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Research Paper

DENOISING OF THE ECG SIGNAL USING NLMS ADAPTIVE FILTERING ALGORITHM

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ABSTRACT
Various Adaptive filtering methods are using to filter Cardiac signals. The two basic adaptive filtering algorithms are LMS (Least Mean Square) and RLS (Recursive Least Square). These Adaptive Algorithms are used to filter artifacts from ECG signal. Adaptive filter minimises the mean square error between the primary input, which is ECG with noise and desired response, which is either ECG or noise correlated with primary input. Various filter structures are presented to reduce diverse forms of noise. In this paper NLMS (Normalized Least Mean Square) method has been used to remove noise from the ECG (Electrocardiograph) signal. NLMS is the variant of the LMS algorithm. This algorithm is applied to the real ECG signal, which is collected by the MIT BIH database. The results show that by applying modification to the NLMS filter the output signal has improved signal to noise ratio and least mean square error.

1. INTRODUCTION

WHAT IS ECG?

Electrocardiogram (ECG) is an important biomedical tool for the diagnosis of heart disorders. ECG is a diagnosis tool that reported to the electrical activity of heart recorded by skin electrode. The morphology and the heart rate reflects the cardiac health of human heart beat. It is a non invasive technique that means this signal is measured on the surface of the human body, which is used in identification of heart diseases. Any disorder of heart beat or rhythm, or change in the morphological pattern, is an indication of cardiac arrhythm, which could be detected by analysis of recorded ECG waveform. The ECG signal provides following information of the human heart,

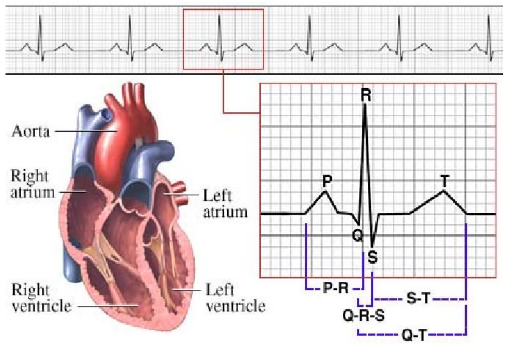
- Heart position and its relative chamber size
- Impulse origin and propagation
- Heart rhythm and conduction disturbances
- Drug effects on heart
- Extent and location of myocardial ischemia
- Changes in electrolyte concentrations

This signal represents an extremely important measure for doctors, as it provides vital information about a patient's cardiac condition and general health. Generally the frequency band of the ECG signal is 0.05 Hz to 100 Hz

HEART ANATOMY

Heart contains four chambers that is right atrium, left atrium, right ventricle, left ventricle and several atrio ventricular and sino atrial node are present. The two upper chambers are called the left and right atria, while the lower two chambers are called the left and right ventricles. The atria are attached to the ventricles by fibrous, non-conductive tissue that keeps the ventricles electrically isolated from the atria. The right atrium and the right ventricle together form a pump to the circulate blood to the lungs. Oxygen-poor blood is received through large veins called the superior and inferior vena cava and flows into the right atrium. The right atrium contracts and forces blood into the right ventricle, stretching the ventricle and maximizing its pumping (contraction) efficiency. The right ventricle then pumps the blood to the lungs where the blood is oxygenated. Similarly, the left atrium and the left ventricle together form a pump to circulate oxygen-enriched blood received from the lungs (via the pulmonary veins) to the rest of the body. Inside the heart there is a specialized electrical conducting system that ensures the heart to expand and contract (as a pump), this action is produced by a sinoatrial node (SA) located below right atrium in the heart. SA node is called pacemaker because it has the ability to initiate electrical pulses at a faster rate of 100p/m.

Four waves are detected while measuring ECG signal P, Q, R and S. an impulse sent from a SA node starts the heart to beat and then the electrical current will flow down to the lower chambers of the heart and produce P wave. Then the electrical current will flow down to the lower chambers of the heart producing Q, R, S wave. As electrical current spreads back over the ventricle in the opposite direction it will produce T waves.



