ECG SIGNAL PROCESSING
Home Assignment 3

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1. Overview

The report consists of three sections, which are reading ECG files and autocorrelation analysis, filtering ECG signal and extracting clinical information from signal. The project of ECG signal processing is built in *LabVIEW* as shown in Figure 1.1.

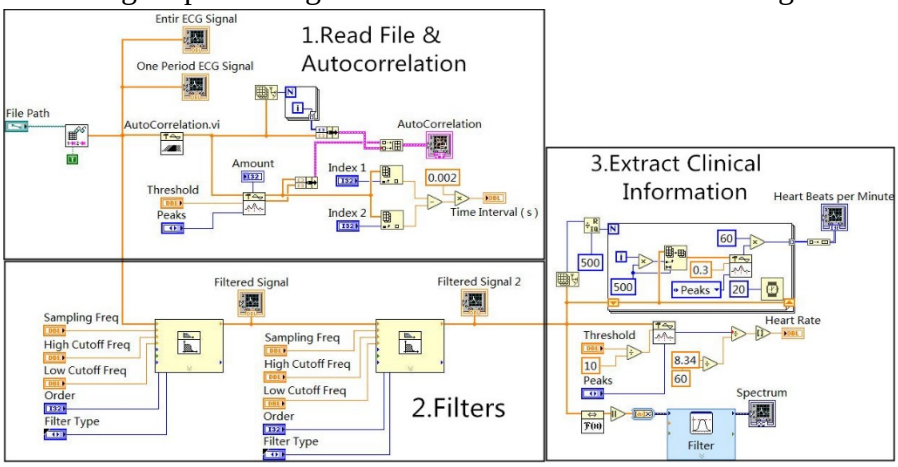


Figure 1.1 Project in LabVIEW

2. Reading ECG Files

2.1 ECG Signal

The ECG signal is read from text file as shown in Figure 2.1. The number of data is 4170, and the sample rate is 500Hz, thus the time of the signal is 8.34 seconds (4170/500). It is obvious that there is a low frequency noise in the signal. Figure 2.2 shows one period of ECG, in which a high frequency noise can be noted.

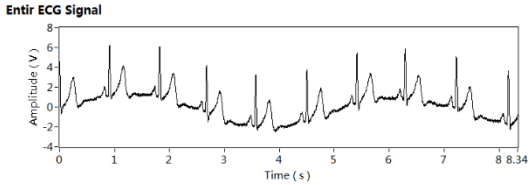


Figure 2.1 ECG Signal

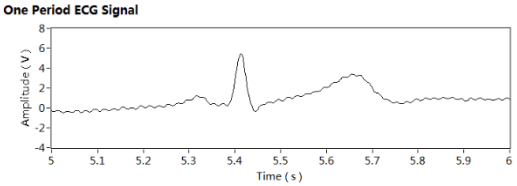


Figure 2.2 One Period of ECG Signal

2.2 Autocorrelation

The autocorrelation of ECG signal obtained from LabVIEW is shown in Figure 2.3. Because of noise, there are too many maximums in the result. Several interested maximums are marked manually as shown in Figure 2.4. These local maximums mean that the mode of signal at a certain delay time is more similar to the original signal.

Here, the mode is the ECG wave (P-QRS-T wave). The distance between two marked maximums may stands for the duration between two heart beats.

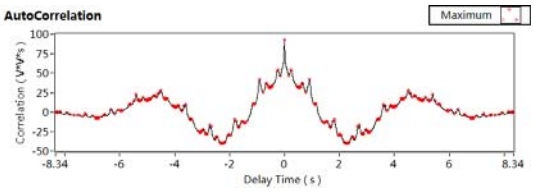


Figure 2.3 Autocorrelation of Signal

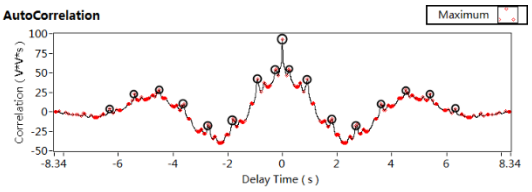


Figure 2.4 Interested Maximums

3. Filtering ECG Signal

3.1 Band Reject Filter

The ECG signal is filtered by a 50Hz band reject filter and a 60Hz band reject filter respectively, and filtering results are shown in Figure 3.1 and 3.2. The 50Hz notch filter has a better performance than the other one, since more high frequency noise has been removed from ECG signal. Maybe, the ECG signal was measured with 50Hz-frequency interference.

