BIOMEDICAL SIGNALS

LAB SESSION 1 WITH MATLAB

INTRODUCION TO SIGNAL PROCESSING

1. DETECTING PVC

In this section, An ECG signal with premature ventricular contractions (PVC) will be analyzed in order to detect the ectopic beats by using cross-correlation function.

- Firstly, upload the matlab file *ecgpvc.mat*. ECG signal was recorded with a sampling frequency of 200 Hz during 250 seconds. You can take a look of the ECG along time plotting the signal using the command *visualpvc*. In the Matlab figure appears 5 subplots with 10 seconds signal each. Thus, in the figure you can watch the first 50 seconds. The figure is in “pause” and clicking the space bar, the figure shows the following 50 seconds and repeating until the end.

  A premature ventricular contraction (PVC) is a relatively common event where the heartbeat is initiated by Purkinje fibers in the ventricles rather than by the sinoatrial node. PVCs may cause no symptoms or may be perceived as a "skipped beat" or felt as palpitations in the chest. Single beat PVCs do not usually pose a danger.

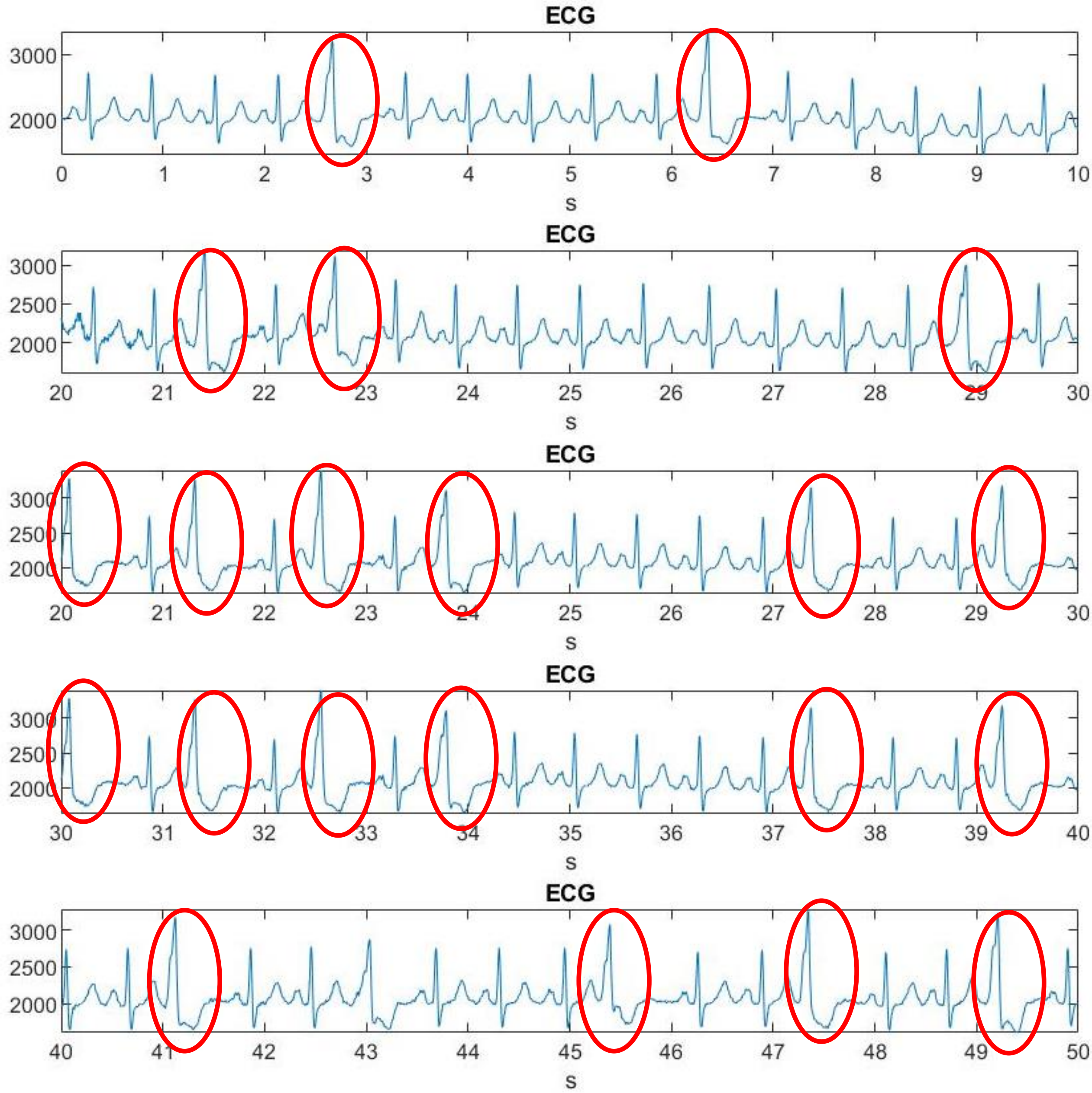
  The electrical events of the heart detected by the electrocardiogram (ECG) allow a PVC to be easily distinguished from a normal heart beat:

