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Improving Performance of basic First Order Difference Operator as a Filter to Remove Base Line Wander Noise in ECG

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ABSTRACT: Noise cancellation requires different strategies for different noise sources or types. An useful method for removing baseline disturbances is the application of a digital linear phase filtering. In this paper both linear and non-linear digital filtering methods are investigated to remove base line wander noise. First order difference operator removes dc component and boost high frequency components in the ECG signal, gain of the filter increases for higher frequencies up to folding frequency fs/2. The noise amplification problem with the first order difference operator is controlled by three point central difference operator, output of the filter is less noisy and the gain of the filter will be zero at f=0 and at f=fs/2.These derivative operator are useful in detecting QRS complex. The first order difference operator and three point central difference operator used as filter removed slow P and T wave and altered QRS complexes. These drawback is overcome by first order IIR filter with a pole at z=0.995 and base line wander noise is completely removed.

KEYWORDS: base line wander noise, First order difference operator, three point central difference operator, IIR filter

I. INTRODUCTION

The function of the human body is based on signals of electrical, chemical or acoustic origin. Such signals provide information which may not be immediately perceived but which is hidden in the structure of the signal. This hidden information has to be decoded in some way before the signals can be given useful interpretations. The decoding of body signals has been found helpful in explaining and identifying several pathological conditions. This decoding process is sometimes easy to perform since only involves a limited manual effort such as visual inspection of the signal printed on a paper or in a computer screen. However, there are signals whose complexity is often considerable and, therefore, biomedical signal processing has become an indispensable tool for extracting clinically significant information hidden in the signal. The process of biomedical signals is an interdisciplinary topic. It is needed some knowledge about the physiology of the human body to avoid the risk of designing an analysis method which may distort or even remove significant medical information. Of course, it is also valuable to have a good knowledge of other topics such as linear algebra, calculus, statistics and circuit design. Some decades ago, when computers first arrived in the area of medicine, automation was the main goal, but this has been modified over the years, since a physician must be ultimately responsible for the diagnostic decisions taken. Nowadays, the goal is develop computers systems which offer advanced aid to the physician in making decision.

One of the main reasons for computer-based ECG analysis is the capability to improve poor signal quality thanks to the use of signal processing algorithms. There are several most common types of noise and artifacts in the ECG. The baseline wander is an extraneous, low-frequency activity in the ECG which may interfere with the signal analysis, making the clinical interpretation inaccurate. When baseline wander takes place, ECG measurements related to the isoelectric line cannot be computed since it is not well-defined. Baseline wander is often exercise-induced and may have its origin in a variety of sources, including perspiration, respiration, body movements and poor electrode contact. The spectral content of the baseline wander is usually in the range between 0,05-1Hz, but, during strenuous exercise, it may contain higher frequencies.

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Baseline drift and ECG amplitude modulation with respiration occurs during the breathing cycle. The amplitude of ECG signal varies mainly influenced by relative distance between heart and electrodes. This distance is increased when lungs fill and reduces at time of lungs become empty. The effect can be observed as a slow modulation of the ECG amplitude with same frequency as the breathing cycle. The amplitude of the ECG signal also varies by about 15% with respiration[1,2,3,4].

Figure 1 summarizes the relative power spectra of the ECG, QRS complexes, P and T waves, motion artifact, and muscle noise. This graph reveals that the ECG signal has their energy mainly concentrated in frequencies below than 25 Hz, where the QRS complex assumes the major area. It also shows that motion artifact overlapping a small part of ECG signal ,and the EMG noise overlaps the entire ECG signal. It is clear that EMG noise can completely destroy ECG signal in presence of low SNR.