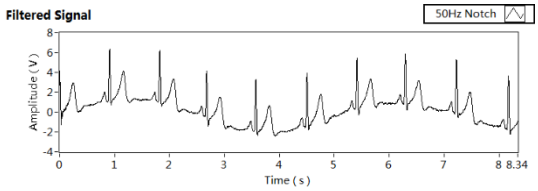


Figure 3.1 Filtered by 50Hz Notch Filter

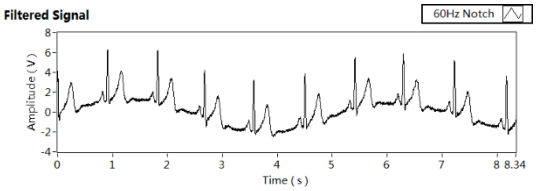


Figure 3.2 Filtered by 60Hz Notch Filter

3.2 High Pass Filter

The ECG signal is filtered by a 10Hz high pass filter and a 20Hz high pass filter. As shown in Figure 3.3 and 3.2, in both results of one period signal, P wave and T wave disappear due to the excessive low cut off frequency. The content of P wave and T wave are mainly contained in the low-frequency part of ECG signal.

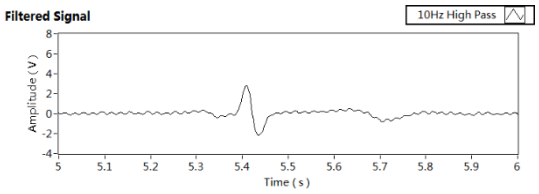


Figure 3.3 Filtered by 10Hz High Pass Filter

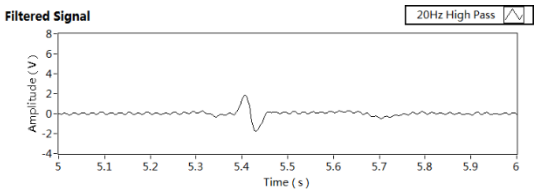


Figure 3.4 Filtered by 20Hz High Pass Filter

3.3 Low Pass Filter

In this part, four low pass filters with different high cut off frequencies (75Hz, 70Hz, 60Hz and 50Hz) are applied to filter the ECG signal. Filtering results of one second signal are shown from Figure 3.5 to 3.8. To be honest, it's hard to distinguish the difference between each single figure. Thus, the difference values between original ECG signal (S) and four filtered signals (LP[75], LP[70], LP[60] and LP[50]) are calculated and shown in Figure 3.9. It's more obvious that the high frequency distortion of filtered signals are mainly located in the period of QRS wave. The amplitudes of Q

wave and S wave of filtered signals are smaller than the original ECG signal's, resulting in a more gradual slope.

