A Comparative Study of window-based FIR Filters and Undecimated Wavelet Transform for ECG De-noising using LabVIEW

J.Palanivel, R.Muthusivagami

Abstract— **Electrocardiography (ECG) is the process of recording the electrical activity of the heart. The analysis of ECG has greater importance in the detection of cardiac diseases. The ECG signal are normally contaminated by various types of noises like power line interference, instrumental noise, external EMF interference, noise due to random body movements and respirational movements. The artifacts and noises need to be eliminated for better clinical evaluation. In this paper, noise reduction is done using window-based Finite impulse response (FIR) filters such as Welch, Hamming, Hanning and Blackman-Harris and Blackman Nutall window and Undecimated Wavelet Transform (UWT). The performance of both the FIR filter method and UWT is evaluated in terms of signal to noise ratio (SNR) by means of LabVIEW (Laboratory Virtual Instrument Engineering Workbench).**

Index Terms— **FIR filter, LabVIEW, SNR, UWT, Virtual Instrument (VI)**

I. INTRODUCTION

The electrocardiogram (ECG or EKG) is a diagnostic tool that measures and records the electrical activity of the heart in exquisite detail. Interpretation of these details allows diagnosis of a wide range of heart conditions. These conditions can vary from minor to life threatening. When an ECG is recorded, it would be contaminated with many kinds of noise. Hence, extraction of pure cardio logical indices from noisy measurements has been one of the major concerns of biomedical signal processing and needs reliable techniques to preserve the diagnostic information of the recorded signal. Electrocardiogram (ECG) signal is some index of the functionality of the heart. For example, a physician can detect arrhythmia by studying abnormalities in the ECG signal. Since very fine features present in an ECG signal may convey important information, it is important to have the signal as clean as possible. The accuracy and content of information extracted from a recording require proper characterization of waveform morphologies, which, in turn, require the preservation of the phase and amplitude important clinical features and high attenuation of noise. ECG signals are usually corrupted with unwanted interference such as muscle noise, Power line interference (PLI), Motion artifacts and Baseline wander. PLI includes the main part of the distortions at 50-60 Hz. Motion artifacts are the transient baseline changes caused by mismatching of impedance between the electrodes and the skin [2]. Baseline wander is the continuous drifting of the ECG Signal from the baseline. It is mainly caused by respiration and increased body movements [3].Several techniques have been proposed to denoise high resolution ECG signals by combining the discrete wavelet transform with the wiener filter [5], to reduce ECG baseline wandering using adaptive kalman filter [6] and discrete wavelet transform [4]. For de-noising purpose, the window based FIR filtering and wavelet Transform are used in this paper by means of LabVIEW.

LabVIEW is one of the powerful tools in recording, denoising, analyzing, and extracting ECG signals easily and conveniently LabVIEW with its signal processing capabilities provides a robust and efficient environment for resolving ECG signal processing problems. LabVIEW also includes execution to see how data passes through the program and single step through the program to make debugging and program development easier [8]. LabVIEW based signal analysis is simple and has good accuracy and less computation time.

Manuscript received March 23, 2016

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II. BRIEF DESCRIPTION OF DE-NOISING TECHNIQUES

The filtering techniques are primarily used for preprocessing of the signal and have been implemented in a wide variety of systems for ECG analysis. At the same time, the filtering method depends on the type of noises in ECG signal. In some signals the noise level is 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. The ECG signal is very sensitive in nature, and even if small noise mixed with original signal the characteristics of the signal changes. Data corrupted with noise must be either filtered or discarded, and thus filtering is an important issue.

A. FIR Filters

FIR filters are digital filters with finite impulse response. FIR filters can be designed using different methods, but most of them are based on ideal filter approximation. The objective is not to achieve ideal characteristics, as it is impossible anyway, but to achieve sufficiently good characteristics of a filter. The transfer function of FIR filter approaches the ideal as the filter order increases, thus increasing the complexity and amount of time needed for processing input samples of a signal being filtered. [10].

There are essentially three well-known methods for FIR

filter design namely:
1. The window method
2. The frequency sampling technique
3. Optimal filter design methods

In this paper, window method is implemented for ECG denosing. In window method, from the desired frequency response specification $H_d(w)$, corresponding unit sample respone $h_d(n)$ is determined using the relation,

$$h_d(n) = \frac{1}{2\pi}\int_{-\pi}^{\pi} H_d(w)e^{jwn}dw$$

Welch window

The Welch window consists of a single parabolic section. The window function is given by,

$$w(n) = 1 - \left[\frac{n - \frac{N-1}{2}}{\frac{N-1}{2}}\right]^2$$

for v=0 to N-1, where N is the length of the window. The defining quadratic polynomial reaches a value of zero at the samples just outside the span of the window.

