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

Due date: 29/03/22, 08:00

Assignment 3

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) Properties of a single Poisson process with refractory period (40 points)

Prof. V. Woolf is writing a paper about the properties of neurons with refractory period. A part of her paper is dealing with a model of a Poisson neuron with refractory period. Help her with the following tasks:

A. Write a code which generates a simulation of a spike train for 90 seconds using a Poisson process with a refractory period, in 1 millisecond bins with the following parameters:
   - The baseline firing rate rate (r_0) is 55 spikes/second.
   - The refractory period as followed:
     - Absolute refractory period: After each spike, 5 ms with no spikes at all (i.e. r(t+1)= r(t+2)= r(t+3)= r(t+4)=(t+5)=0, where t (in ms) is the time of the spike)
     - Recovery period: a period of 6 ms, in which the firing rate of the Poisson process (r_{ref}) increases linearly from 0 back to r_0 (i.e. r(t+6)=(r_0*1/6) , r(t+7)=(r_0*2/6), r(t+8)=(r_0*3/6), etc.)

B. Based on your simulation, calculate and plot the following:
   a. TIH and TIH in logarithmic scale
   b. Survivor Function
   c. Hazard Function
   d. Autocorrelation (maximal time lag ± 100 ms) normalized to rate. Assign 0 for zero time-lag.

C. The paper is comparing the differences of neurons with and without refractory periods. For each graph, write a comparison between your results to and a simple Poisson neuron (without refractory period). Illustrate the differences by adding at least one plot for the simple Poisson neuron.

D. Organize all your results into one figure (you can use PowerPoint for that) and add a figure legend, a short explanation with the title of the figure and an explanation for each plot. Emphasize the results shown in the plots. We recommend using a paper from your research as an example.

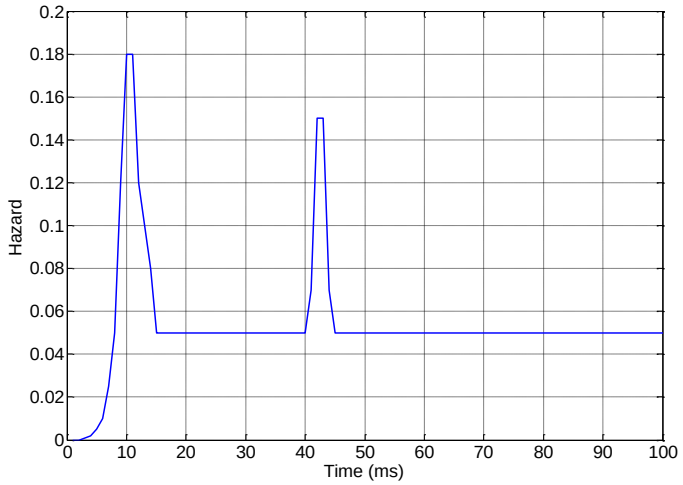
Grading Table

Grade component	Requirements	Points
Code writing (Submit code only for section A)	Relevant method for simulation, comments to explain your code, code is running (no bugs). No point reducing for code efficiency.	15
Explanations	250-500 words for section B and C together.	10

	Use clear and concise explanations, describing in full details your figures and the conclusions from them. No point reducing for grammar and spelling mistakes.	
Figures	Correspondence to instructions, no missing components, clear visibility, short and precise explanations in the figure legend.	15

2) Extracting the autocorrelation from the Hazard function (10 points)

Given the following hazard function:



A. Sketch the autocorrelation function ±1 second and explain how your computations.
B. Is the neuron Poisson, Regular, Bursty? Explain your answer

Important note: "Sketch" means draw by hand a coarse solution when you should provide values for points of special interest (min/max). Values can be either accurate calculation if results are easy to extract. Otherwise, provide a rough estimation.

Grading Table

Grade component	**Requirements**	**Points**
Calculations and sketches	Accuracy, no missing components	6
Explanations	250-500 words for the whole question. No point reducing for grammar and spelling mistakes.	4

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3) Cross-correlation (20)

In this question you need to calculate the autocorrelation and cross-correlation of three neurons:

1. Neuron A is a regular neuron, alternating between ISIs of 100 and 200ms (e.g. spike at 100, 300, 400, 600, 700, 900, etc.).
2. Neuron B is a Poisson neuron excited by neuron A. Every spike of neuron A leads to an increase in neuron B firing rate from a baseline of 10 spikes/sec to 20 spikes/sec, for a period of 20 ms, following a delay of 4 ms.

Recordings from these neurons were conducted 5 times, for 3 minutes each with a sampling rate of 30000 Hz.

Draw by hand a solution and indicate exact values for points of special interest (critical points in X and Y axes):

A. Draw the autocorrelation functions of A & B in the range of ±500ms, normalize to rate.
   10 points
B. Draw the cross-correlation of (A,B) in the range of ±500ms, normalize to rate.
   10 points

For each section add a one-two paragraph explanation about the method of calculating the autocorrelation.

Grading Table

Grade component	**Requirements**	**Points**
Calculations and sketches	Accuracy, no missing components	10 (5 for each section)
Explanations	250-500 words for the whole question. No point reducing for grammar and spelling mistakes.	10 (5 for each section)

4) Common input Cross-correlations analysis (30)

Two neurons (A&B) receive a common inhibitory input from a third neuron (C).

A. Sketch the expected shape of the cross-correlations A->B, A->C, B->C. For each cross-correlation explain how you calculate the shape and describe if there's a peak or a trough, and at what time lag.
B. Write a code for a simulation of neurons which demonstrates your answer and plot the cross correlation between the neurons.
   You can re-use parts of the simulation from question 1.

Grading Table

Grade component	Requirements	Points
Code writing (Submit code only for section B)	Relevant method for simulation, comments to explain your code, code is running (no bugs). No point reducing for code efficiency.	10
Explanations	500-1000 words. Use clear and concise explanations, describing in full details your sketches and the conclusions from them. No point reducing for grammar and spelling mistakes.	15
Figures	No missing components, clear visibility	5

Good luck!
SDA team.