COMPARISON OF FILTER OUTPUTS FOR ECG SIGNALS

SAURABH PARULEKAR, SUMEDH NAIK, RASHMI PHADNIS, DR. REENA KUMBHARE

saurabh.parulekar@spit.ac.in, sumedh.naik@spit.ac.in, rashmi.phadnis@spit.ac.in, reena kumbhare@spit.ac.in

SARDAR PATEL INSTITUTE OF TECHNOLOGY

Bhartiya Vidya Bhavan's campus

Munshi Nagar,Andheri-West

Mumbai-400058

Abstract

ECG (Electrocardiogram) is the graph of voltage recorded from the electrical impulses generated by the heart versus time. It typically consists of the P-wave, the QRS complex and the T-wave. They are used to determine the healthiness of a patient's heart. In a medical environment, there is a need to filter out the noise added throughout this signal to generate a precise rendition of a patients ECG. This has been attempted through the use of FIR high-pass, low-pass and band-pass filters. Their output has been compared on the basis of parameters like Signal-to-noise-ratio (SNR). The output through the filters was compared with the noisy input by the method of correlation to determine how much noise had been attenuated. Thus, the optimal filter was decided.

Keywords : Electrocardiogram, filter, low-pass, high-pass, band-pass

INTRODUCTION

As stated above, an ECG denoted the electrical activity of a human heart. It is a periodic wave with typical characteristics that can help differentiate between a healthy and a diseased heart. The range of frequency of an ECG signal is usually from 0.05 Hertz to 100 Hertz with the amplitude ranging from 1 mV to 10 mV.

The ECG is measured with the help of ten electrodes attached across the body to measure the polarisation and depolarisation with respect to blood flow. The outlined process to measure the ECG signal can introduce two types of noise[1]. The first type is noise with a high frequency and consists of white Gaussian noise and Electrocardiogram and the second type is low frequency noise. Our experiment aims at reducing additive white Gaussian noise. With the aid of FIR filters [1] of the type low-pass, high-pass and band-pass with fixed passband and stopdband frequencies, the ECG signal with noise is brought back from degradation and the outputs are compared [2].

RELATED THEORY

The results of the experimentation depend on the working of the FIR filters used. Finite Impulse Response filters accept delayed input signal to give an almost linear phaseresponse. The types of FIR filters applied here are the lowpass, highpass and bandpass filters. In low-pass filters, there is a threshold frequency specified called the stopband frequency above which all the signal is attenuated. The high-pass filter has a threshold frequency also called the stopband frequency below which all the signal is attenuated. The band-pass filter has two passband frequencies. The signal below and above this range of frequencies is attenuated.
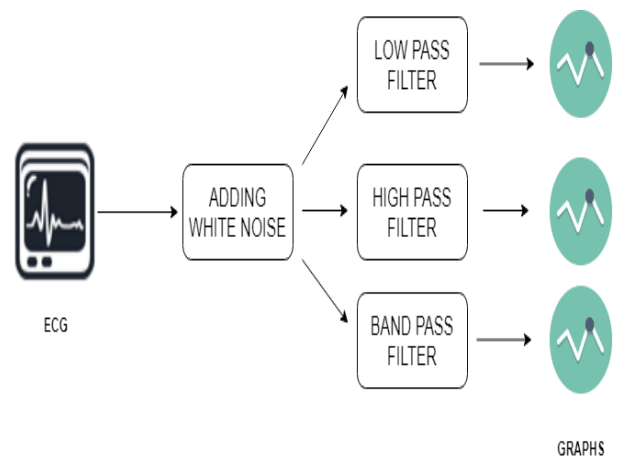
PROPOSED SYSTEM DESIGN

Fig. 1. Block Diagram.

MATLAB

The software used to run the simulation for the specified setup was MATLAB (matrix laboratory). MATLAB [3] provides a convenient and easy-to-use interface and environment to run the simulation and view the desired output for our analysis.

ECG Signal

The ECG [4] signal is distinctively characterized by P, Q, R, S, T and U points which make up the P wave, the QRS complex, the T wave and the rarely seen U wave. Each wave is a result of the polarisation, depolarisation and repolarisation of the heart's atria and ventricles.

FIR High-pass filter

A high-pass filter has a specified stop-band frequency. Below this frequency, the input signal is attenuated to be almost zero. Thus, it allows only the part of the signal above the frequencies to pass.