Hamming Window

Generally Hamming windows are of the form:

$$w(n) = \alpha - \beta\cos\left(\frac{2\pi n}{N}\right), \frac{-(N-1)}{2} \le n \le \frac{(N-1)}{2}$$

where $\alpha = 0.54$ and $\beta = 1 - \alpha = 0.46$

Hanning Window

The Hanning window otherwise called raised cosine window is defined by,

$$w(n) = 0.5\left[1 - \cos\left(\frac{2\pi n}{N-1}\right)\right], 0 \le n \le N-1$$

The ends of the cosine just touch zero, so the side-lobes roll off at about 18 dB per octave.

Blackman-Harris window

The Blackman-Harris window is a modified version of the Exact Blackman window. The following equation defines the Blackman-Harris window.

$w(n)=0.422323 - 0.49755\cos(\omega)+0.07922\cos(2\omega)$

for $n = 0, 1, 2, \ldots, N - 1$,where N is the length of the window and ω=(2*pi*n)/N

Blackman Nuttall window

The Blackman Nuttall window is a modified version of the Exact Blackman window. The following equation defines the Blackman-Nuttall window.

$w(n)=0.3635819-0.4891775\cos(\omega)+0.1365995\cos(2\omega)$

for $n = 0, 1, 2, \ldots, N - 1$,where N is the length of the window and ω=(2*pi*n)/N

B. *Wavelet Transform*

The wavelet transform is similar to the Fourier transform with a completely different merit function. The main difference is, Fourier transform decomposes the signal into sines and cosines, i.e. the functions localized in Fourier space; in contrary the wavelet transform uses functions that are localized in both the real and Fourier space.

The discrete wavelet transform (DWT) is an implementation of the wavelet transform using a discrete set of the wavelet scales and translations obeying some defined rules. In other words, this transform decomposes the signal into mutually orthogonal set of wavelets, which is the main difference from the continuous wavelet transform (CWT). Discrete wavelet transform which is based on sub-band coding perform fast computation of wavelet transform. It is easy to implement and reduces the computation time and resources required. Unlike the discrete wavelet transform (DWT), which down-samples the approximation coefficients and detail coefficients at each decomposition level, the undecimated wavelet transform (UWT) does not incorporate the down-sampling operations. Thus, the approximation coefficients and detail coefficients at each level are the same length as the original signal. The UWT upsamples the coefficients of the lowpass and highpass filters at each level. The upsampling operation is equivalent to dilating wavelets. The resolution of the UWT coefficients decreases with increasing levels of decomposition.

III. Methodology

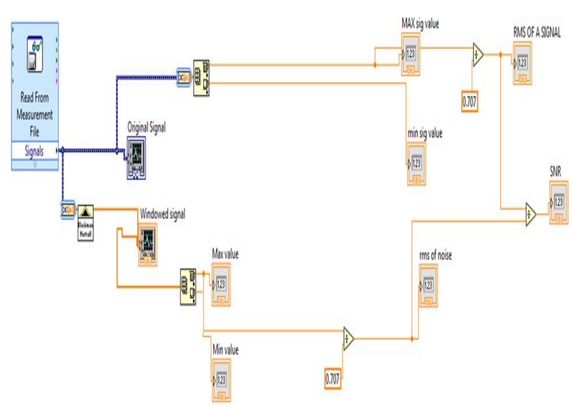
A. *ECG Signal Acquisition and Processing*

ECG signal is generated and analyzed on personal computer using software NI LabVIEW. Data is imported from online data bank files Physio-bank MIT-BIH database. The LabVIEW file conversion utility imports many common biomedical data logger formats into NI Technical Data Management Streaming (TDMS) format. The input signal of TDMS format is read from Read from Measurement file Virtual Insturment (VI).

B. *De-nosing of ECG signal using widow- based FIR Filters*

In this paper, the implementation of FIR filter with various window techniques is done using LabVIEW signal processing window tool and the results are analyzed.