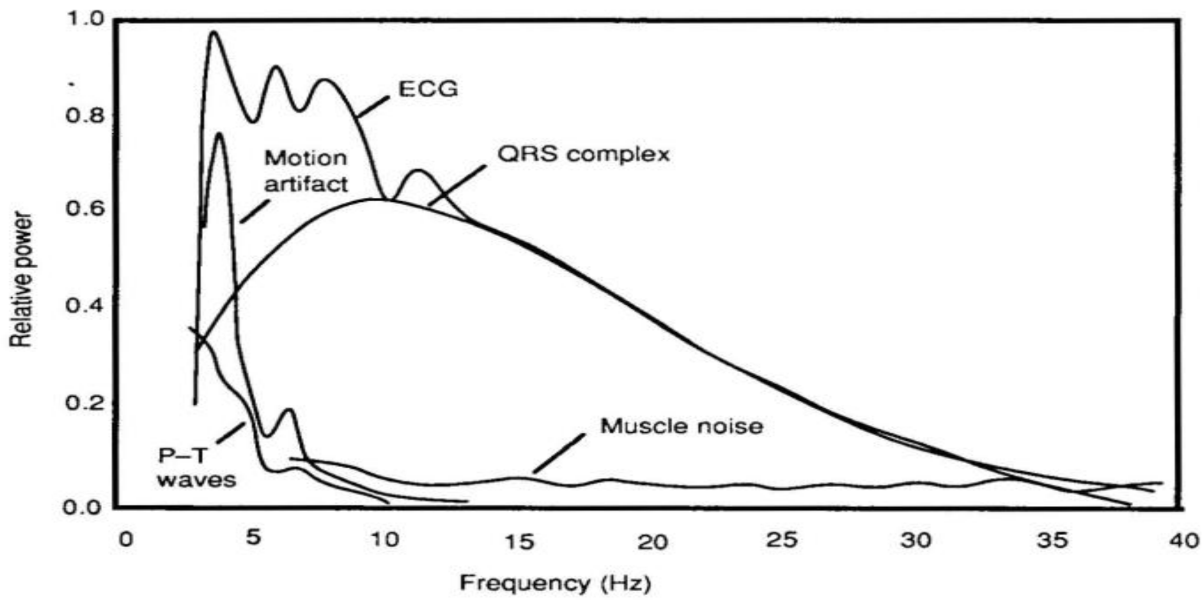

Figure:1 Relative power spectrum of QRS complex, P and T wave, muscle noise and motion artifact based on average of 150 beats[5]

II. METHODOLOGY

Noise cancellation requires different strategies for different noise sources or types. An useful method for removing power line and baseline disturbances is the application of a digital linear phase filtering[6]. This method can be used to reduce signal magnitude spectrum while preserving the signal time domain as much as possible. The disadvantage of this method is the computational requirements. This is mainly caused by linear phase narrow-band filtering, that requires a long impulse response, and the corresponding number of filter coefficients caused by a large number of multiplications involved in the time domain[7].

III. SIGNAL PROCESSING METHODS

The derivative operator in the time domain removes the parts of the input that are constant (the output is zero). Large changes in the input lead to high values in the output of the derivative operator. Improved understanding of the

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derivative operation may be obtained by studying its transform in the frequency domain. The ideal d/dt operator in the time domain results in multiplication of the Fourier transform of the original signal by jw =j2πf in the frequency domain. If X(f) represents the Fourier transform of the signal x(t), then the Fourier transform of is dx/dt is j2πfX(f) or jwX(w). The frequency response of the operation is H(w) = jw. It is seen that the magnitude of the frequency response increases linearly with frequency, starting with H(W) = 0 at w = 0. Thus, the DC component is removed by the derivative operator, and higher frequencies receive linearly increasing gain, the operation represents a high pass filter. The derivative operator may be used to remove DC and suppress low-frequency components (and boost high-frequency components).

