Suppression of Noise in ECG Signal Using Low pass IIR Filters

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Abstract: In Diagnosing of ECG Signal, Signal acquisition must be noise free. Experienced physicians are able to make an informed medical diagnosis on heart condition by observing the ECG signal. This paper deals the application of the digital IIR filter on the raw ECG signal. In this paper Butterworth, Chebyshev Type-I and Chebyshev Type-II filter are utilized. At the end all these filter types are compared. In this paper using 222txt ECG data set from MIT-BIH arrhythmia database.

KEYWORDS- 222txt MLII ECG Data Signal, IIR Filter, Signal to Noise Ratio (SNR), Average Power, Welch Power Spectral Density.

1. INTRODUCTION

The electrocardiogram is a diagnostic tool that is routinely used to assess the electrical and muscular functions of the heart. It is also a non-invasive test that records the electrical activity of the heart over time and it is very useful in the investigation of heart disease, for example a cardiac arrhythmia. The ECG signal is a trace of an electrical activity signal generated by rhythmic contractions of the heart and it can be measured by electrodes placed on the body’s surface. An electrode lead, or patch, is placed on each arm and leg and six are placed across the chest wall. The signals received from each electrode are recorded. Fig. 1 depicts, each ECG signal of normal heart beat consists of six continuous electromagnetic peaks namely PQRS and U. The P wave reflects the activation of the right and left atria. The QRS complex shows depolarization of the right and left ventricles. The T wave, that is after QRS complex reflects ventricular activation [6]. The repolarization of atria is not recorded on the reading of ECG. The electrocardiogram can measure the rate and rhythm of the heartbeat, as well as provide indirect evidence of blood flow to the heart muscle. The ECG signal corrupted due to different types of artifacts and interferences such as Power line interference, Electrode contact noise, Muscle contraction, Base line drift, Instrumentation noise generated by electronic and mechanical devices, Electrosurgical noise. For the meaningful and accurate detection, steps have to be taken to filter out or discard all these noise sources. The work on design and implementation of Digital filter on the ECG signal is in progress in the different part of the world. The investigation addressed the analysis of the effects of AC interference and its filtering on the precision and accuracy of heart rate detection. Removal of noises from ECG signal is a classical problem and many researchers work on signal noise removing by different filtering method and algorithms. Baseline wanders and power line interference reduction is the first step in all electrocardiography signal processing. Mahesh Chavan, R.A. Agrawal, paper deals with design and development of digital FIR equiripple filter [4], baseline wander and PLI by digital IIR filter[5]. Ferdjallah M., Barr R.E. has given Frequency-domain digital filtering techniques for the removal of power line noise [7]. The equiripple FIR low-pass filter by superimposing of the optimal method, the Butterworth IIR low-pass filter, the 8-point moving-average filter, and the FIR filter designed by using a Kaiser window [8]. Choy TT, Leung P M. have used 50 Hz notch filters for the real time application on the ECG signal.
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[9]. S.Pooranchandra, N.kumarave have used the wavelet coefficient threshold based hyper shrinkage function to remove power line frequency [10]. Santpal Singh Dhillon and Saswat Chakrabarti have used a simplified lattice based adaptive IIR Notch filter to remove power line interference [11]. Hejjel L, used the analog digital notch filter for the reduction of the power line interference in the ECG signal for the heart rate variability analysis. A new least-squares (LS) based algorithm is proposed to estimate the FIR filter coefficients [12]. Mapreet Kour, J.S. Ubhi to present digital filtration of ECG for removal of baseline drift and in results are shown by comparision of average power of signal [13]. Yue-Den Lin, deals with recursive least-squares adaptive notch filter and linear discriminant analysis algorithm [14]. K.D. Chinchkhede, presents paper on the implementation of FIR filter with various window techniques [1], according to this paper design the IIR filter with help of FDA tool in matlab software and analysis to reducing the ECG signal noise by using Butterworth, Chebyshev Type-I, and Chebyshev Type-II IIR Filter. In results are showing to comparatively in average power and signal to noise ratio.

2. DIGITAL IIR FILTER

IIR systems have an impulse response function that is non zero over an infinite length of time. IIR Filter may be implemented as either analog or digital filter. In digital filter, the output feedback is immediately apparent in the equation defining the output.

