IBEHS 3A03 – Biomedical Signals and Systems (2024)

Assignment #3: Fourier Analysis of Biomedical Signals

Submission deadline: 11:59pm on Monday, November 18th.

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 the Week 7 lecture) and of EEG signals (see the Week 8 lecture) 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 in units of m/s collected at the sampling rate given by the variable `BFV_Fs` (= 100 Hz). Download this file and develop a MATLAB script that uses `fourier_dt.m` to compute and plot the discrete-time signal and the magnitude spectrum of:

1. the entire signal `BFVdu`,
2. the first half of the signal `BFVdu`, and
3. the first half of the signal `BFVdu` with zero-padding equal to the length of this portion of the signal, such that the total length is equal to the original signal.

Include these plots in your report and discuss how these three magnitude spectra compare to each other and whether zero-padding appears to be beneficial or not in estimating the spectrum of the first half of the signal.

Note:

- You may need to zoom in on the harmonics of the spectra to see them clearly.
- You may need to adjust the scaling of the magnitude spectrum of the zero-padded signal, because of how `fourier_dt.m` scales the magnitude spectrum by the signal length.

Create a modified version of the signal `BFVdu` by subtracting out the mean value of the entire signal and repeat steps 1–3 above. Include these plots in your report and discuss how the results compare to those for the original signal. Is the zero-padding more beneficial for this modified signal than for the original signal? If so, discuss why this might be the case.

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 in units of μV collected at the sampling rate given by the variable `EEG_Fs` (= 500 Hz). 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 and Parseval's Theorem 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	5