Fig 3.3 Denosing of ECG Signal using Blackmann-Nutall window



A. *De-noising of ECG signal using Wavelet Transform.*

Wavelet packet WA Detrend VI is used to remove the baseline wandering by eliminating the trend of the ECG signal. The LabVIEW provides the WA Detrend virtual instrument which removes the low frequency trend of the signal

$$Trend = \frac{\log_2 2t}{\log_2 n}$$

where t is the sampling duration and N is the number of sampling points. The WA detrend virtual instrument has an option to specify the wavelet type used for the discrete wavelet analysis. The one selected here is db02 wavelet.

After the removal of base-line wandering, the resulting ECG signal is more stationary and explicit than the original signal. However, some other types of noise might still affect feature extraction of the ECG signal. The noise may be complex stochastic processes within a wideband..

Wavelet De-noise Express VI provides the noise reduction of 1D and 2D signals using Discrete Wavelet Transform (DWT) and Undecimated Wavelet Transform (UWT). In this paper, to remove the wideband noise, Undecimated wavelet Transform is used and the filtered signals are obtained. The filtered signal is obtained with db02 wavelet with level 5 decomposition.

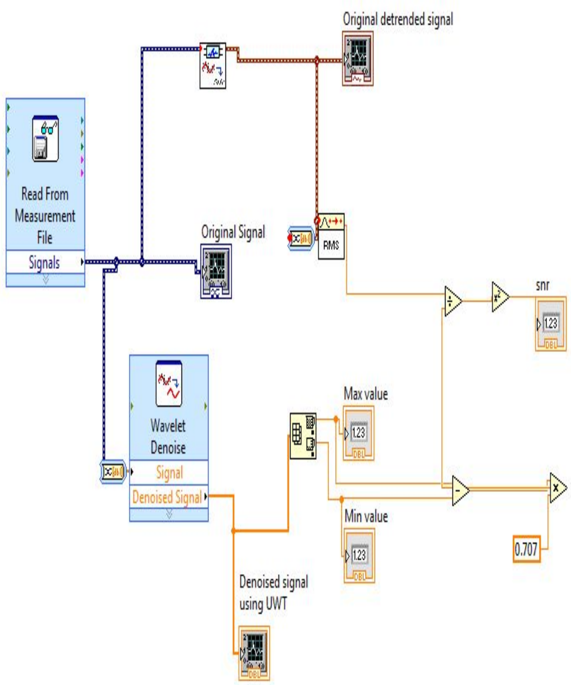


Fig 3.4 Denoising of ECG signal using UWT

IV. ANALYSIS AND PERFORMANCE MEASURE

The first step is to generate the ECG signal from Read from measurement file VI. The signal is filtered by various digital FIR filters and Wavelet transform and its performance is evaluated. In this paper, the comparative study is made by FIR filtering technique and Undecimated wavelet Transform technique and the performance is evaluated in terms of Signal-to-noise ratio (SNR).

$$SNR(dB) = 10\log_{10}\frac{P_{Signal}}{P_{noise}} = 10\log_{10}\left(\frac{A_{Signal}}{A_{noise}}\right)^2$$