2.1 Butterworth Filter

The Butterworth filter provides the best Taylor Series approximation to the ideal lowpass filter response at analog frequencies \( \Omega = \infty \) and \( \Omega = 0 \), for any order \( N \), the magnitude squared response has \( 2N-1 \) zero derivatives at these locations. Response is monotonic overall, decreasing smoothly from \( \Omega = \infty \), to \( \Omega = 0 \).

\[
|H(j\Omega)| = \sqrt{\frac{1}{2}} \quad \text{at} \quad \Omega = 1 \quad (i)
\]

2.2 Chebyshev Type I Filter

The Chebyshev Type-I Filter minimizes the absolute difference between the ideal and actual frequency response over passband by incorporating an equal ripple of \( R_P \) dB in the passband. Stopband response is maximally flat. The transition from passband to stopband is more rapid than for the Butterworth filter.

\[
|H(j\Omega)| = 10^{R_P/20} \quad \text{at} \quad \Omega = 1 \quad (ii)
\]

2.3 Chebyshev Type-II Filter

Chebyshev Type-II filter minimizes the absolute difference between the ideal and actual response over the entire stopband by incorporating an equal ripple of \( R_S \) dB in the stopband. Passband response is maximally flat. The stopband does not approach zero as quickly as the type I filter. The absence of ripple in the passband, however, is often an important advantage.

\[
|H(j\Omega)| = 10^{R_S/20} \quad \text{at} \quad \Omega = 1 \quad (iii)
\]

3. METHODOLOGY

ECG Data Signal 222txt (ML II) take from Physionet Bank ATM as a input signal in analysis of removing noise by using IIR Filter Design techniques. The first group is intended to serve as a representative sample of the variety of waveforms and artifact that an arrhythmia detector might encounter in routine clinical use. The band pass-filtered signals were digitized at 360 Hz per signal relative to real time using hardware constructed at the MIT Biomedical Engineering Center and at the BIH Biomedical Engineering Laboratory. The sampling frequency was chosen to facilitate implementations of 60 Hz (mains frequency) digital notch filters in arrhythmia detectors. Since the recorders were battery-powered, most of the 60 Hz noise present in the database arose during playback. Sampling frequency of the data signal is 360 and amplitude ±1 mv. Filter of noisy ECG signal set up in two step, in first step input data signal removing from the baseline drift after then 10 db awgn noise introduce in input data signal. In second step design a filter with the help of FDA tool in mat lab software. FDA tool parameters set up as low pass IIR filter with sampling frequency 360 Hz and minimum order. Frequency of pass band \( (F_P) \) and stop band \( (F_S) \) are
54 Hz and 60 Hz. Attenuator of filter $A_p$ is 1db and $A_S$ is 80 dB set in FDA tool. The original signal of ECG data signal 222txt before and after baseline remove shown in fig. 2.

Figure 2. Original ECG Data Signal and with baseline remove of Data 222txt.

In FDA tool IIR Filter by method of Butterworth, Chebyshev Type-I, and Chebyshev Type-II magnitude and Phase responses shown in respect fig.3, 4, and 5. The signal with noise applies to each method of IIR Filter.
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Figure 4. Magnitude and Phase Response of Chebyshev Type-I Filter

Figure 5. Magnitude and Phase Response of Chebyshev Type-II Filter
Figure 6. Noisy Signal and Filter with various IIR Filter Techniques.

Figure 7. Welch Power Spectrum density Original and Filter ECG Data Signal 222txt (ML II)
Original data signal with AWGN noise and the filter data signal spectrum analysis at 60 Hz frequency shown by the Welch power spectrum diagram in fig. 7. Signal to Noise Ratio after with various methods shown in table1. And table2 show the average power. Signal to noise ratio of the filtered signal calculated by

(iv)
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Where \( \mu \) is mean and \( \sigma \) standard deviation of signal.

Table 1. SNR for various IIR Filter Techniques.

<table>
<thead>
<tr>
<th>Before Filtering</th>
<th>After Filtering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butterworth</td>
<td>Chebyshev Type-I</td>
</tr>
<tr>
<td>-29.2902</td>
<td>-23.8055</td>
</tr>
</tbody>
</table>

Table 2. Average Power for various IIR Filter Techniques.

<table>
<thead>
<tr>
<th>Before Filtering</th>
<th>After Filtering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butterworth</td>
<td>Chebyshev Type-I</td>
</tr>
<tr>
<td>-12.2257</td>
<td>-10.3198</td>
</tr>
</tbody>
</table>

4. CONCLUSION

The results obtained from Butterworth filter, Chebyshev Type-I and Chebyshev Type-II are compared on the basis of signal to noise ratio and average power. It is forward that Butterworth low pass filter removes more noise. Table-1 has shown the signal to noise ratio for before filtering and after filtering using the IIR filters. Table-2 has shown the average power before filtering and after filtering using the IIR filtering.

Reference