The signal generation is explained below:

P wave: signal spread from SA node to make the atria contract.

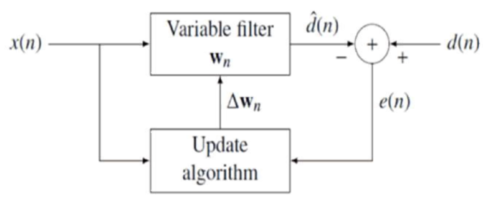
P-Q Segment: signal arrives AV node stay for a instant to allow the ventricle to be filled with blood.

Q wave: After the Buddle of His the signal is divided into two branches and run through the septum.

R,S wave: Left and right ventricle contraction are marked by the R,S wave.

T wave: ventricle relaxing.

WHAT IS ADAPTIVE FILTER?



The figure above is general adaptive filtering diagram. The idea behind the block diagram is that a variable filter extracts 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) =[Wn(0), Wn (1), ... Wn (N-1)]T

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

$y(n)=W(n)Tx(n)$

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

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

the 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 and estimate of the desired filter. 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.

2. LITERATURE REVIEW

Ansari et al. (2013) implemented adaptive filters for the cancellation of motion artefact noise and power line interference in ECG. A ECG signal(without noise) was mixed with a constant 0.1m vpp 50 Hz interference and motion artefact noise processed with Adaptive filter based on LMS algorithm and RLS algorithm. Performance of filters are analyzed based on SNR and MSE. Results show that convergence rate is slow and SNR of adaptive filter based on LMS algorithm is lower. Adaptive filter based on RLS algorithm gives best performance based on SNR and MSE.[4]

Mandavi et.al (2013) proposed Adaptive filtering and Compression of Biomedical signals using Neural networks. This paper presents an adaptive filtering technique for removing noise from ECG signal using the Recursive Least Square (RLC) method. Twelve significant features are extracted from an ECG dataset. Due to superior convergence properties, Recursive Least Square method is used in adaptive filtering.[14]

Bai et.al (2013) researched for a hierarchical method for removal of baseline drift from biomedical signals which is used as an application in ECG analysis. This method uses high-pass filter and adaptive notch filter also for removal of baseline wander.[13]

Ahmad et.al (2013) described the comparison between Adaptive Filter Algorithms (LMS, NLMS and RLS). Implementation aspects of these algorithms their computational complexity and signal to noise ratio are examined. The algorithms use small input and output delay. The performance criteria used are: the minimum mean square error, the algorithm execution time and the required filter order. The conclusion is that RLS algorithm exhibits high initial convergence speed and less steady state error compared to both LMS and NLMS algorithm.[1]

Singh et.al (2013) defined a Patch Based Method and adaptive filtering algorithms for Denoising of ECG signal. Conventional filters remove the artifacts up to some extent but these filters are static filters. The denoised ECG signal is recovered using LMS adaptive algorithm. The LMS algorithm is simple, easy and robust to implement. LMS algorithm has slow convergence.[6] **Zope et.al** (2012) proposed filtering techniques for reduction of Power Line Interference in ECG signals. The various filters used are Adaptive Volterra Filter, Nyquist filter, FIR filter and IIR Notch filtering. Results show that IIR filter practically fails to eliminate the line interference at frequencies other than 50 Hz, where as adaptive IIR notch filter gives a nearly noise free output.[8]

3. CONCLUSION FROM LITERATURE REVIEW

LMS is a stochastic gradient descent method in that the filter is only adapted based on the error at the current time. It minimizes the cost function of the coefficients. The drawback of the LMS algorithm is that it is sensitive to the scaling of its input which makes it very hard to choose μ (step size parameter) that gurantees the stability of the algorithm. NLMS algorithm is a variant of the LMS algorithm that overcomes the disadvantage of the LMS by normalising the power of the input.

The additional merit of the NLMS is that the step size can be chosen independent of input signal power and number of tap weights which gives NLMS better convergence rate and steady error rate as compared to LMS algorithm. But with this faster convergence rate NLMS comes with the cost of greater residual error and has slow convergence for colored input signals.