V. RESULTS AND DISCUSSION

A. Original ECG signal

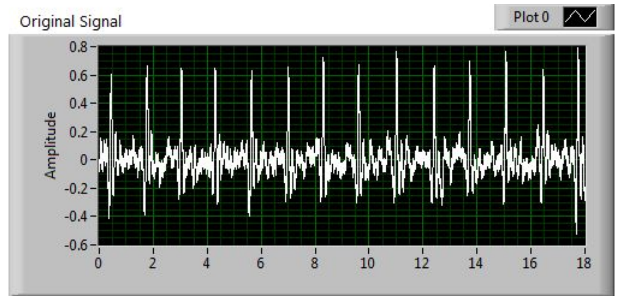


Fig.5. 1 Original ECG signal

B. Results of FIR Window Techniques

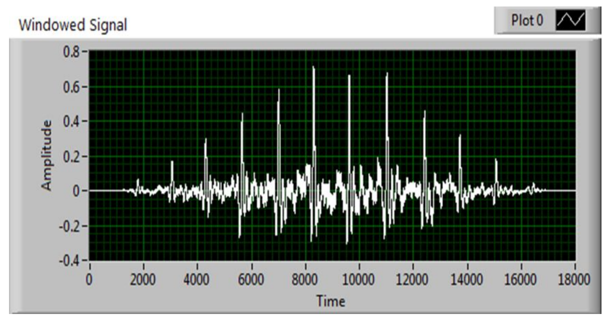


Fig 5.2 Filtered signal using Hanning window

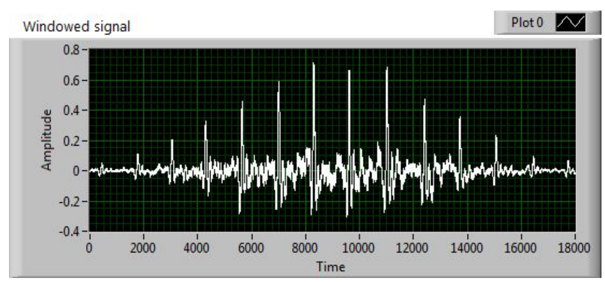


Fig 5.3 Filtered signal using Hamming window

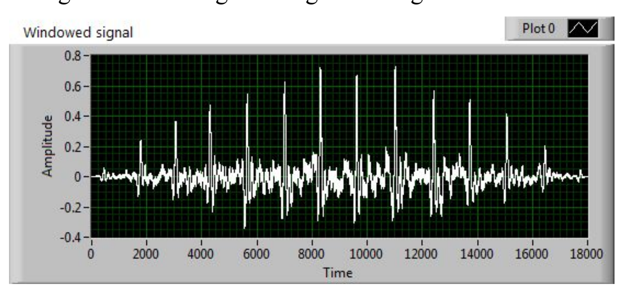


Fig 5.4 Filtered signal using Welch window

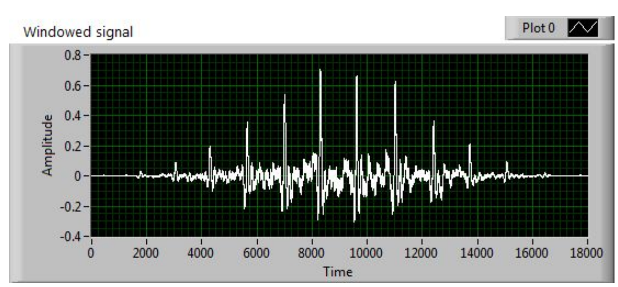


Fig 5.5 Filtered signal using Blackman-Harris window

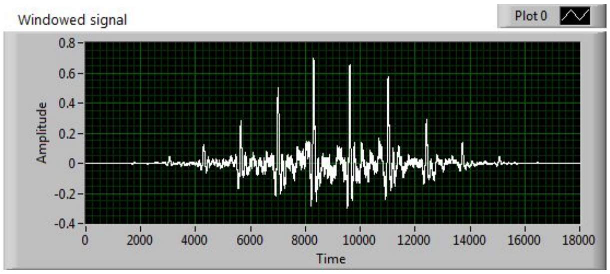


Fig 5.6 Filtered signal using Blackman Nuttall window

C. *Result of Undecimated Wavelet Transform*

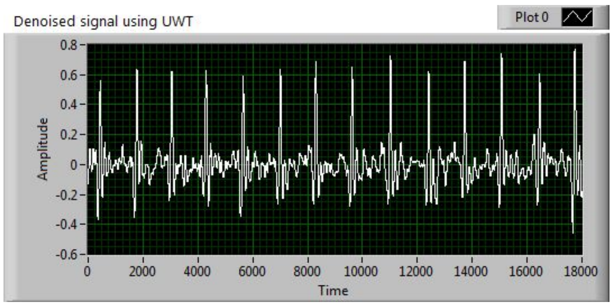


Fig 5.7 Filtered signal using UWT

The Signal to Noise ratio (SNR) of FIR Filters and Wavelet Transform is shown in Table I.

Technique	*SNR (dB)*
Hanning window	9
Hamming window	8.89
Welch window	7.4
Blackman – Harris window	9.8
Blackman Nutall window	10.6
Undecimated Wavelet Transform	15.8

CONCLUSION

In this paper, we proposed a denoising technique based on Undecimated wavelet transform and FIR filters using LabVIEW and the performance is compared in terms of SNR. From the filtered figure it can be easily concluded that wavelet filter is giving better ECG graph. In the Table-I, signal-to-noise ratio of different filter methods is compared. Using FIR filter method, Blackman Nutall window is giving better result and comparing both the denoising techniques Wavelet Transform is giving better result than FIR filter techniques.

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