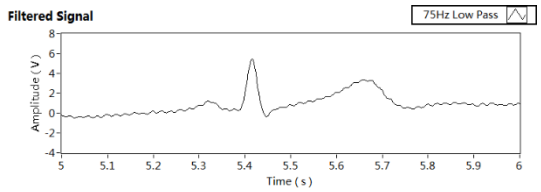


Figure 3.5 Filtered by 75 Hz Low Pass Filter

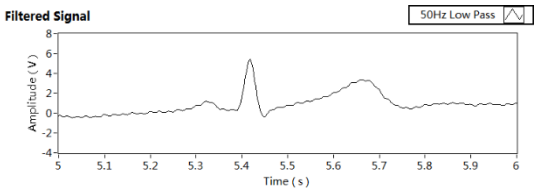


Figure 3.6 Filtered by 50 Hz Low Pass Filter

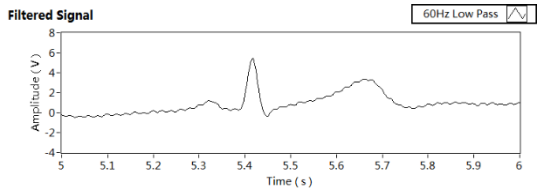


Figure 3.7 Filtered by 60 Hz Low Pass Filter

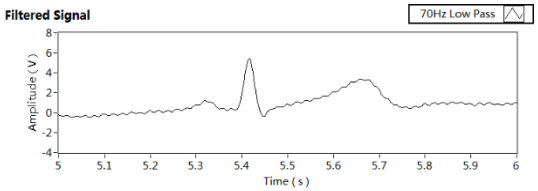
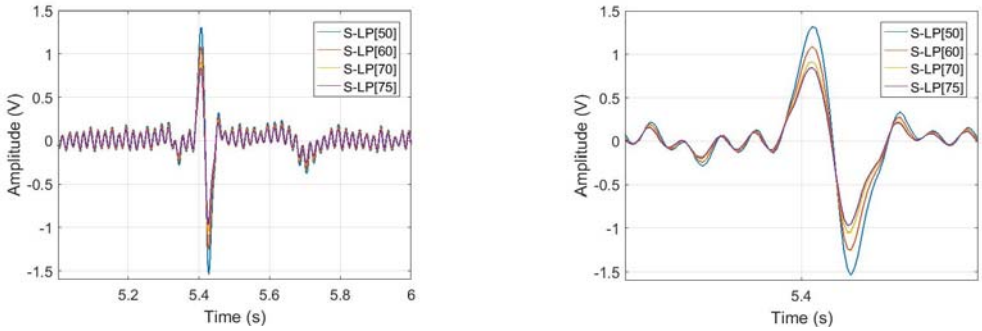


Figure 3.8 Filtered by 70 Hz Low Pass Filter



(a) A Whole Second *(b) Signal around 5.4s*

Figure 3.9 Differences between Low Pass Filtered Results

3.4 Band Pass Filter

As shown in Figure 3.10, ECG signal is filtered by a band pass filter within the range of 0.1Hz to 150Hz. Comparing with the ECG signal, filtered result of first 3 seconds has less low frequency distortion.

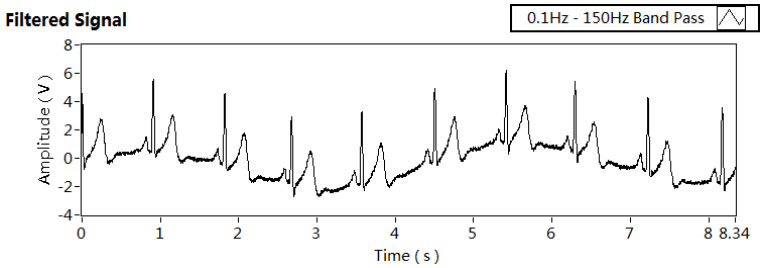


Figure 3.10 Filtered by 0.1Hz to 150Hz Band Pass Filter

3.5 Cascade Filter

Before connecting band pass filter to band stop filter, the low frequency distortion of ECG signal should be removed first. The low-frequency part (0.1Hz to 0.5Hz) of ECG signal is shown in Figure 3.11. It can be seen that there is a noise with four-second period (0.25Hz). The signal with the frequency between 0.25Hz and 0.5Hz is shown in

Figure 3.12, in which a three-second period noise can be found. The signal in the range of 0.33Hz to 0.5Hz is shown in Figure 3.13. There is little low-frequency noise left. Thus, the range of band pass filter is from 0.33Hz to 150Hz. After which, the band pass filter is connected to the band stop filter, and filtered signal is shown as Figure 3.14. Both high frequency distortion and low frequency distortion have been removed form original ECG signal.

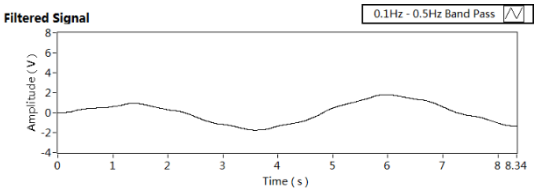


Figure 3.11 Low Frequency Part of Signal

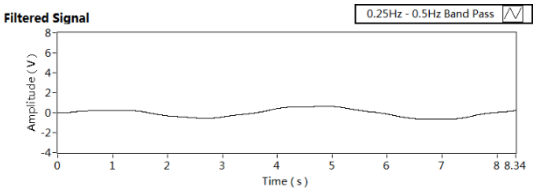


Figure 3.12 Low Frequency Part of Signal

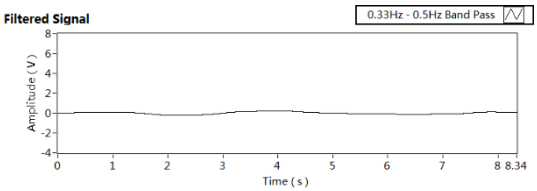


Figure 3.13 Low Frequency Part of Signal

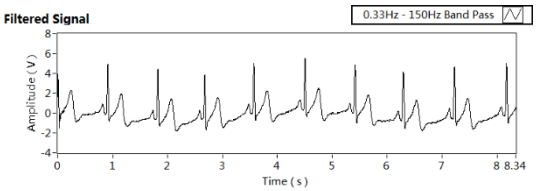


Figure 3.14 Filtered ECG Signal

4. Extracting Clinical Information

4.1 Heart Rate of ECG

In order to calculate the heart beats per minute (BPM), the peaks of R wave are extracted first. The threshold is set to 3 volts. Thus, there are 10 peaks (10 beats) during the time of 8.34 seconds, heart rate can be calculated as shown in Figure 4.1, which is 72 beats per minute (10/8.34*60).