FIR Low-pass filter

A low-pass filter has a specified stop-band frequency. Above this frequency, the input signal is attenuated to be almost zero. Thus, it allows only the part of the signal below the frequencies to pass.

FIR Band-pass filter

A band-pass filter has a specified stop-band frequency and a pass-band frequency. Outside this frequency range, the input signal is attenuated to be almost zero. Thus, it allows only the part of the signal between the frequencies to pass.

METHODOLOGY

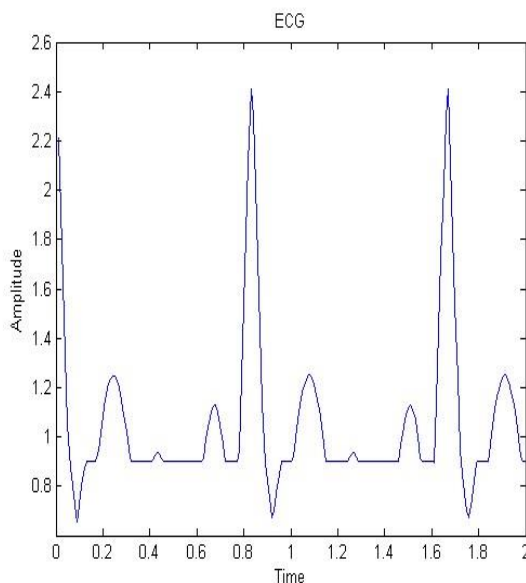The generated ECG signal is passed through the three filters as mentioned above.

Fig. 2. Generated ECG Signal

The corresponding obtained graphs are also displayed along with the respective filter names.
The ECG wave is generated using the above mentioned 6-point functions for a default 72 beats per second signal. The wave can be customized separately for both, higher and lower beats/second signals and also at each of the 6 constituent points. When ECG (Fig. 2) is coupled with white Gaussian noise, using the 'awgn' matlab function, (Fig. 3) is obtained. This noise added ECG is then checked for multiple possible values of input Signal to Noise Ratio (SNR) and an ideal value is obtained. Once the SNR values are adjusted, the noise-added signal is passed through

three different filters simultaneously for comparison. As explained, the Low Pass Filter filters out the signals higher than the cut-off frequency, the high pass filter allows only the higher frequency signals to pass while the band-pass filter sends only the required frequency band through it. The final output signals for a number of cut-off frequencies are observed and again compared to the original ECG signal. The best possible outcome [5] for each of the filters is noted and recreated as shown (Fig.4, Fig.5, Fig.6).

A filter output can be efficiently analysed [6] and compared to each other with respect to the input Signal-toNoise Ratio, Cutoff-Frequency and similarity to the input signal. All these factors were calculated and correlation of input and all outputs was separately found. (Fig. 7, Fig. 8, Fig. 9)
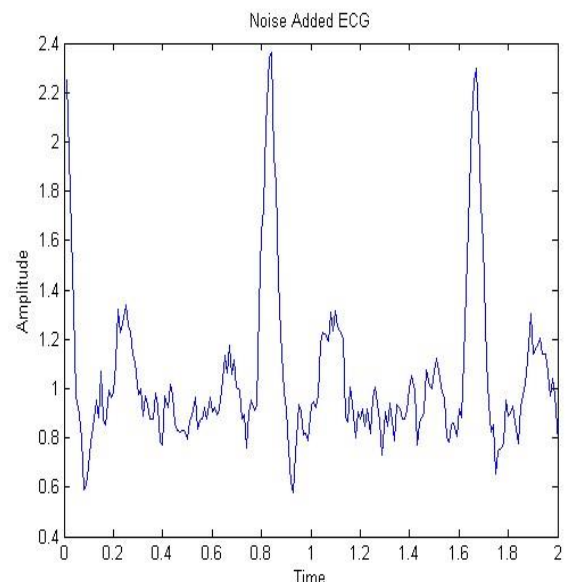
SIMULATIONS

