REMOVAL OF ECG SIGNALS ARTIFACTS USING MULTISTAGE ADAPTIVE FILTERING TECHNIQUE

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Abstract

This paper is about the technique used for removal of ECG Signals Artifacts Using Multistage Adaptive Filtering. Electrocardiogram (ECG) is the diagnostic tool to monitor rhythm of heart activity. It is of low amplitude and contains numerous noises which include power line interference, baseline drift, movement artifacts and electrosurgical noise. For better diagnostic and treatment of cardiac patient the removal of such noise are very much important. Initially various method were proposed to remove the artifacts for better understanding of cardiac problem. These were static or fixed filters i.e. Band pass Low pass or High pass which based on the nature of the noise. The static filters possess fixed filter coefficients which makes it strenuous to eliminate time varying noise from the signals. To overcome this shortcoming of the fixed filters, various adaptive filtering procedures have been introduced. Since the ECG signal suffers from several artifacts at a time, which makes a single stage adaptive filter unsuitable for multiple noise signals removal. This paper presents a Multistage Modified Normalized Least Mean Square (MNLMS) algorithm for the eradication of multiple artifacts from signals of ECG. The results of the suggested algorithm are compared with existing adaptive algorithms including Multistage LMS, MNLS, CNN, DNN including Signal to Noise ratio (SNR), convergence rate as well as the computational time, which elaborate the effectiveness
of the suggested algorithm. After the removal of noise, db'6 wavelets are used for the
detection of features (PQRST) of ECG wave because wavelet tree offers a very good
time-frequency resolution analysis which is not possible with the Fourier transform.

Keywords: ECG, Noise Removal, Adaptive filtering algorithms, Feature
Extraction, Neural Networks

I. Introduction

Examination of the electrical activity of the heart is basically known as
Electrocardiogram abbreviated (ECG). The output is normally appeared on a paper
that presents a graph on a display screen of the laptop or computer. The amplitude of
ECG is normally put between 0.5mv to 2mv and the bandwidth of ECG is from 0.1
Hz to 120 Hz [I]. During acquisition and transmission of the ECG wave, it is often
corrupted with noises. The major causes of these artifacts are biological and technical.
The biological artifacts are caused by the random body movements or respiration
Known as motion artifacts whereas the technical artifacts are caused by device of
noise and power line interference. For automatic ECG analysis these artifacts leads to
wrong clinical diagnosis. Many filtering algorithms have been found in the literature
to overcome this issue

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Mostly during transmission, the ECG Signal mostly corrupted with certain
interruption and noises. The foremost reasons of those artifacts are organic and
complex. They are produced resulting from random movements known as movement
artifacts. While on other hands complex and technical artifacts are due to poor
instrument. There are different filtering algorithms have observed within the literature
to triumph over this issue [II].

The major types of artifacts caused are power line interference (PLI) and the artifacts
cased by the movement of the body known as EMG (Electromyography), baseline
wander and system noise. In this paper, some of the adaptive filters are used. The
ability of the suggested methodology is exhibited by exploring ECG signals are taken
from the renown MIT-BIH. It is platform used for most research activities in this era.
This uncovers the adequacy of the proposed strategy as a successful structure for
accomplishing high-goals ECG from uproarious ECG recordings [III].

Exact understanding and investigation of the ECG signal can be accomplished by
disposing of the clamor. [IV]. To overcome this short coming of the fixed channels,
multiple adaptive algorithm like Kalman Filtering, LMS Adaptive Filtering, and
Modified LMS channel. Neural Networks like convolution and de convolution are
also used and wavelets are likewise utilized for removing the morphological
highlights from the ECG sign and programmed identification of specific ailments.

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In this exploration a few versatile channels like Multistage LMS, Multi and Multistage MNLMS along neural networks have been executed. Mean square Error, convergence rate and computation time determined

II. Methodology:

All the Adaptive algorithms implemented for ECG de-noising. After de-noising the extraction of features of ECG signals using the wavelet transform and calculation of heartbeat by measuring the distance between two consecutive R-R peaks of the signals.

![Fig 1. Proposed Block Diagram/ Methodology](image)

Multistage Adaptive Filtering

Fixed filter deals with the stationary atmosphere or linear time invariant systems. In time variant environment adaptive algorithm along neural networks are utilized. Adaptive filter used due to less complexes, easy in design and implementation, Reliability Efficiency and robustness. It’s all have impact in filter design [V].

Least Mean Square (LMS) Algorithm

The adaptive filter implemented in the paper are mostly based on LMS algorithms because of its simplicity and less complexity. It can be implemented with finite precision arithmetic. It is a search based algorithm. It continuously estimates results by updating filter coefficients. It provides learning curves which is useful in machine learning in [VIII].

Deep Neural Network Based Filtering

In recent years developments in machine learning introduced deep neural networks. We have used for ECG filtering. ECG filtering is achieved through regression model. Deep neural network model consist of an encoder decoder combination. This is the most famous model usually used to remove noise from data. It consists of a sequential model with 12 dense connected layers. Encoder starts with first layer containing 1024 units and then 512, 256, 128, 64 to 32 units. Decoder again translates from 32 to 64 and same way back to 1024 units. Each layer used “Relu” activation function. Final layer contain one unit and sigmoid activation function. This model is compiled using “Adam” optimizer and mean square error as loss function.

