IBEHS 3A03 – Biomedical Signals and Systems (2021)

Tutorial Assignment #3: Fourier Analysis of Biomedical Signals

Submission deadline: 11:59pm on Tuesday, November 23rd.

Submission requirements: Please see the document **IBEHS3A03 - Assignments - General Instructions** on Avenue.

Motivation:

In lectures, we have looked at how Fourier analysis of discrete-time signals, including real physiological signals, can be conducted using the custom function `fourier_dt()`, which is based on the inbuilt MATLAB function `fft()`, and the function `spectrogram()` from the MATLAB Signal Processing Toolbox. In this assignment, you will gain hands-on experience in using these functions to analyze the frequency content of a blood-flow velocity signal obtained from doppler ultrasound (see Lecture #20) and of EEG signals (see Lecture #23) and in how to interpret the results of the spectral analysis.

Instructions:

Part A

Posted on Avenue in the content section **Assignments** and subsection *Assignment 3* is a MATLAB data file named `BFVdata_assignment3.mat`, which contains an array named `BFVdu` consisting of a time-domain blood-flow velocity signal collected at the sampling rate given by the variable `Fs` (= 100 Hz) in arbitrary units of amplitude. Download this file and develop a MATLAB script that uses `fourier_dt.m` to compute and plot the magnitude spectrum of:

1. the entire signal `BFVdu`,
2. a portion of signal `BFVdu` starting at element 1 in the array and going up to element L, where L is some integer less than the length N of the entire array, and
3. the signal portion up to sample L with zero-padding of length L.

Using your code, determine the smallest value of L for which the harmonic structure observed in the spectrum of the entire BFV signal (task 1 above) is well represented in the signal segment (task 2), and comment on whether zero-padding (task 3) helps with obtaining a better estimate of the entire signal's spectrum when using the signal segment of length L.

In your report, include a written explanation and example plots to describe how you decided on a suitable minimum value of L.

Part B

Posted on Avenue in the content section **Assignments** and subsection *Assignment 3* is a MATLAB data file named `EEGdata_assignment3.mat`, which contains arrays named `EEG1` and `EEG2`, consisting of EEG time-domain signals collected at the sampling rate given by the variable `Fs` (= 1 kHz) in units of μV. Download this file and develop a MATLAB script that:

1. uses `fourier_dt.m` to compute and plot the magnitude spectra of `EEG1` and `EEG2`, and
2. uses the magnitude spectra from above to compute and plot the signal *band power* in each of the following frequency bands for both `EEG1` and `EEG2`, as well as the power in each band normalized (i.e., divided) by its *bandwidth* (in Hz):

Rhythm/wave:	Delta	Theta	Alpha	Beta	Gamma
Frequency band range: (Hz)	[0, 3)	[3, 8)	[8, 13)	[13, 25)	[25, 100]

(Hint: the inbuilt MATLAB function `find()` is very helpful for finding the indices for elements of an array that match a prescribed logical argument.)

These two signals were measured in one human subject at different stages of consciousness in the one recording session. From your analysis of `EEG1` & `EEG2`, determine in which of the two recordings the subject was awake and resting with their eyes closed and in which of the two recordings the subject was in deep NREM sleep. (Note that these signals may also contain some low-frequency recording noise and/or 60-Hz powerline noise.)

In your report, you should show the plots from your code and answers to questions raised above.

Bonus:

Write MATLAB code that uses the `spectrogram()` function from the MATLAB Signal Processing Toolbox to compute and plot how the amplitude spectra of the blood-flow velocity and EEG signals from the main part of the assignment might change over time throughout the duration of the signals. In your report, include example plots and explain what you observe for any parts of this bonus that you attempt.

Grading Scheme:

Completing all components listed under **Instructions** above.	60
Following requirements listed in the document **IBEHS3A03 - Assignments - General Instructions** on Avenue.	40
Bonus	10