rapidly in biomedical science to remove the noise by an appreciable amount.In this paper, noise of ECG signal has been reduced by using adaptive filter based on RLS algorithm.The RLS algorithm performs well irrespective of the nature of signal and noise and its convergence rate is very fast. The abrupt changes in the ECG signal are best handled by RLS algorithm. The proposed filter has been designed and simulated using MATLAB. The results show that the developed filter can reduce ECG noise to 0.15 percent upto 30 order filter with 0.4680 seconds convergence time.
***Keywords**:* Adaptive Filter, ECG, MATLAB

I. INTRODUCTION:

ECG(electrocardiogram signal) plays a pivotal role in providing the functions of heart.It records the heart's electrical activity. With each heartbeat, an electrical signal spreads from the top of the heart to the bottom. As it travels, the signal causes the heart to contract and pump blood. The process repeats with each new heartbeat. It gives the information about the rhythm of the heart providing information about the normal and abnormal behavior of heart. ECG of a normal human has a characteristic shape. Any abnormality in the heart of the patient changes the shape of recorded ECG. This change may occur owing to their family history of heart disease or because of obesity,smoking or having diabetes, high blood pressure or cholesterol. The ECG test is performed by transferring the electrical activity on the skin using electrode to displayed system. Different types of leads are used for recording. These leads are based on the simultaneous measure of electrical signal from different parts of the body. 3-lead, 5-lead, 12-lead are generally used for recording[1].

The ECG Signal is basically an electromagnetic wave generated by heart. The signal is converted into electrical form to observe on a display system. During this processing, several sources of noise, affects the original ECG signal. A small change in amplitude or shape of the ECG signal may cause a severe problem in decision making by doctors.This variation changes the form factor of ECG signal(coming from patient). The ECG signal can be corrupted by power line interference, electrode contact noise, baseline drift,instrumental noise, Motion artifacts. Power lineconsists of (50-60) Hz harmonics. This noise can be modeled as sinusoids. The variation in the electrode-skin impedance causes the motion artifacts noise. The impedance mismatching causes less power transfer to the ECG amplifier used for converting ECG electromagnetic signal into a particular level of electrical ECG signal. Baseline Drift noise is continuous drifting of ECG signal from base line. The sinusoidal component of frequency of respiration added to ECG signal can be represented by base line drift noised ECG signal. The noise added in the ECG signal, is variable in amplitude and frequency. We can't design a notch filter to remove noise. Instead we need a dynamic system, in which filtered frequency should be adjusted time by time.Adaptive filtering is a kind of dynamic approach which can adapt itself depending upon requirement [2].

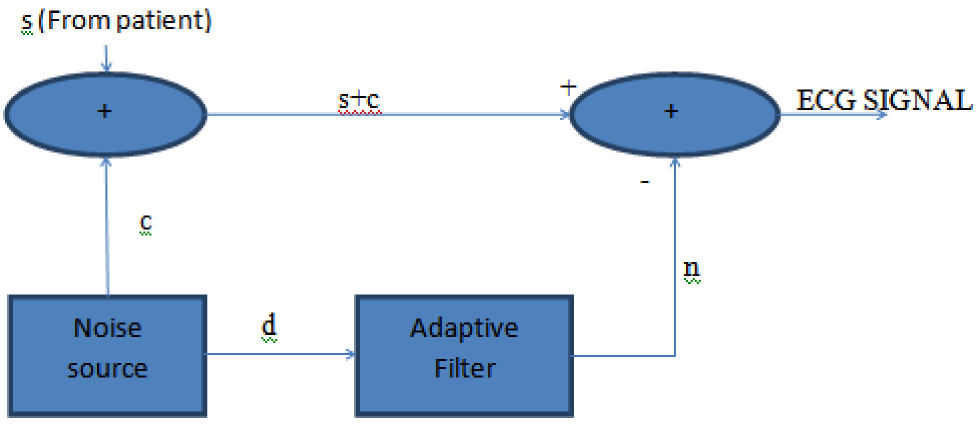


Figure 1. Adaptive filter noise reduction

The recursive least square algorithm is used in adaptive filters to find the filter coefficients which provides highly correlated output as that of noise signal added in original ECG signal. As shown in Figure1, The ECG signal, s is the uncontaminated signal. (s+c) is the contaminated ECG signal. c and d are the noisy signals, generated by noisy source. Our basic task here is to correlate the signal n (which is the reference signal)with that of c by identifying the parameters of adaptive filter. This n signal is mixed with the contaminated ECG signal. At the end we obtain the original ECG signal. So the filter coefficients are estimated iteratively to minimize the error between contaminated signal and original ECG signal just by finding the closest value of n as that of c.