4. PROBLEM IDENTIFICATION

The different kinds of interference waveforms (artifacts) added to the ECG signal during the recording, common Artifacts sources are:

- EMG related to coughing, breathing, or squirming affecting the ECG
- Breath, lung, or bowel sounds contaminating the heart sounds (PCG).
- Muscle sound (VMG) interference in joint sounds (VAG).
- Maternal ECG getting added to the fetal ECG of interest.
- Electrical interference external to the subject and recording system
- High-frequency noise in the ECG
- Motion artifact in the ECG
- Noise due to variation of electrode skin contact impedance
- Power-line Interference in ECG signals
- Noise generated by electronic devices used in signal processing circuits

5. PROPOSED METHODOLOGY

- Collection of the data base
- Selection & Implementation of the filter
- Filtering of noisy ECG signal
- Calculation of the parameters of interest.
- Comparison with existing techniques
- Reporting the result

i. Collection of the database

ECG signal is collected from MIT BIH arrhythmia database ECG recording or from physionet ECG database with sampling frequency is given as reference. Both stationary and non stationary noise is considered. The noise is generated by the frequency coming from power supply is generated in MATLAB. Then to validate the denoising process the generated noise is added to generate ECG signal.

ii. Selection of the filter

The ECG is a relatively strong signal with a readily identifiable waveform. Most types of interference that affect ECG signals may be removed by band pass filters; but Band pass filter is not able to give best result, our need changes according to, type of noises in ECG signal, in some signals the noise level very high and it is not possible to recognize it by single recording, it is important to gain a good understanding of the noise processes involved before one attempt to filter or preprocess a signal.

There are various algorithms used by the adaptive filtering. The most widely used of them are Least Mean Square (LMS) algorithm , Normalized Least Mean Square (NLMS) algorithm and Recursive Least Square (RLS) algorithm. The performance of these adaptive filtering algorithms is dependent on their filter length(n) and the convergence parameter(μ) commonly known as step size.

iii. Implementation of filter

The main drawback of the pure LMS algorithm is that it is sensitive to the scaling of its input $x(n)$. This makes it very hard to choose a learning rate μ that guarantees stability of the algorithm . The Normalized least mean squares filter (NLMS) is a variant of the LMS algorithm that solves this problem by normalising with the power of the input.

The NLMS algorithm can be summarised as:

Parameters: p = filter length

μ = step size

Initialization: = 0 n w

Computation: For n = 0,1,2.......

$$x(n) = [x(n), x(n-1), \ldots, x(n-p+1)]T$$

$$\overline{W}_{n+1} = \overline{W}_{n} + \frac{\mu e(n)\overline{x}(n)}{\overline{x}^{T}(n)\overline{x}(n)}$$

The only difference with respect to the LMS algorithm here is in the coefficient updating equation , which has been normalized by the conjugate transpose $xT(n)x(n)$ of the input vector $x(n)$ .NLMS differ from LMS in its weight updating rule. In NLMS step size parameter is not constant; selecting the normalized step size parameter. The step size parameter μ changes to μ(n).

The weight updating equation for NLMS is

w(n+1)=w(n)+μ(n)x(n)e(n)

Advantage of the NLMS algorithm is that step size can be chosen independent of the input signal power and number of tap weights. Hence the NLMS algorithm has a convergence rate and a steady state error rate better than LMS algorithm.

The major disadvantage of the adaptive filter based on NLMS and LMS algorithm is excess mean square error. This causes signal distortion in filter output. For NLMS larger filter length yields better results for high step sizes, but worst result for small step sizes.

6. EXPECTED OUTCOME

In order to cope with both the complexity and convergence issues without any restrictive tradeoff Modified NLMS algorithm is proposed for removal of noise from ECG signal. By this updating the weight relation and the filter coefficients depending upon the multiple input vectors, more effective result is obtained. This provides a decrease in Mean Square Error (MSE) and hence reducing the signal distortion.

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