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CANCELLATION OF MOTION ARTIFACT NOISE AND POWER LINE INTERFERENCE IN ECG USING ADAPTIVE FILTERS

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Abstract- Background: The electrocardiogram(ECG) has the considerable diagnostic significance, and applications of ECG monitoring are diverse and in wide use. Noises that commonly disturb the basic electrocardiogram are power line interference(PLI), instrumentation noise, external electromagnetic field interference, noise due to random body movements and respiration movements. These noises can be classified according to their frequency content. It is essential to reduce these disturbances in ECG signal to improve accuracy and reliability. The bandwidth of the noise overlaps that of wanted signals, so that simple filtering cannot sufficiently enhance the signal to noise ratio. It is difficult to apply filters with fixed filter co-efficients to reduce these noise. Adaptive filter technique is required to overcome this problem as the filter coefficients can be varied to track the dynamic variations of the signals. Adaptive filter based on the least mean square (LMS) algorithm and recursive least squares (RLS) algorithm are applied to noisy ECG to reduce 50 Hz power line noise and motion artifact noise. Method: ECG signal is taken from physionet database. A ECG signal (without noise) was mixed with constant 0.1 mVp-p 50 Hz interference and motion artifact noise processed with Adaptive filter based on the least mean square (LMS) algorithm and recursive least squares (RLS) algorithm. Simulation results are also shown. Performance of filters are analyzed based on SNR and MSE.

Result: Convergence rate is slow and SNR of Adaptive filter based on the least mean square (LMS) algorithm is lower.

Conclusion: Adaptive filter based on Recursive least squares (RLS) algorithm gives best performance based on SNR and MSE.

Key Words- *Electrocardiogram (ECG), power line interference(PLI), Least mean square (LMS), Recursive least squares (RLS).*

I. INTRODUCTION

Adaptive filtering involves the change of filter parameters (coefficients) over time. It adapts to the change in signal characteristics in order to minimize the error. During past few years, various contributions have been made in literature regarding noise removal, beat detection and classification of ECG signal. Most of them use either time or frequency domain representation of the ECG waveforms. In the paper “Efficient sign based normalized adaptive filtering techniques for cancellation of artifacts in ECG signals: Application to wireless biotelemetry”, M.Z. Rahman, R.A. Shaik and D.V. Rama Koti Reddy have used several simple and efficient sign based normalized adaptive filters for cancelation of noise in electrocardiographic (ECG) signals, which are computationally superior having multiplier free weight update loops [1].

The proposed implementation is suitable for applications such as biotelemetry, where large signal to noise ratios with less computational complexity are required . In 2010, Dr. K.L. Yadav and S. Singh have used adaptive algorithms i.e. LMS and RLS for noise cancellation in their paper “Performance evaluation of different adaptive filters for ECG signal processing” [2]. According to their paper, the RLS algorithm based adaptive filter has better performance. Many methods were proposed in the past for the removal of high frequency noise in the ECG [3]-[7]. They can be categorized into two: non-adaptive and adaptive filtering.

The non-adaptive filtering approach employs a sharp notch filter either in analog or digital form and has advantages of easy implementation and low cost but long transient response time and ringing effect lower the quality of ECG signal.

Adaptive filtering on the other hand is able to remove the time-varying power line signal effectively. Motion artifacts are transient baseline change due to electrode skin impedance with electrode motion.

It can generate larger amplitude signal in ECG waveform. An adaptive filter can be used to remove the interference of motion artifacts.ECG signal is taken from physionet having sampling frequency of 500 Hz.

This signal is processed by Adaptive filter based on the least mean square (LMS) algorithm and recursive least squares (RLS) algorithm. Performance of filters are analyzed based on SNR and MSE.

Input ECG:
ECG signal is taken from physionet ECG database with sampling frequency of 500 Hz as shown below in Figure 2. A ECG signal (without noise) was mixed

with constant 0.1 mVp-p 50 Hz interference and motion artifact noise shown in Figure 3.

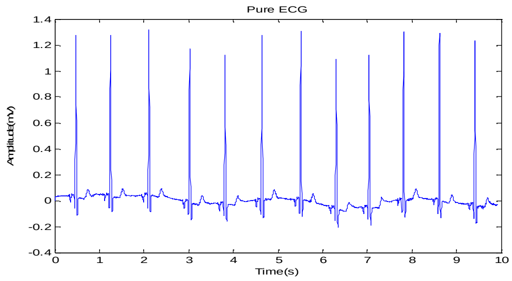

Figure 1: Input ECG signal with sampling frequency of 500 Hz

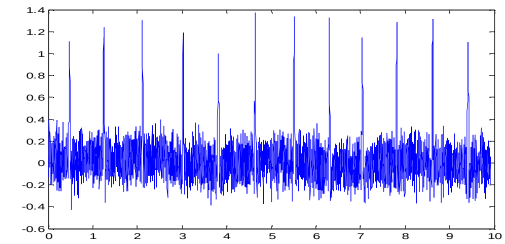

Figure 2: Noisy ECG signal (contain 50 Hz power line noise and motion artifact noise)