II. Adaptive Algorithm

An adaptive filter adjusts or modified its frequency response automatically to improve its performance according to some criterion. Owing to the self- adjusting performance and in-built flexibility, adaptive filters are used in diverse applications. We use adaptive filters where it is must for the filter characteristics to be variable and adapted to changing condition and when there is a spectral overlap between the signal and noise. Adaptive algorithms are used to modify the coefficients of digital filter. LMS (least mean square) and RLS(recursive least square) algorithms are basically used. The LMS is based on the steepest descent algorithm where the weight vector(coefficients) is updated from sample to sample .The LMS algorithm does not require any priori information of the signal statistics that is correlation, but it provides the estimation of filter coefficients which are gradually improved with time. The RLS algorithm is based on the least squares.The RLS algorithm has fast convergence than LMS algorithm. It has more complexity than LMS but high convergence speed, makes it pretty good choice. The following equation provides the update coefficients for RLS algorithm[3]-[4].

$w(n+1) = w(n)+e(n).k(n)$ …………………..(i)

where w(n) is the filter coefficient vector,k(n) is the gain factor, e(n) is error signal.

k(n) is defined by the following equation:

$$k(n) = \frac{P(n).u(n)}{\lambda + u^t(n)P(n).u(n)} \quad \dots\dots\dots\dots (ii)$$

Where λ is the forgetting factor and $P(n)$is inverse correlation matrix of the input signal and is defined as

$$P(n) = \delta^{-1}u(n) \quad \dots\dots\dots\dots\dots. (iii)$$

Where δ is regulation factor and u(n) is unity matrix. The RLS algorithm uses following equation(iv) to update the inverse correlation matrix.

$$P(n+1) = \lambda^{-1}P(n)- \lambda^{-1}k(n)u^t(n)P(n) \quad \dots\dots\dots\dots.. (iv)$$

The parameter that we can adjust in RLS algorithms are forgetting factor and regulation factor. The range of forgetting factor lies between 0 to 1. The regulation factor is the initial value of inverse correlation matrix.

III. MATLAB based design simulation

Noise free ECG signal is generated from MATLAB function of desired length and then mixed with random noise. And after that RLS algorithm is used to nullify the effect of noise. The whole step is illustrated in Figure2(a)-(d).

(a)

