MATLAB ECG HOMEWORK

In this homework, you will investigate Electrocardiogram (ECG) which is the major tool in the diagnosis of heart diseases. You will investigate some common issues of ECG measurements like *baseline wander* and power *line interference.* Moreover, you will reconstruct unknown lead measurements with using relations between lead voltages and obtain cardiac vector plots. All work will be done in MATLAB environment. You will be given 2 sets of real ECG data retrieved from https://physionet.org/ [1] which is a repository of freely-available medical research data, managed by the MIT Laboratory for Computational Physiology.

THIS IS AN INDIVIDUAL STUDY. Everyone will submit a PDF file that contains the output plots, comments and answers related to homework and a **single** .m file that contains all your codes thorough ODTUClass before the due date. If you have any technical difficulties that prevent you to do work on this homework please inform us (your instructor or any course assistant) ASAP. You can ask your questions related to this homework to Mert Şişman anytime via e-mail. (*merts@metu.edu.tr*)

Q1) Load the dataset named "SingleLeadMeasurement". This is a Lead II ECG signal measured at 360 *Hz* frequency for 10 seconds. **Plot** the waveform. What heart related anomaly seems to exist in this patient? What physiological reasons can cause this anomaly?

Write a MATLAB code to obtain the heart beats per minute vs. time plot. Provide the plot.

Q2) Load the dataset named "2LeadMeasurement". In this dataset there are 2 waveforms which are Lead I and Lead II ECG signals measured at 257 *Hz* sapmling frequency for 30 minutes. **Plot** the Lead I signal in the 23:00-23:05 (5 seconds) interval. Also, **sketch** the CTFT of the overall signal. Only plot the CTFT's magnitude response's ¼'th power. The shrinking is needed to make the signal more inspectable. You can observe that the original magnitude response is strongly dominated by the DC component. (Remember that you can transform DTFT (you can use FFT to acquire the DTFT) result to CTFT by simple scaling of both axes. Be sure that 2π of DTFT corresponds to the sampling frequency in CTFT. Also, don't forget to scale the y-axis. Besides, you can use *fftshift* comment to organize the frequency response into a more familiar form.)

What artifacts do you observe in the ECG signal or its CTFT?

(CTFT: Continuous time Fourier transform; DTFT: Discrete time Fourier transform;

FFT: Fast Fourier transform)

Q3) In this question you will carry out baseline correction in the ECG signal you examined in Q2. Design a filter to extract the baseline waveform from the Lead I signal. The impulse response of your filter will be in the form:

$$h[n] = \frac{1}{L}[1\ 1\ 1\ 1\ \dots 1]$$

The length of the filter is L. You will choose L such that the baseline you obtain will be neither constant nor very similar to the waveform itself.

Apply the filter you designed to the Lead I signal. **Plot** again the Lead I signal in the 23:00-23:05 (5 seconds) interval and in the same figure plot the obtained baseline using a different color. Subtract the obtained baseline waveform from the original signal. Moreover, **plot** the magnitude of the frequency response of the baseline-corrected signal (not ¼'th the power this time).

Hint: You may discard $L/2$ samples from the result of the convolution in order to synchronize your input and output sequences.

What was your filter length L? What happened when you tried smaller or larger values of L? What is the function of the designed filter? What is the type of this filter in terms of frequency response (i.e., high-pass, low-pass, band-pass, band-stop, notch, etc)?

The procedure you followed to remove the baseline can also be done in a single filtering step. What should be the frequency response of the new filter in terms of $h[n]$ in order to obtain exactly the same result? What is the type of this new filter in terms of frequency response (i.e., high-pass, low-pass, band-pass, band-stop, notch, etc)?

Compare the frequency responses of the original signal and the baseline-corrected version. What differences do you observe? Are there any similarities?

Q4) In this question you will eliminate the 50 Hz powerline interference. For this purpose you need to design a Low Pass Filter. A smoothing window such Gaussian window can be used for this purpose. Design a Gaussian filter using either the *gausswin* function or using the definition of Gaussian function (with zero mean). The parameters you need to choose are filter length and standard deviation (σ) of the Gaussian function. Filter the Lead I signal in the 23:00-23:05 (5 seconds) interval and **plot** the filtered signal and the magnitude of the frequency response of the filtered signal.

Hints: You can use a smaller filter size this time and don't forget to normalize your filter. You may discard $L/2$ samples from the result of the convolution in order to synchronize your input and output sequences.

Compare the obtained plots with those of the original signal.

Note: You can also use a Notch filter at 50 Hz to eliminate the 50 Hz powerline interference. Optional: design such a filter and apply to your signals. Do you see any difference in this filtered signal compared to the previously low pass filtered signal?

Q5) Apply the procedures in **Q3** and **Q4** to Lead II signal too. No plots are necessary this time. After obtaining both Lead I and II signals without any distortions, obtain the Lead III waveform of the same measurement using the relation between the lead voltages. **Plot** the Lead III signal in the 23:00-23:05 (5 seconds) interval.

Q6) Plot the cardiac vector in 8 uniformly spaced moments in the signal in the half second (one period) right after 23:00 seconds. In each plot also include Lead I, Lead II and Lead III vectors (in their predefined directions). Make the color of the lead vectors the same but different from the cardiac vector. You can use plot_arrow [2] function provided, or you can create your own plot. Use subplot function to create a single figure containing 4×2 vector plots.

NOTE: Please prepare your code as a single .m file where answers to each question is a section. You can separate sections with "%%". Your overall script should look like:

```
%%Name - Surname - ID
%%Q1
clear all
close all
clc
load('SingleLeadMeasurement.mat');
.
.
.
%%
%Q2
.
.
.
%%
%Q6
.
.
.
```

References

[1] Goldberger AL, Amaral LAN, Glass L, Hausdorff JM, Ivanov PCh, Mark RG, Mietus JE, Moody GB, Peng C-K, Stanley HE. PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals. Circulation 101(23):e215-e220 [Circulation Electronic Pages; http://circ.ahajournals.org/content/101/23/e215.full]; 2000 (June 13).

[2] Ohad Gal (2020). plot arrowhead (https://www.mathworks.com/matlabcentral/fileexchange/3345-plot-arrowhead), MATLAB Central File Exchange. Retrieved March 30, 2020.