MIDTERM #2 PROGRAMMING ASSIGNMENT:

INSTRUCTIONS:

A. Submit your write up and MATLAB code as a single .mlx file through Stellar before **Wednesday 4/25 11:59 pm**.
B. Follow PSET submission guidelines. Keep your write up short and to the point.
C. You must work **alone**, and you may not discuss this assignment with other students. You may refer to course notes, problem sets, recitation materials, MATLAB documentation, and online MATLAB help.
D. Do not post on Piazza nor email the teaching staff with questions regarding this assignment.
E. Please ensure that all your plots and answers are properly labeled and have the correct units.
F. This programming assignment is worth 100 points total.

Programming assignment:

In this assignment, you will demonstrate your ability to perform spike train analyses from raw electrophysiological data. There are 2 data sets that come from Maurice Chacron's lab (McGill University, Montreal, Canada). This lab studies electrolocation and communication in the weakly electric fish *Apteronotus leptorhyncus* (brown ghost knifefish). The recordings are from pyramidal cells in the electrosensory lateral line lobe, an area of the fish brain which is specialized in processing the electric sense of these fish and has a resemblance in structure and organization to the cerebellum.

PART 1: Analyzing an intracellular recording [65 points]

The file *`intracellular.mat`* contains three variables: `Vm`, `timeaxis`, and `SpikeTimes`. `Vm` is the membrane potential (in mV) of a pyramidal cell obtained from an intracellular sharp electrode recording. `timeaxis` gives the times (in seconds) at which the values of `Vm` where sampled. `SpikeTimes` are the timestamps at which action potentials (spikes) occurred in this recording in units of seconds.

1. [5 points] What is the frequency in Hz at which `Vm` was sampled at?
2. [5 points] Make a figure with 2 subplot panels. On the first panel, plot the first 3 seconds of the data. On the second panel, plot the first action potential in the recording (choose an axis scaling so that you can see the features of the spike clearly).
3. [10 points] In this question we will write code to retrieve the times at which spikes occurred from a membrane potential recording. To do so, use MATLAB function

`findpeaks`[1] to generate a list of times (in units of seconds) at which action potentials occurred. You will need to adjust the parameters: `'MinPeakHeight'` to choose a reasonable threshold for detection, and `'MinPeakDistance'` to avoid counting a spiking event more than once. To check your detection scheme, use the provided function `testSpikeDetector` (this function takes spike times lists in units of seconds) and the supplied `SpikeTimes` array. This function will compare your list of spike times with the one we have supplied to you and return two performance metrics: the percentage of correct detection (PCD[2]), and the false alarm rate (FAR[3]). Your detection scheme must achieve a PCD greater than 90% and a FAR of less than 2 spikes/second. Report these values and the number of spikes detected.

4. [5 points] What is the mean firing rate in Hz for this recording?
5. [10 points] Compute the inter-spike interval (ISI) sequence from the spike times and plot an ISI histogram with a bin-width of 1 millisecond going up to 200 milliseconds.
6. [5 points] How variable is this neuron? Answer the question by computing the coefficient of variation (CV). Is it more variable than a Poisson process?
7. [10 Points] Make a binary spike train for this data sampled at 1 kHz. Use this binary representation to estimate the instantaneous firing rate (IFR) as a function of time. To obtain an estimate of the IFR convolve the binary spike train with a square window kernel of width 100 milliseconds. Make sure that your kernel has an area of 1, it is sampled at the same frequency as the binary train, and that the IFR is reported in Hz. Plot the IFR as a function of time. What is the mean value of the IFR?
8. [10 points] Compute the raw autocorrelation of the spike train and divide it by the total number of spikes. Explain intuitively what the y-axis represents. Plot the autocorrelation on a time scale of -50 to 50 milliseconds.
9. [5 points] From the above analyses estimate the absolute refractory period of this neuron. Provide a succinct rationale for your answer.

PART 2: Measures of neural encoding [35 points]

The file *`SpikeTrain.mat`* contains two variables: `data` and `stim`. A given neuron has been stimulated with "frozen noise". I.e. the stimulus has been repeated many times and each epoch lasts 50 seconds. The stimulus is sampled at 2kHz and is the variable `stim`. The stimulus is zero-mean Gaussian white noise.

The `data` matrix is organized as follows: the first column contains the trial indices, the second column contains the spike times (in msec), and the third column contains the inter-spike intervals (in msec).

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[1] Check the MATLAB documentation for syntax details

[2] A correctly detected spike is defined here as one with a reported time within +/- 2 milliseconds of the actual spike time.

[3] The number of spikes reported per second that did not actually occur

1. [10 points] You suspect that the information on the stimulus type has an important omission. To check your hunch, you decide to compute the power spectrum of the stimulus. Plot the power spectrum of the stimulus on a dB-scale. Based on this plot: was some information omitted? If so, what you think this stimulus consist of?
2. [5 points] Plot a raster plot of the spike data (you simply need to select the appropriate 2 columns of the `data` matrix). Restrict your time-axis to the first 500 milliseconds of data.
3. [10 points] Make a binary spike train representation of each trial at 2kHz. It is easier if you organize these trains in a matrix where each row is the binary train for a given trial.
   Build a PSTH from the spike data with a bin-width of 1 millisecond. Then make a 2-panel figure. On the top one plot the PSTH, on the bottom one the stimulus as a function of time.
4. [5 points] Compute and plot the raw cross-correlation function between the binary spike train for trial 1 and the stimulus.
5. [5 points] In a few words, what does the cross-correlation represents from the perspective of the recorded neuron?