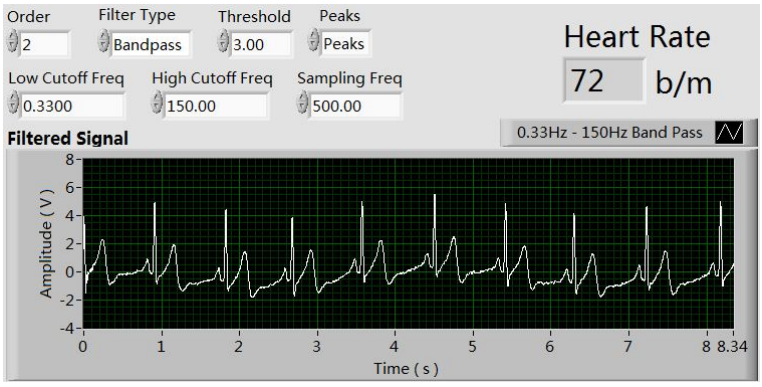


Figure 4.1 Heart Rate of ECG Signal

4.2 Heart Beat per Minute

In this part, BPM is measured in each second. In every loop, 500 samples (1 second) are read to get the number of peaks. For instance, at the first second, there are 2 peaks, thus BPM is 120 (2*60). During the following second, there is only one peak, so that the BMP in this second is 60 (1*60). The BMP measured by seconds is shown in Figure 4.2.

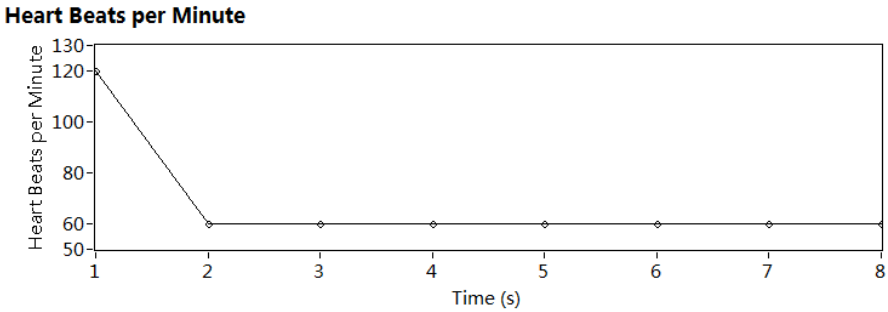


Figure 4.2 Heart Beats per Minute

4.3 Fast Fourier Transform of Signal

The fast Fourier transform of filtered signal is shown in Figure 4.3. Since the sampling frequency is 500Hz, the range of spectrum should be from 0Hz to 250Hz. The scale of x-axis should be 500/4170 where 500 is the sampling rate and 4170 is the length of signal. The low pass filter with a cut off frequency of 0.02Hz is used to filter the spectrum. It is observed that the signal spectrum has a low amplitude around 50Hz, because a 50Hz notch filter is applied to remove high frequency distortion of original ECG signal. Due to the using of band pass filter, the high frequency part of filtered signal also has a low amplitude.

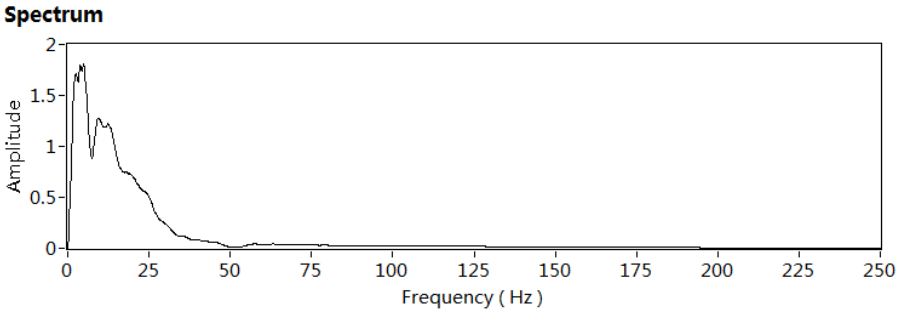


Figure 4.3 Fast Fourier Transform of ECG Signal