3 A. LOW FREQUENCY NOISE SUPPRESSION USING FIRST ORDER DIFFERENCE OPERATOR:

In digital signal processing, the basic derivative is given by first order difference operator[2]:

$y(n)=1/T(x(n)-x(n-1)$ $\quad$ $H(z)=1/T(1-z^{-1})$

The filter has zero at z=1, the DC point $|H(w)|=2/T|\sin(w/2)|$ $\quad H(w)= \pi/2-w/2$

The frequency response of the filter $H(z)=1/T(1-z^{-1})$

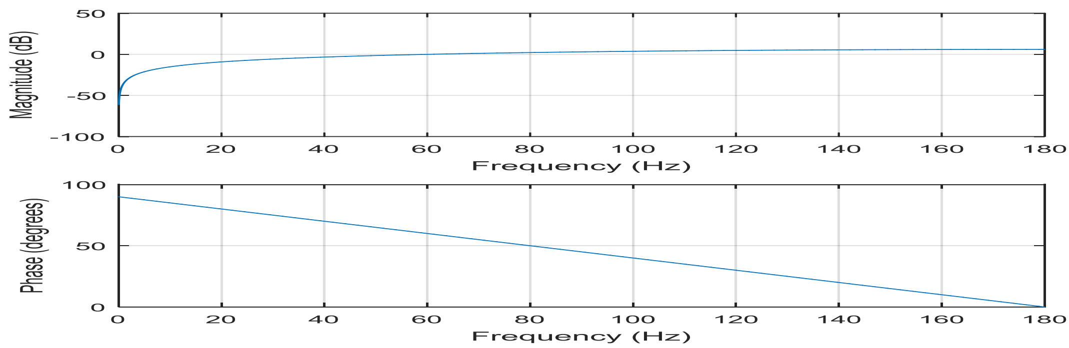

Figure 2 The gain of the filter $H(z)=1/T(1-z^{-1})$ increases for higher frequencies up to the folding frequency fs/2.

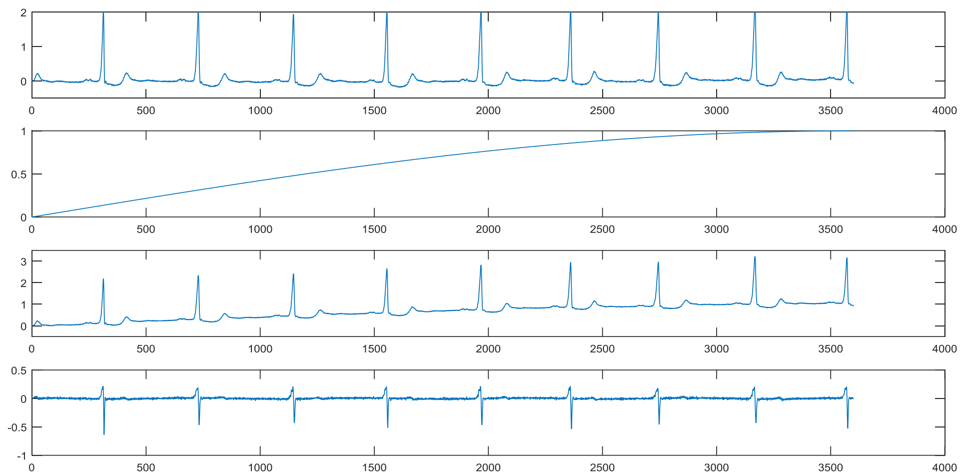

Figure 3: the first plot is a input ECG signal with fs=360 Hz ,

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the second plot is a base line wander noise signal, the third plot is a input ECG signal with base line wander noise and the fourth plot is the result of the filtering the ECG signal with base line wander noise using first order difference operator.

The gain of the filter increases for higher frequencies up to folding frequency fs/2. Any high- frequency noise present in the signal will be amplified significantly.

3 B. LOW FREQUENCY NOISE SUPPRESSION USING THREE POINT CENTRAL DIFFERENCE OPERATOR:

The noise amplification problem with the first order difference operator can be controlled by taking the average of two successive output values:

$Y1(n)=y(n)+ y(n-1)/2$

$Y1(n)=x(n)-x(n-2)/2T$; $H(z)=(1-z^{-2})/2T$ $|H(w)|=|\sin(w)|/T$ $H(w)= \pi/2-w$