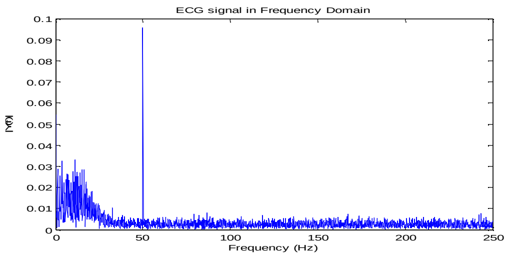

Figure 3: Noisy ECG signal (contain 50 Hz PLI and motion artifact noise) in frequency domain

Adaptive filter design and simulation:

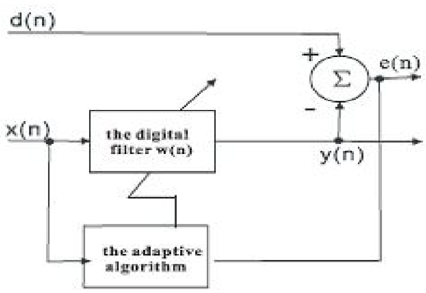

Figure 4: general Adaptive filtering diagram

The figure above is general adaptive filtering diagram. A digital filter is applied on the input signal x(n), produce output signal y(n). Adaptive algorithm adjusts the filter coefficient included in the vector w(n), in order to let the error signal e(n) be the smallest. Error signal is the difference of desired signal d(n) and the filter output y(n).The adaptive filter has a Finite Impulse Response (FIR) structure. For such structures, the impulse response is equal to the filter coefficients. The coefficients for a filter of order N are defined as

$W(n) = [W_n(0), W_n(1), \ldots\ldots W_n(N-1)]^T$

The output of the adaptive filter is y(n) which is given by

$y(n)=W(n)^T x(n)$

The error signal or cost function is the difference between the desired and the estimated signal

$e(n)=d(n)-y(n)$

he variable filter updates the filter coefficients at every time instant

$W(n+1)=W(n)+\Delta W(n)$

where $\Delta W(n)$ is a correction factor for the filter coefficients. The adaptive algorithm generates this correction factor based on the input and error signals.

LMS algorithm :

It is a stochastic gradient descent method in which the filter weights are only adapted based on the error at the current time. According to this LMS algorithm the updated weight is given by

$W(n+1)=W(n)+2.\mu.x(n).e(n)$ where μ is step size.

RLS algorithm

RLS algorithm iteration expressions are following:

$\pi(n)=P(n-1)x(n)$

$k(n)= \pi(n)/(\lambda+x^T(n)\pi(n))$

$e(n)=d(n)-w^T(n-1)x(n)$

$w(n)=w(n-1)+k(n)e(n)$

$P(n)=\lambda-1P(n-1)-\lambda-1k(n)xT(n)P(n-1)$

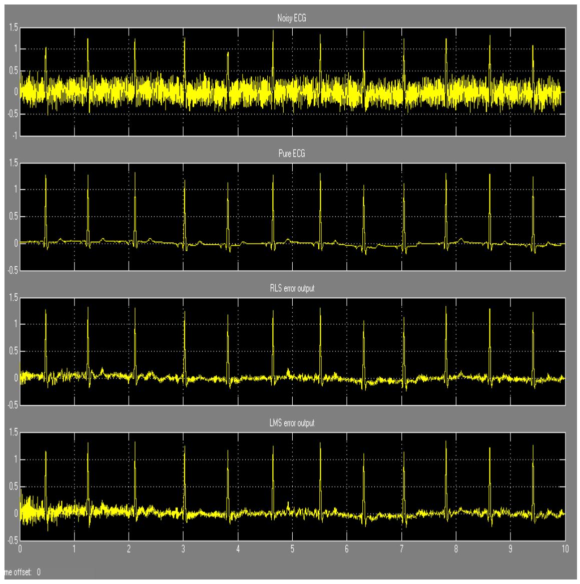

Figure 5:The noisy ECG signal processed by Adaptive filters based on the least mean square (LMS) algorithm and recursive least squares (RLS) algorithm.

Result:

For performance measures SNR and root mean square error MSE are considered.

Algorithm	MSE	SNR of input ECG	SNR of output ECG
LMS	0.00013	5.0332 dB	17.8163 dB
RLS	0.00062	5.0332 dB	23.206 dB

CONCLUSION:

The obtained results indicate that LMS and RLS algorithm based adaptive filters have estimated the respective signals from the noisy environment accurately, but LMS algorithm convergence rate is slow as it is evident from mean square error value which is 0.00013 for LMS and 0.00062 for RLS. The signal to noise ratio for LMS is 17.8163 dB and for RLS is 23.206 dB, LMS filter output is not satisfactory as compared to RLS as shown in Figure 5.Rresidual noise still present can be removed by wavlet filter.

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