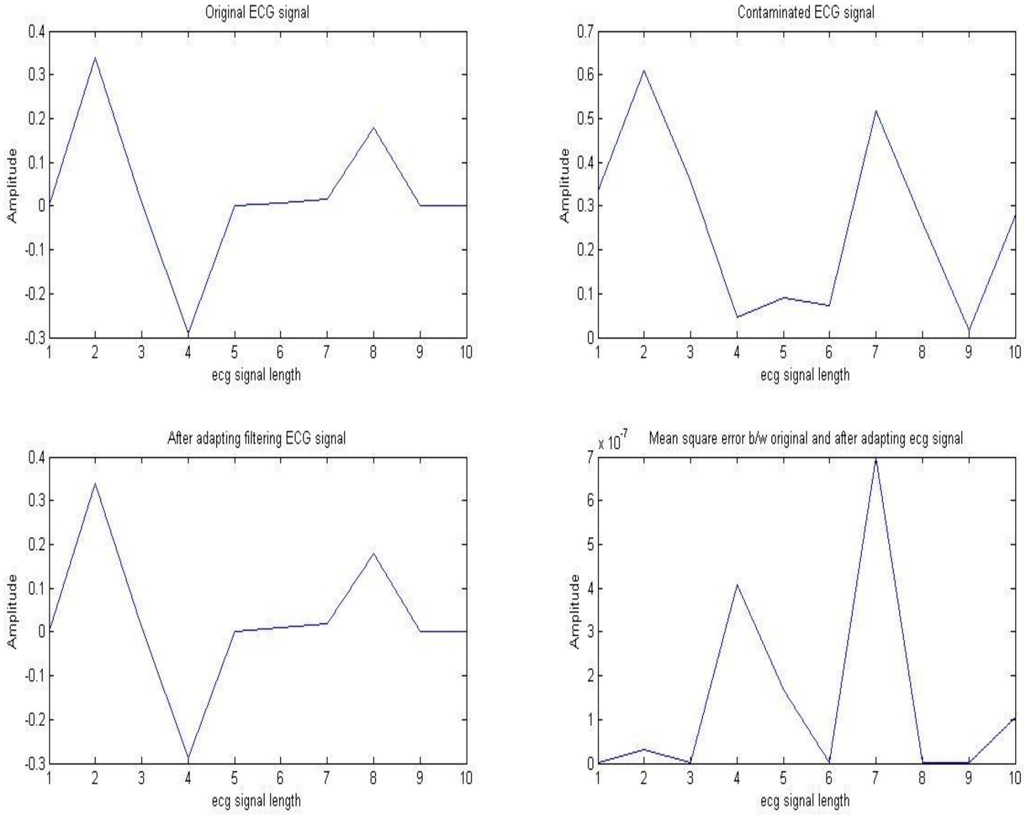
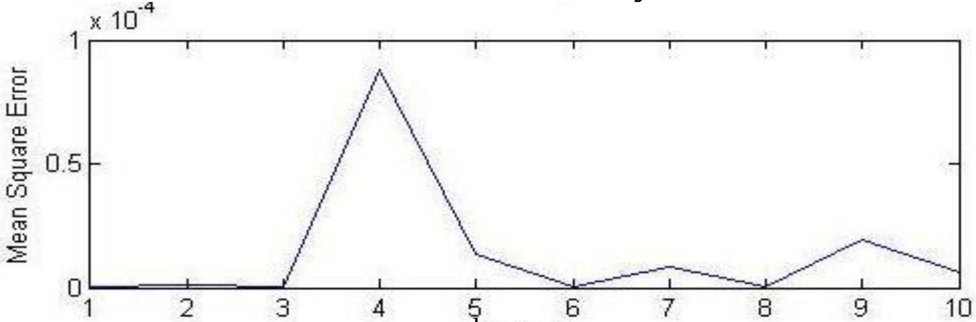


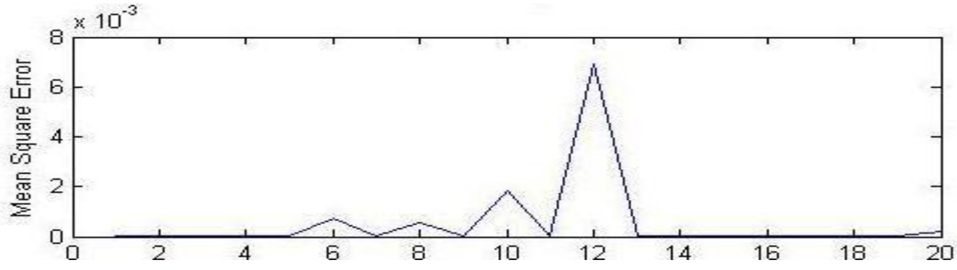
Figure2 (a) Original error free signal (b) Contaminated ECG signal (c) ECG signal recovered after adaptive filtering (d) Mean square error plot

Figure2(a) shows the original ECG signal which is free from noise. While travelling through system some noise gets added to the original ECG signal. Figure2(b) shows the noise corrupted signal. we can see from figure2(b) that owing to addition of noise, the shape of ECG pulse changes as compared to original ECG signal shown in Figure2(a). Figure2(c) shows the ECG signal recovered using adaptive filter. Figure2(d) is the mean square error plot.

IV. Result Analysis

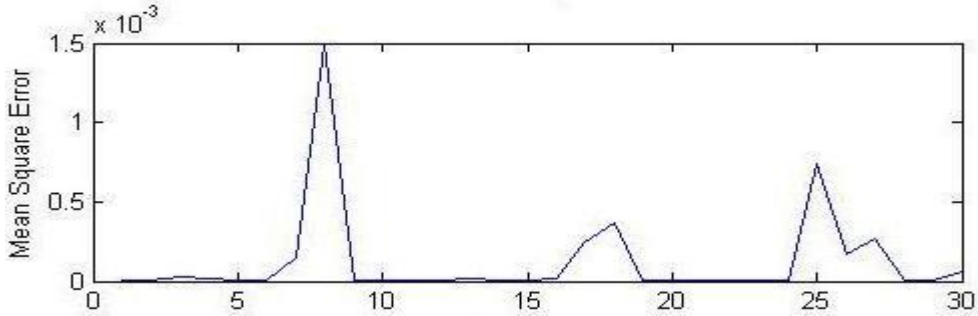


(a)



Samples

(b)



Samples

(c)

Figure3. Mean square error plot v/s Samples ; Number of Filter coefficients (a) 10 ,(b) 20 , (c) 30

The Figure3.Shows the plot between mean square error and filter coefficients. The error gives the mean square difference between the desired output and the output coming after using adaptive filter. The Figure3.Shows the plot for different number of samples.The Figure4.Shows the convergence time versus filter order plot.