Fig. 3. Noise Added ECG

The Above signal shows the Original ECG Signal(Figure 2) introduced with white Gaussian noise, hence the distorted signal is obtained containing the high frequency components.Due to these high frequency components the information present in the ECG signal are lost.In general processing of signal noise is introduced in signals which hinders the analysis and increases the inaccuracy in measurements.
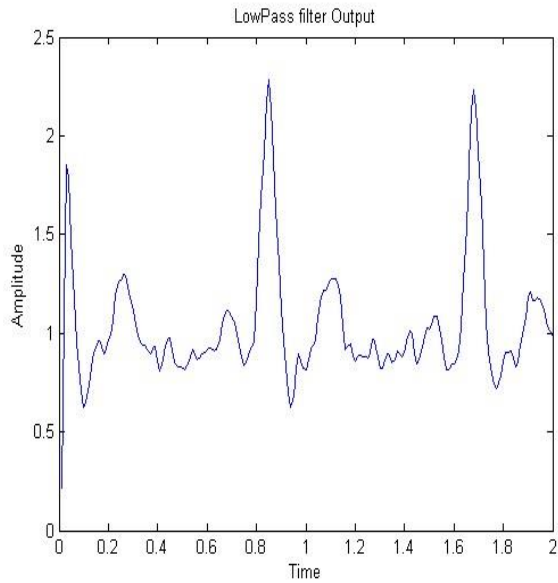
Fig. 4. Low Pass Filter Output

The above signal is the output when the noise added ECG signal is passed through a Low Pass Filter, the cutoff frequency obtained are presented later.A low pass filter allows of lower frequencies to be passed hence all the high frequency components are removed.White Gaussian noise has a Gaussian distribution hence it has some components in the lower frequency as well therefore we do not obtain the exact ECG signal it still has some noise components.
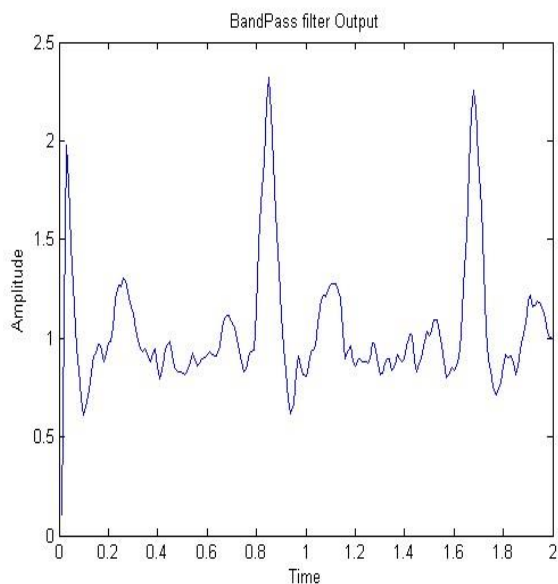

Fig. 5. Band Pass Filter Output

The above signal shows the output when the noise added ECG is passed through a Band-Pass filter.In this case some of the higher frequencies are also included due to

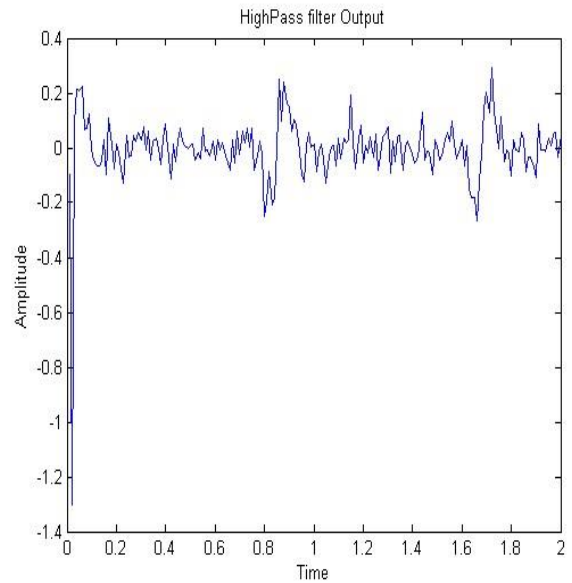the upper cut-off of the band-pass filter.the recovered signal can still be used for retrieving information.