The frequency response of the filter ; $H(z)=(1-z^{-2})/2T$

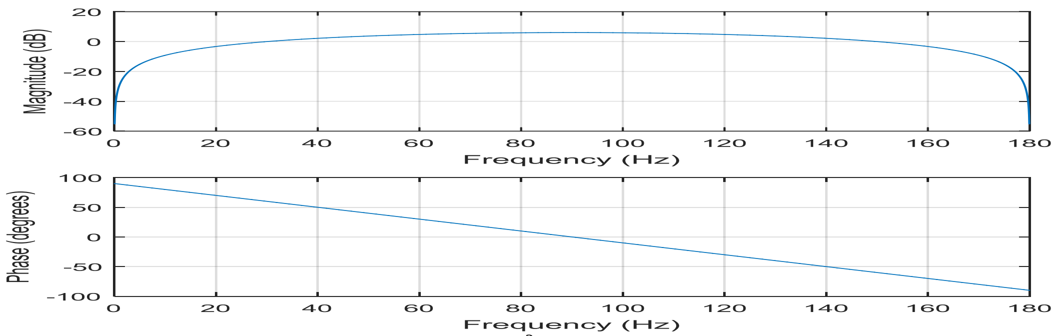

Figure 4 the magnitude and phase response of $H(z)=(1-z^{-2})/2T$ shown above has two zeros at z=1 and z=-1. Therefore the gain of the filter will be zero at f=0 and at f=fs/2.

The response of the filter for ECG signal mixed with base line wander noise is shown in figure 5

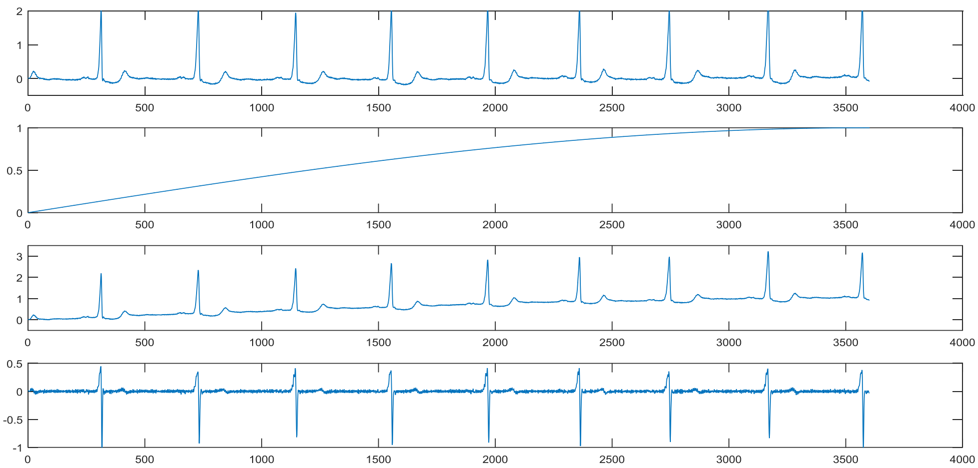

Figure 5: the first plot is a input ECG signal with fs=360 Hz ,

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the second plot is a base line wander noise signal, the third plot is a input ECG signal with base line wander noise and the fourth plot is the result of the filtering the ECG signal with base line wander noise using three point central difference operator.

3 C. LOW FREQUENCY NOISE SUPPRESSION USING FIRST ORDER IIR FILTER WITH POLE AT Z=0.995:

The drawback of first order difference operator and three point central difference operator lies in the fact that their magnitude responses remain low for a significant range of frequencies well beyond the band related to base line wander. In order to maintain the gain of output signal close to unity beyond 0.5 Hz, a pole has to be placed with in unit circle. we place a pole at z=0.995[6,7,8]

Magnitude and phase response of the filter to remove base line wander i.e. $H(z)=(1-z^{-1})/(1-0.995z^{-1})T$