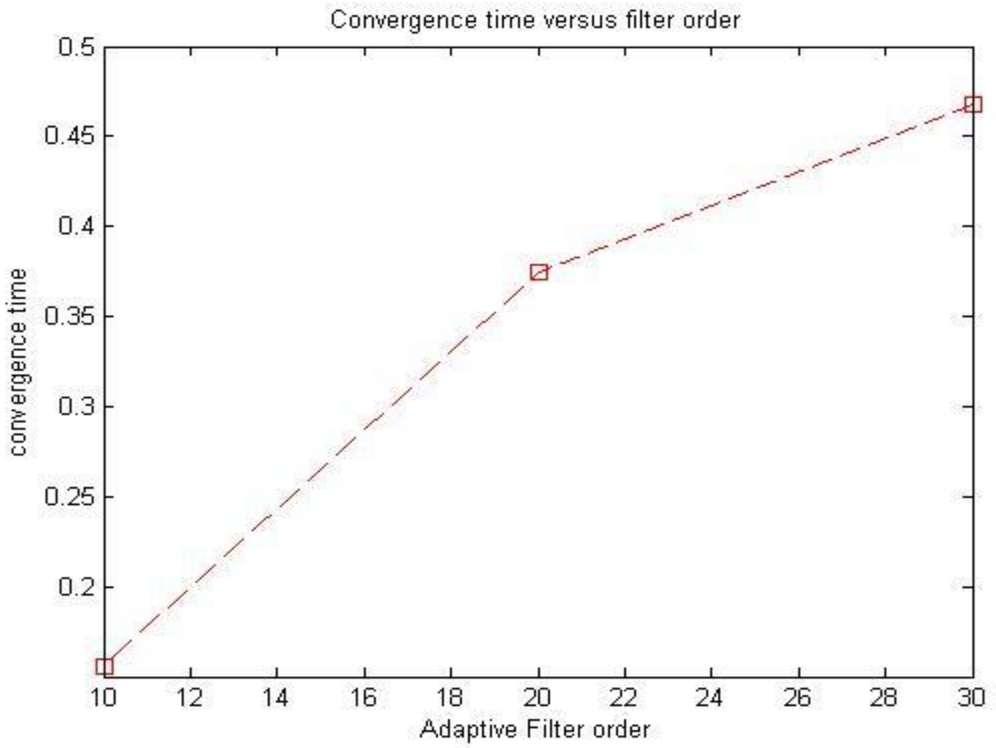


Figure4. Adaptive filter convergence time versus filter order

For filter lenth 10, the system takes 0.1560sec to converge.For filter lenth 20, it takes 0.3744sec and for 30, it takes 0.4680sec to converge. The convergence time increases as complexity in the system increases.The convergence time and mean square error gets adjusted by changing the adaptive filter parameter that is the forgetting factor and regulation factor. The adaptive filter gets its optimum value when forgetting factor lies between .98 and 1.

V. CONCLUSION

The proposed adaptive RLS technique provides an optimum quality of the corrupted ECG signal. The analysis is done on different filter lengths. The mean square error and convergence time has a trade off on each other. An optimum value of convergence time is being taken where the mean square error is also optimum. As the order of filter gets increased, the adaptive filter noise reduction system takes more time to converge. The convergence time and mean square error gets adjusted by changing the adaptive filter parameter that is the forgetting factor and regulation factor. The adaptive filter gets its optimum value when forgetting factor lies between .98 and 1. As the order increases, the optimal condition is obtained by choosing large values of regulation factor and keeping forgetting factor is equal to 1. For lower values of forgetting factor , the system takes more time to converge . For lower values of regulation facor the mean sqaure error is greater as compared to large values of regulation factoe. The proposed method gives a satisfactoryresults whether it is the concern of mean square error or the convergence time.

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