Fig. 6. High Pass Filter Output

The above graph shows the output when the ECG is sent through a High-pass filter.The signal obtained is only noise as all the lower frequencies signal components are rejected.Hence this filter cannot be used for filtering ECG

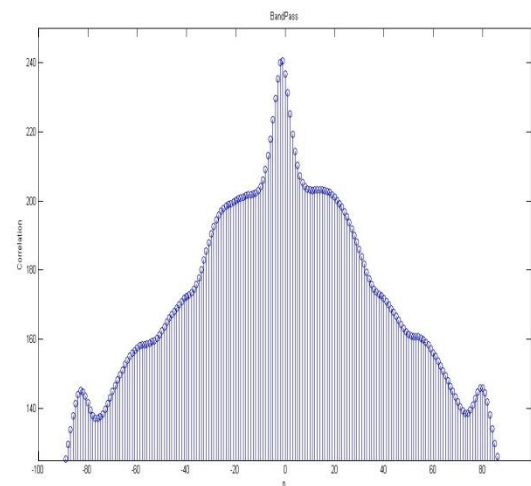Fig. 7. Correlation: Input and Low Pass Output

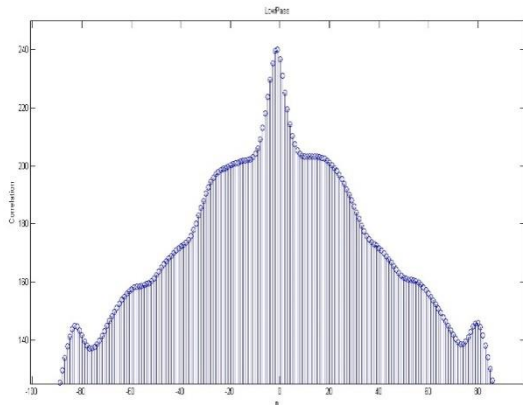Fig. 8. Correlation: Input and Band Pass Output

Fig. 7. Correlation: Input and Low Pass Output

The above to graphs are the correlation between the ECG signal and the outputs from Low-pass and Band-pass filters respectively. The graphs obtained are quite similar hence it shows that the output from the two filters can be used for processing and retrieving information.
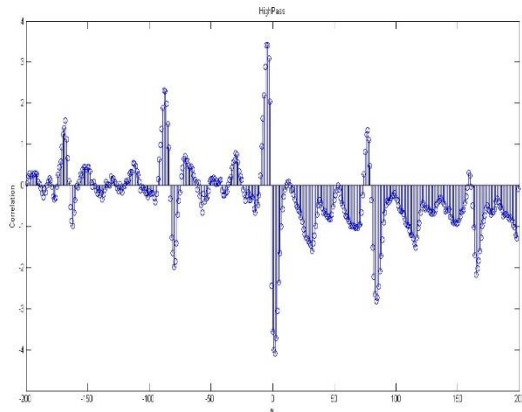

Fig. 9. Correlation: Input and High Pass Output

As it was evident from the filter output that the signal cannot be used for retrieving information hence we do not obtain a standard correlation graph for High-pass filter output

RESULT

SNR: There is a chance of recreating the ECG signal for SNR above 10.

For SNR above 21, the correlation comes to be 243 always thus making it possible to produce recreated wave always.

	SNR	Stopband /Passband	Observation
Lowpass	Above 11	5-6Hz	Reproduces original wave quite well
Highpass	Above 24	1 Hz	Cutoff at 1 Hz gives a slight ECG signal.Highpass is redundant as noise is added at all frequencies
Bandpass	Above 20	5Hz to 10Hz	Works better than Highpass but worse than Lowpass

TABLE I
CUT-OFF FREQUENCIES OF VARIOUS FILTERS

CONCLUSION

As per the embodiment of our experimentation, we have created three filter designs on matlab and passed the ECG signal through all of them. It is observed and concluded that the low-pass filter acts as a better attenuator of noise followed by the band-pass filter and then the high-pass filter

REFERENCES

[1] Li, C. (2010). Design and realization of FIR digital filters based on MATLAB. 2010 International Conference on Anti-Counterfeiting, Security and Identification.

[2] Zhenhe Sun, Wei Yu, Chen He. (2012). FIR digital filter design and MATLAB simulation. Proceedings of 2012 International Conference on Measurement, Information and Control.

[3] FIR Filter Designs - www.mathworks.com

[4] Noise Analysis and Different Denoising Techniques of ECG Signal - A Survey by AswathyVelayudhan, Soniya Peter

[5] Denoising of ECG Signals Using FIR IIR Filter: A Performance Analysis : Ms. Chhavi Saxena1 , Mr. Vivek Upadhyaya2 ,Dr. Hemant Kumar Gupta3, Dr.Avinash Sharma4

[6] Das, N., Chakraborty, M. (2017). Performance analysis of FIR and IIR filters for ECG signal denoising based on SNR. 2017 Third International Conference on Research in Computational Intelligence and Communication Networks (ICRCICN).