ENEL 563 Biomedical Signal Analysis

Project on Frequency-domain Analysis of Heart Sounds

1 Objectives

- Segmentation of phonocardiographic (PCG) signals using the ECG as a reference.
- Computation of an averaged power spectral density (PSD) of segments of a PCG signal.
- Parametric representation of PSDs.
- Auditory analysis and classification of heart sounds.

2 Specific Tasks

1. Get a few PCG signals of normal subjects and patients with murmurs. You may use the files `pec1.dat, pec33.dat, pec41.dat, pec42.dat, pec52.dat,` and `pec_sound.m` from

   `http://www2.enel.ucalgary.ca/People/Ranga/enel563/SIGNAL_DATA_FILES/`

   Each `.dat` file contains sampled values of the ECG, PCG, and carotid pulse signals of a subject. The sampling rate per channel is $f_s = 1,000$ Hz. Use the program `pec_sound.m` provided to read, separate, and plot the data, as well as to listen to the PCG signals. Some of the datafiles have artifacts at the beginning and/or ending of the recording session: delete such portions in your program.

   The files `pec1` and `pec52` contain signals from normal subjects. The files `pec33` and `pec42` contain signals from two subjects with ventricular septal defect (a hole between the two ventricles, causing blood to leak from the left ventricle to the right ventricle during systole), causing systolic murmur in the PCG. The file `pec41` contains signals from a subject with aortic stenosis (stiffened leaflets of the aortic valve causing incomplete opening of the valve and constrained ejection of blood into the aorta during ventricular systole), causing systolic murmur in the PCG.

2. Detect the QRS complexes in the ECG signals by applying the Pan–Tompkins algorithm (see Chapter 4 of the textbook). Note that the Pan–Tompkins algorithm is designed for signals sampled at 200 Hz. In order to apply the algorithm to the ECG signal in the `pec` signals, prefilter the ECG channel only using a suitable Butterworth lowpass filter and downsample by a factor of five before applying the Pan–Tompkins

algorithm. Transfer the QRS point detected for each beat to the beginning of the corresponding S1 point in the PCG channel after incorporating the required correction or scaling factors.

3. Segment the systolic portions of the PCG signal by selecting a window of duration $300 - 350$ ms starting from the beginning of each QRS complex. Ensure that the window that you define for each subject includes the beginning of S1 and systolic murmur (if present), but not S2. Compute the PSD of each segment (see Chapter 6 of the textbook). Obtain the averaged PSD of the systolic portions of each PCG signal, using as many cardiac cycles as possible in a synchronized-averaging procedure (see Chapter 6 of the textbook).

4. Compute the mean frequency of the averaged PSD for each case (see Chapter 6 of the textbook). Estimate the approximate bandwidth of each PCG signal. Prepare a table of the mean frequency and the approximate bandwidth for each of the five signals provided. Give the appropriate units for the parameters that you compute from the PSDs. Analyze the parameters and discuss your findings.

5. Listen to each PCG signal and describe your observations in your report. Relate your auditory analysis to the PSDs.

   The sampling rate of the signals provided to you is 1 kHz. Time-scale (oversample or interpolate) the given PCG signals to 8 kHz by using the `interp` command. Some of the datafiles have artifacts at the beginning and/or ending of the recording session: delete such portions in your program. (A loud and strange sound could affect your perception of the immediately following sounds.) Refer to the commands provided in `pec_sound.m` to convert the PCG data array into a `.au` audio file. You may also convert the PCG signal into a `.wav` file using the command `wavwrite`. You may then listen to the `.au` or `.wav` files using suitable audio tools.

See figures in the textbook for examples on how to illustrate signals before and after filtering, how to label plots with the results of detection or segmentation, how to show plots of features belonging to different types of signals, and how to evaluate the results of classification.

Use graphs to explain your results as necessary. Always label the axes of your graphs and show the proper units. If the units of a variable are not calibrated or are unknown, label the corresponding axis as "arbitrary units" or "AU".