ELL720: Advanced Digital Signal Processing

Design Problem 3

Due date: 24 April 2023

30 March 2023

ECG Signal Analysis

The electrocardiogram (ECG) is a technique of recording bio-electric currents generated by the heart. Clinicians can evaluate the conditions of a patient's heart from the ECG and perform further diagnosis. ECG records are obtained by sampling the bio-electric currents sensed by several electrodes. The goal of this assignment is to familiarise you with ECG signals, and simple algorithms for extracting heart rate and other statistics. A typical one-cycle ECG trace is shown in Fig. 1.
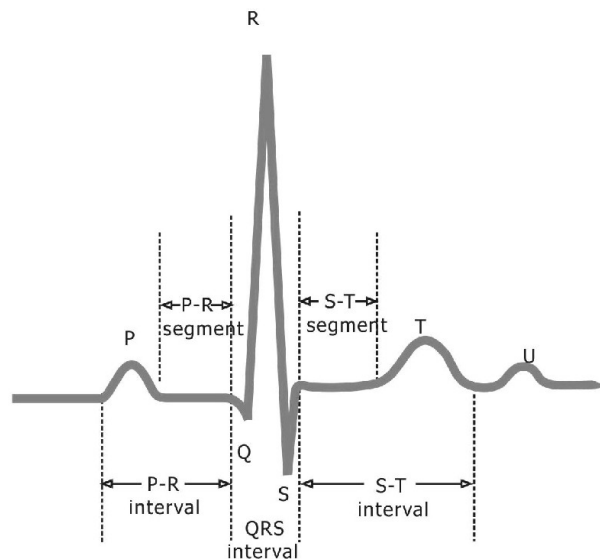

Figure 1: Typical one cycle ECG trace (Source: National Instruments).

Generally, the recorded ECG signal is often contaminated by noise and artifacts that can be within the frequency band of interest and manifest with similar characteristics as the ECG signal itself. In order to extract useful information from the noisy ECG signals, you need to process the raw ECG signals. In this assignment you will use two ECG data sets which are available here: `http://privateweb.iitd.ac.in/~seshan/ECG_signals.zip`. The ECG signals are sampled at 360 Hz and each sample is recorded in scientific notation (e.g. $9.9300000e+002$). In this assignment you will evaluate the following aspects of the ECG signal:

- **Heart Rate**: Design an algorithm to estimate the beat-by-beat heart rate (in beats per minute or BPM) from the data (using the R-R interval). Implement your algorithm in Matlab and run it on the two data files.

    1. Describe your algorithm with appropriate illustrations. Document any assumptions that your algorithm makes and what would happen if the assumptions were violated.
    2. Does your heart rate algorithm work correctly over the entire data set? If no, comment on (possible) discrepancy that you observed.

3. RR Histogram: Plot a histogram of the beat-by-beat heart rate estimates. Comment on this distribution.

4. RR Change: From your beat-by-beat R-R interval estimates, compute the observed change from one beat to the next. Plot a histogram of these RR changes and comment on how quickly the heart rate changes in these data sets?

- **QRS Interval**: Design an algorithm to estimate the beat-by-beat QRS interval (shown in Fig. 1). Run your algorithm over the data sets and plot a histogram of the QRS intervals.

You should prepare a report, giving a brief description of the algorithms you have implemented, compiling all your results and your interpretation of them, along with your overall conclusions. In particular, you should attempt to answer all of the questions posed above. Any graphs or other visualisations should also be included in the report.