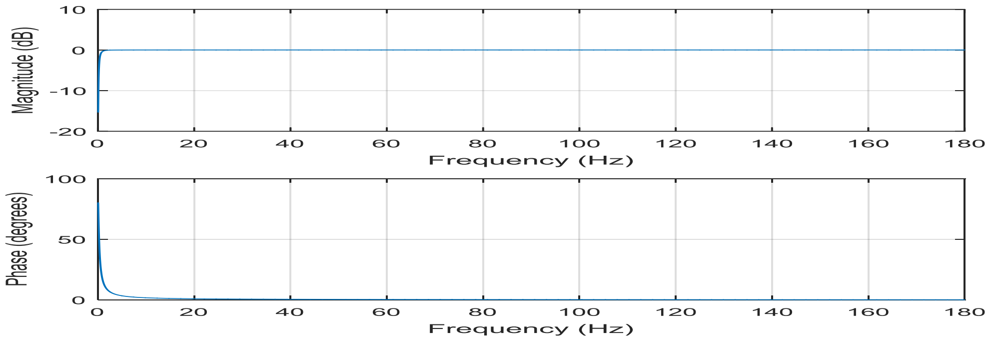

Figure 6 The gain of the filter is close to unity for frequencies greater than about 1 Hz.

The response of the filter for ECG signal mixed with base line wander noise is shown in figure 7

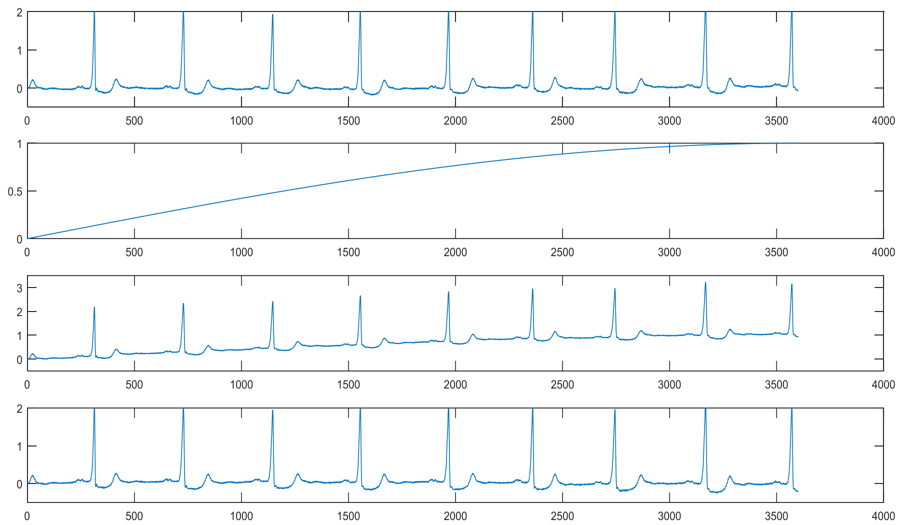

Figure 7: the first plot is a input ECG signal with fs=360 Hz ,

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the second plot is a base line wander noise signal, the third plot is a input ECG signal with base line wander noise and the fourth plot is the result of the filtering the ECG signal with base line wander noise using first order IIR filter with pole at z=0.995.

IV. RESULTS

The result of the filtering the ECG signal with low frequency noise using first order difference operator and three point central difference operator is shown in figure 3 and 5.It is that the base line wander noise has been removed. It is also observed that first order difference operator and three point central difference operator used as filter removed slow P and T wave and altered QRS complexes. We observed that low frequency base line wander noise has been removed without any significant distortion of the ECG waveform using first order IIR filter with pole at z=0.995.

V. CONCLUSIONS

The derivative operator in the time domain removes the parts of the input that are constant (the output is zero). First order difference operator removes dc component and boost high frequency components in the ECG signal, gain of the filter increases for higher frequencies up to folding frequency fs/2. The noise amplification problem with the first order difference operator can be controlled by three point central difference operator, output of the filter is less noisy and the gain of the filter will be zero at f=0 and at f=fs/2.These derivative operator are useful in detecting QRS complex. Base line wander noise is completely removed with first order IIR filter with a pole at z=0.995, as the gain of the filter is close to unity for frequencies greater than about 1 Hz which is not the case with first order difference operator and three point central difference operator.

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