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The block diagram of the model is shown below.

![Block Diagram of Encoder Decoder Model for ECG Filtering](image)

**Convolutions Neural Network (CNN) for ECG Filtering**

We have also compared our proposed algorithm with convolution neural network (CNN). This is one of the most powerful machine learning models for data regression. Our model consists of 8 layers. First layer is a 2-dimensional convolution layer of size $28 \times 28 \times 32$ followed by a 2-dimensional maximum pooling layer of size $14 \times 14 \times 32$. This layer is again followed by a 2D-convolution layer of...
size $14 \times 14 \times 32$ and is followed by a 2D-Max pooling layer of size $7 \times 7 \times 32$. This layer is followed by a 2D-convolution layer of size $7 \times 7 \times 32$. Up to this point this is an encoder model and is followed by a decode model. A layer of 2D-up sampling is used with size $14 \times 14 \times 32$ followed by 2D convolution layer of size $14 \times 14 \times 32$. This layer is again followed by a up sampling and convolution layers of size $28 \times 28 \times 32$ and $28 \times 28 \times 1$. The model is shown in following figure.

![Diagram of CNN Based Auto Encoder Model for ECG Filtering](Fig 3)

**Normalized Least Mean Square (NLMS) Algorithm**

In Simple LMS algorithm the problem was how to select the step size as the convergence and performance was based on this parameter. Usually a small step size is applied in LMS algorithm to achieve optimal coefficient compromising on the convergence filter. [IX]To overcome the deficiency of LMS filter in terms of convergence, NLMS filter is implemented. In the NLMS algorithm the step size is based upon on normalizes the power of input .Hence stability of the filter is maintained.
III. Results

Fig 4. Filtered Multistage LMS

Fig 5. Filtered Signal & MSE Plot Using LMS
Fig 6. Filtered Multistage NLMS

Fig 7: Filtered Signal & MSE Plot Using NLMS
Fig 8: Filtered DNN

Fig 9: Filtered Signal & MSE Plot Using DNN
Fig 10: Filtered CNN

Fig 11: Filtered Signal & MSE Plot Using CNN
Fig 12: Filtered MNLS

Fig 13: Filtered Signal & MSE Plot Using MNLMS
IV. Analysis of Algorithms

Based on above tables and graphs it concluded that MNLMS performs best as comparatively because MNLMS has greater Signal to noise ratio (SNR) and the convergence rate of MNLMS algorithm is the fastest and signal converges at approximately 600 samples.
The performance of LMS algorithm is also good but it converges very slowly on the other hand it is simple and less complex than MNLMS. NLMS achieves faster adaptation but its performance is not good. We already applied the neural network but at that extent we did not got fruitful results as we were expecting In this study, Linear and nonlinear step size selected on hit and trial basis techniques like Neural Networks, Genetic Algorithms for the best selection of Step size. Here below is the comparative table of all the applied algorithms based on the convergence rate, computational time and the signal to noise ratio.

Table 1: Comparison of Selected Algorithms

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>LMS</th>
<th>NLMS</th>
<th>CNN</th>
<th>DNN</th>
<th>MNLMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNR</td>
<td>27.51</td>
<td>26.32</td>
<td>21.08</td>
<td>24.12</td>
<td>36.21</td>
</tr>
<tr>
<td>Convergence Rate</td>
<td>2600</td>
<td>1100</td>
<td>50</td>
<td>25</td>
<td>600</td>
</tr>
<tr>
<td>Computational Time</td>
<td>0.433052</td>
<td>0.561209</td>
<td>0.4325</td>
<td>0.6723</td>
<td>1.148173</td>
</tr>
</tbody>
</table>

Calculation of Heart Rate

The Heart rate can be calculated by evaluating the time interval of two consecutive R-R peaks by using the following formula.
Heart Rate = 1/(R-R Interval) * 60

Table 2: Calculation of Heart Rate

<table>
<thead>
<tr>
<th>Algorithms</th>
<th>R-R Interval</th>
<th>Heart Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMS</td>
<td>0.7868</td>
<td>76.06</td>
</tr>
<tr>
<td>NLMS</td>
<td>0.8246</td>
<td>73.65</td>
</tr>
<tr>
<td>CNN</td>
<td>0.7586</td>
<td>79.09</td>
</tr>
<tr>
<td>DNN</td>
<td>0.7686</td>
<td>78.06</td>
</tr>
<tr>
<td>MNLMS</td>
<td>0.7479</td>
<td>80.11</td>
</tr>
</tbody>
</table>

V. Conclusion

Execution measurements are SNR, Convergence rate and computational time. From the diagrams and tables, it very well may be seen that the presentation of MNLMS calculation was best among all. LMS calculation additionally gives great execution yet the assembly pace of LMS is extremely moderate. The benefit of
utilizing LMS calculation is that it is straightforward and less intricate. NLMS accomplishes quicker adjustment yet its presentation isn't great.

VI. Acknowledgement

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