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

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

Assignment 2

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) Signal to noise ratio (30 points)

Dr. Borges have use recording electrodes from the muscles of a human subject in a coma to study the proprioceptive signals in that area. Dr. Borges is interested in changes of the signal with a resolution of 100 ms. Unfortunately, the recording was very noisy. Help Dr. Borges to reduce the noise in his data. The file 'noisy_signal.csv' contains 5000 noisy samples of a recorded signal with sampling rate of 1000 Hz. Dr. Borges would like to estimate the signal to noise ratio. To do that, Dr. Borges would like to separate the noise from the signal.

A. Create a generalized function which optimizes the smoothing of data using a gaussian window. The function needs to perform the following steps:
    1. For the given gaussian size, the function will smooth the signal using gaussian windows with STD from the range 0.5-500
    2. For each window the function subtracts the smoothed signal from the original one and computes the SNR between the original signal and the residual noise in dB using the RMS definition.
    3. The function optimizes the smoothing window using the SNR values.

    The function must include the following definitions:

    input: signal (1D vector of floats)
    size of smoothing window

    output: SNR of best gaussian in dB
    STD of the window
    Best smoothed signal
    A plot of the original signal and the smoothed one
    Residual plot (scatter plot of the residuals when the smoothed data is subtracted from the original one).

B. Using your function plot 4 possibilities of smoothing windows ranging between 5 and 2000. For each graph write the STD of the smoothing window SNR.
    Explain the differences between the results and give your advice for the best size of the window Dr. Borges should use. Note the relevant time resolution for his study.

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.	15
Explanations	250-500 words. Use clear and concise explanations, describing in full details your figures and the conclusions from them. 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	5

2) Tuning Curves (40 points)

An experiment was performed to record extracellularly from a neuron in the eye of a Donnis Qixotenis that reduces its spiking rate when presented with various wavelengths of light. 14 different wavelengths were presented (labeled 1-14). 50 trials were made for each wavelength. A trial consists of 1 second recording at a sampling rate of 1000 samples/s, the stimulus is presented for 0.4 seconds and starts 0.2 second after recording began.

The file 'q2data' contains a 3d array with size 14X50X1000 containing the results (provided in .pkl format).

A. Compute the baseline firing rate of the neuron. Explain the duration you chose for the calculation and your estimation. Justify your estimation using a figure demonstrating the distribution of firing rates in all trials recorded.

   10 points

B. Write three functions, each computes a qualitative size representing the sensitivity of the neuron to each of the wavelengths. Each function averages across trials, and follows one of the three following methods:
   1. Function 1 computes the mean firing rate during the presentation of the stimulus
   2. Function 2 computes the mean firing rate assuming a delayed 100 ms response of the neuron to stimulus onset.
   3. Function 3 computes the mean difference in firing rate baseline and the firing rate during the presentation of the stimulus.

   15 points

C. Describe the neuron's activity pattern according to the results and explain the differences (if any) between the three methods. Use figures to justify your claims and decide what kind of graph is the relevant one.

   10 points

D. Find a model for the tuning curve based on the first method in section B (Hint: use a gaussian distribution). Explain the relation of each of the parameters of the model to the neuron's preferred stimuli.
5 points

Grading Table

Grade component	**Requirements**	**Points**
Figures	Relevant graphs, correspondence to instructions, no missing components, clear visibility	5
Code writing (Submit code only for section B)	Accurate calculations, comments to explain your code, code is running (no bugs). No point reducing for code efficiency.	15
Explanations (Sections A,C,D)	150-500 words for each section. Use clear and concise explanations, describing in full details your figures and the conclusions from them. No point reducing for grammar and spelling mistakes. Points will be reduced for overly long, vague explanations.	10
Argumentation	Presenting persuasive and strong arguments for the claims. Accuracy in the details provided.	5
Calculations (Section D)	Accuracy, full details	5

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3) Stochastic Point Process (30)

The files 'spk1.csv' and 'spk2.csv' contain spike times of stochastic point processes recorded for 50 seconds. Spike times are in seconds.

A. Write a general function which computes the Fano Factor (FF) and Coefficient of variation (CV) for a given vector of spike times.
   The function must include the following definitions:
   input: signal (1D vector of floats)
   size of window for calculations
   output: Fano Factor value (FF)
   Coefficient of variation (CV)
B. Run your function with the two signals using windows of 1 second, 500 ms and 100 ms. Present your results for each window and explain the differences between them.
C. Determine if any of the given signals fits the Poisson model for a neuron. If one doesn't fit the model, offer another model for its behavior (general description, not mathematical one).

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.	12
Explanations (Sections A,C,D)	A paragraph for each section. Use clear and concise explanations. No point reducing for grammar and spelling mistakes. Points will be reduced for overly long, vague explanations.	18

Good luck!
SDA team.