Signal and Data Analysis in Neuroscience
Bar-Ilan, spring 2022

Due date: 15/03/22, 08:00

Assignment 1

General Instructions:

1. Remember legends, axis labels (for all axes) and units for all graphs/plots.
2. Please add comments to your code and submit only the codes specified in the grating grade.
3. Write codes in python.
4. We encourage you to write your solution in English. (5 points bonus)
5. Submit a softcopy (including source code) to biu.sigproc@gmail.com.
6. Note the due date and time.
7. Individual work - No code sharing.

1) Sampling and quantification (30 points):

Two neuroscientists, Prof. Hemingway and Prof. Garcia-Marquez, are studying the field of sleep:

- Prof. Hemingway experiments are carried out with human subjects using EEG with a temporal resolution of 10 ms.
- Prof. Garcia-Marquez studies are conducted with mice in the hippocampus region using extracellular recordings with a temporal resolution of 1 ms.

Both are studying the effects of a new drug on the transition between two phases of sleep, wakefulness (alpha waves with frequency of 12 Hz) and phase 1 (theta waves with frequency of 6 Hz).

A. Plot an example single trial samples recording for each of the methods. Assume that the first half of the recording is alpha wave and the second is theta. Use a scatter plot with the corresponding resolution on the time axis. Duration of the single trial can be different between the two examples.
B. One of the students of Prof. Hemingway offered him to use averaging bins to reduce the noise in the data. Plot two scatter plots, one for bin of 4 samples and one for 5 samples. Add their interpolating plots.
   Explain which bin is better for detecting the sleep phase. Add a detailed calculation.
C. Explain how the use of the wrong temporal resolution can lead to a confusion between the two oscillations. Illustrate your explanation by plotting a scatter plot of the ground truth oscillation and interpolating plot for the false-detected oscillation. Write on the legend the frequency values of each of them.

Grading Table

Grade component	Requirements	Points
Calculations	Accuracy, full details	10
Explanations	One paragraph for each section with Clear and concise explanations. No point reducing for grammar and spelling mistakes. Points will be reduced for overly long, vague explanations.	10
Figures	Correspondence to instructions, no missing components, clear visibility	10

2) Stochastic process (30 points):

The data files '*eeg1.csv*', '*eeg2.csv*' and '*eeg3*.csv' are matrices each containing 300 repetitions of an experimental EEG recording. Each 5 second recording has 500 samples performed at a rate of 100 samples/second (i.e. 200 random variables).

A. Write a general function which its input is one matrix and its outputs are two binary variables representing if the recording is stationary in the wide sense and ergodic.
B. For each of the 3 recordings, determine if the process is stationary in the wide sense and ergodic. Demonstrate your statements using relevant figures and calculations.

Grading Table

Grade component	Requirements	Points
Code writing (Submit code only for section A)	Accurate calculations, comments to explain your code, code is running (no bugs). No point reducing for code efficiency.	10
Explanations	One paragraph for each statement with Clear and concise explanations. No point reducing for grammar and spelling mistakes. Points will be reduced for overly long, vague explanations.	15
Figures	No missing components, clear visibility	5

3) Firing rates and convolution (40 points)

The data file 'spike_times.csv' contains spikes times recorded over 10 seconds. Spikes times are in seconds but recorded with sub-millisecond resolution. Use milliseconds bins to create the spike train.

A. Calculate the mean firing rate over the whole period. **3 points**
B. Find the spike firing rate r(t) using non-overlapping windows of length 0.2s. Repeat this for windows of 0.5s, 1s and 3s.
   Plot r(t) for the different windows in the same plot (in different colors).
   6 points
C. Write your own convolution function 'MyConv'. Compare 'MyConv' to the built-in convolution function (python – numpy.convolve).
   Display the result of convolving a simple uniform function [x = ones(30,1)] with a small rectangular window (length = 6 bins). Plot also the result from the built-in function for comparison. Make sure to treat the edges correctly.
   7 points
D. Find the spike firing rate r(t) using a sliding rectangular window of length 0.2s.
   Repeat this for windows of 0.5s, 1s and 3s.
   Plot r(t) for the different windows on the same plot.
   Remember to normalize each window's area to 1.
   6 points

E. Find the spike firing rate r(t) using a sliding Gaussian (window span = 0.8 sec, std =0.25s).
   Repeat with a Gaussian window of span = 0.45 sec and std = 0.1s.
   Plot r(t) for the different windows on the same plot. Plot both windows.
   6 points
F. Write one-two pages to summarize your results. Display the results of sections A,B,D,E together and explain the differences between them (one page). **12 points**

Notes:

1. In case 'MyConv' results are different form the built-in functions, use the built-in functions for D-E. Otherwise, use your function.
2. Data for the assignment is CSV format with a ',' delimiter, you can load it using the np.genfromtxt('file', delimiter=',').

Grading Table

Grade component	**Requirements**	**Points**
Code writing (Submit code only for section C)	Accurate calculations, comments to explain your code, code is running (no bugs). No point reducing for code efficiency.	7
Figures and calculations	Accuracy, no missing components, clear visibility	21
Explanations	No point reducing for grammar and spelling mistakes. Points will be reduced for overly long, vague explanations.	12

Good luck!
SDA team.