BME/ELE 772 Biomedical Signal Analysis (Fall 2018)

Lab 3: QRS Detection and ECG Rhythm Analysis

1 Objective

- To detect QRS complexes using the Pan-Tompkins algorithm
- to measure ECG parameters for rhythm analysis

2 Background

The QRS complex detection algorithm developed by Pan and Tompkins identifies QRS complexes based on analysis of the slope, amplitude, and width. The various stages of the algorithm are shown in Figure 1.

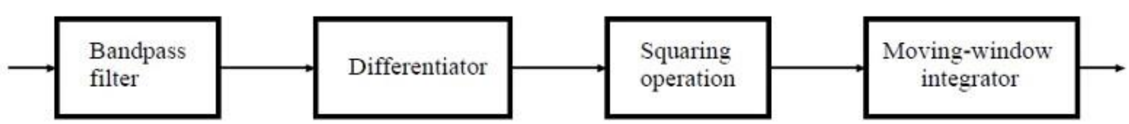

Figure 1: Block diagram of Pan-Tompkins algorithm

The bandpass filter, formed using lowpass and highpass filters, reduces noise in the ECG signal. Noise such as muscle noise, $60Hz$ interference, and baseline wander are removed by bandpass filtering. The signal is then passed through a differentiator for highlighting the high slopes that distinguish QRS complexes from low frequency ECG components such as the P and T waves. The next operation is the squaring operation, which emphasizes the higher values that are mainly due to QRS complexes. The squared signal is then passed through a moving window integrator of window length $N - 30$ samples (for sampling frequency of $f_s = 200Hz$). The result is a single smooth peak for each ECG cycle. The output of the moving window integrator may be used to detect QRS complexes, measure RR intervals, and determine the QRS complex duration (see Figure 2).

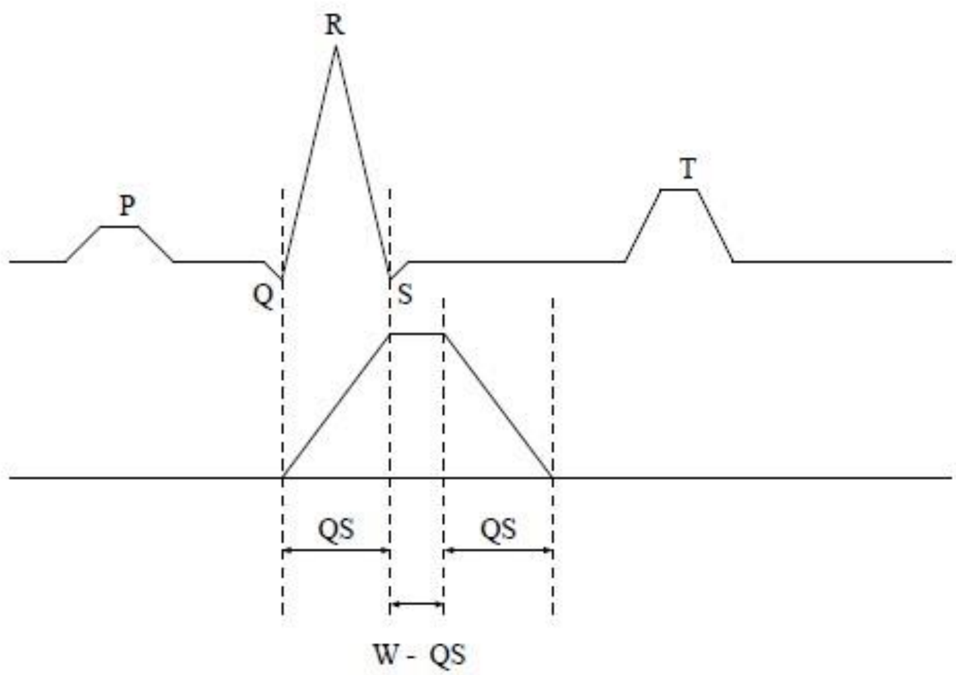

Figure 2: The relationship of a QRS complex to the moving-window integrator output. (a) Schematic ECG signal. (b) Output of the moving-window integrator. QS:QRS complex width. W: width of the integrator window, given as $N/f_s s$

3 Pre-Lab

1. A digital filter is specified in terms of its impulse reponse as

$$h_1(n) = \delta(n) + \delta(n-1) + \delta(n-2) \tag{1}$$

Derive its transfer function as well as the magnitude and phase parts of its frequency response. Explain the nature and effects of the filter

2. Another digital filter is specified in terms of its impulse response as

$$h_2(n) = \delta(n) - \delta(n-1) \tag{2}$$

   Derive its transfer function as well as the magnitude and phase parts of its frequency response. Explain the nature and effects of the filter

3. The two filters are used in series to filter a signal. Derive and plot the impulseresponse of the combined filter.
   Derive transfer function as well as the magnitude and phase parts of the frequency response of the combined filter. Explain the nature and effects of the combined filter.

4 Lab Exercise

Copy the data files of four ECG signals ECG3, ECG4, ECG5, and ECG6 available in the BB directory (sampled at 200*HZ*). Develop a MATLAB program to perform the various filtering procedure that form the Pan-Tompkins algorithm. Use the 'filter' command for each step. Study the plots of the results at the different stages of the QRS-detection algorithm.

Plot the pole-zero diagram and the frequency response (magnitude and phase) of each of the initial lowpass, highpass, and the combined bandpass filters, and also the derivativebased and integrating filters.

Implement a simple thresholding procedure including a blanking interval for the detection of QRS waves from the output of the Pan-Tompkins algorithm.

Develop MATLAB code to use the output of the Pan-Tompkins algorithm to detect QRS complexes and compute the following parameters for each of the four ECG signals provides (ECG3, ECG4, ECG5, and ECG6):

1. Total number of beats in each signal and the heart rate in beats per minute.

2. Average RR interval and standard deviation of RR intervals of each signal (in *ms*).

3. Average QRS width comuted over all the beats in each signal (in *ms*).

Include comments in your code to explain your procedures.

5 MATLAB Command to Learn

Use the help command in MATLAB and learn the following commands: filter, freqz,zplane.

6 What to submit

- Documented MATLAB program to perform QRS detection and compute the above mentioned parameters.
- Sets of parameters for the four ECG signals given and your analysis of the parameters.
- A brief note on the advantages and drawbacks of the Pan-Tomplins QRS detection method.

Due Date
14 days from the lab date at the beginning of the lab.