  However, very frequent PVCs can be symptomatic of an underlying heart condition (such as arrhythmogenic right ventricular cardiomyopathy). Furthermore, very frequent (over 20% of all heartbeats) PVCs are considered a risk factor for arrhythmia-induced cardiomyopathy, in which the heart muscle becomes less effective and symptoms of heart failure may be developed.

  More information can be found for example in the Wikipedia or elsewhere.

- The objective is to detect automatically these ectopic beats using normalized cross-correlation between the ECG signal and a “representative” ectopic beat pattern. When the resulting correlation is close to unity, it means that an beat associated with the PVC is detected but when the correlation is high but not so close to unity, the beat detected is normal. In the first figure that appears when executing *visualpvc* the following PVCs can be detected visually:



The representative ectopic beat will be built using the average of the first five ectopic ones. To obtain the time when the maximum value, which corresponds to the R wave, appears is suggested.

- Once the sample with R waves from the first five ectopic beats are detected, a representative ectopic ECG beat pattern should be calculated. For this purpose, a fixed time window around the R wave should be considered in order to include normally the P and T waves of the beat. All segments or time windows should be averaged in order to get a representative beat.

- Finally, with the normalized crosscorrelation using the MATLAB command *xcorr* between the ECG signal and this average beat you should stablish thresholds to detect ectopic and normal beats. The former are the objective of this Section. This works properly in the case that ectopic beats are similar although this does not happen always. In this case, the option could be to detect normal beats and the ectopic ones will be supposed in between when the cardiac period (interval between two consecutive R waves) is too long.

2. FILTERING ECG

In this section, a short ECG segment will be analyzed in frequency and time domain before and after appropriate filtering.

- Firstly, upload the matlab file *ecgf.mat*. ECG signal was recorded with a sampling frequency of 1kHz. Take a look of the ECG along time plotting the signal as a function of time (seconds). Show that it seems to have noise at high frequencies and it is necessary to filter it.
- It is necessary to decide the type and the cut-off frequency of the filter. For this reason, the calculation of the PSD is necessary (you should do it using the DFT/FFT and a Hanning or Hamming time window). Plot the PSD and decide what kind of noise the signal has and the type of Butterworth filter (low pass, high pass, stop band, comb .. etc …) you suggest to use (try to select always the simplest option among the effective ones).
- After filtering with the Butterworth filter (select the order 4^{th}), compare in two figures overlapping both time signals and PSD before and after filtering. Comment if the filtering has been effective in this case. The filtered signal will be named *ecgff*.
- Then, the purpose is to filter a little bit the T waves. See again the PSD obtained from the signal *ecgff* and using the information from the slide 17 about ECG in the section 1.4 from the presentation of Chapter 1, decide the type of filter and cut-off frequency to attenuate the T wave preserving as much as possible the other waves, particularly the QRS complex. Design an appropriate 4^{th} order Butterworth filter and applied it to the signal *ecgff*. Again, overlap in the same figure the ECG signal obtained at this moment and *ecgff*. Show and comment if T waves are the most filtered ones with respect to the rest of the waves in the ECG. Compare also their PSD overlapping the functions in a figure to verify the filtering effect.
- The same filter used in the previous point will be applied to the signal *ecgff* using two approaches: passing the filter twice (double pass) to cancel the non linear phase and only once. Compare in two figures overlapping both filtered signals and their PSD. Comment and show the effect of the phase of this IIR filter.
- Finally, a FIR filter with order 4 will be applied to the signal *ecgff* in order to evaluate its efficiency to attenuate the T wave. Show this comparing the resulting signal with the filtered one obtained two points above when using the IIR filter. Increase the order of the FIR filter and find the appropriate one to obtain a similar attenuation of T waves found with the IIR filter.