BMEN90002 Neural Information Processing

Laboratory Assignment 1

This assignment should be done individually with each student submitting their own report. The laboratory carries 10% of the assessment for this subject.

You are required to submit a report (including answers to the questions below and clearly-labelled figures) and your (clearly commented) MATLAB code via LMS by

11:59 pm, Friday, 30th August 2019.

Late submissions will incur a penalty of 20% of the laboratory marks per day, including weekends.

Your report should be in PDF format with file name:

```
Lab1_StudentNumber.pdf
```

where you substitute your student number in the file name. Your document should also include your name and student number on the first page of the submission.

Your MATLAB code should be contained in two m-files that are named

```
Lab1_StudentNumber_Q1.m
Lab1_StudentNumber_Q2.m
```

where each file contains the code for Questions 1 and 2, respectively, and where you substitute your student number in the file name.

Each of your MATLAB m-files must start with the commands:

```
clear
close
```

You must ensure that all submissions comply with University of Melbourne policy on academic honesty and plagiarism: http://academichonesty.unimelb.edu.au

Question 1.

In this question, you will numerically generate a set of spikes and check their distribution.
You may use MATLAB's inbuilt random number generator,

```
rand(M,N)
```

that returns an M by N matrix of pseudo-random numbers distributed between zero and one.
Place the command

```
rand('state', sum(100*clock))
```

at the start of the m-file to ensure that a different set of random numbers are used each time you run your program.

(a) Generate `N=10000` input spikes with a Poisson rate of $\lambda = 10$ Hz. Note that a set of N interspike intervals with a Poisson distribution corresponding to a spiking-rate 1 Hz can be generated using (see slide 17 of Lecture 6):

```
isi = -log(rand(1,N));
```

Q1: How must this function be modified to generate the spikes with the correct Poisson rate?

Plot the inter-spike interval (ISI) histogram with 50 time bins up to just under 1 sec using the following MATLAB functions

```
t = 0:0.02:0.98;
h = histc(isi,t);
bar(t,h,'BarWidth',1);
```

(b) Compare the ISI histogram with the expected (analytic) distribution by plotting the analytic expression on the same figure for `t=0:0.02:0.98`.
You will need to appropriately scale the analytic distribution.

Use the command "`hold on`" to keep the first plot while plotting the second.

Q2: Describe the scaling method that you used to help match up the histogram with the plot of the analytic expression.

Include the plot of the ISI histogram and the expected distribution in your report and comment on similarities and differences.

Q3: How does changing `N` to lower or higher values affect the result? Why?

(c) Compute the statistics of the simulated ISI spikes.

Q4: What are the mean, variance and coefficient of variation of the simulated ISI distribution for 10,000 spikes?

Q5: Compare them to the mean, variance, and coefficient of variation for the theoretical distribution. Recall that the coefficient of variation is defined as:

$$C_V = \frac{\text{Standard Deviation}}{\text{Mean}}$$

Question 2.

In this question, you will numerically simulate a model of an orientation-selective V1 neuron in the visual system.

In this model, the estimated firing rate is determined from the response tuning curve,

$$r_{\text{est}}(t) = f(s(t)) = r_{\max} \exp\left(-\frac{1}{2}\left(\frac{s(t)-s_{\max}}{\sigma_f}\right)^2\right),$$

where $r_{\max} = 50$ Hz is the maximum firing rate, $s(t)$ is the stimulus orientation (in degrees), $s_{\max} = 0$ degrees is the stimulus orientation that gives the maximum response, and $\sigma_f = 15$ degrees represents the width of the response.

You are required to simulate an experiment where the orientation angle is modified in a sequence of steps over a 500 msec period. The orientation angle starts (at $t = 0$) at –40 degrees. The orientation angle instantaneously increases by 20 degrees every 100 ms, finishing after 500 ms at +40 degrees. Be sure to include the plots in your report.

(a) Using the MATLAB plotting function `subplot`, plot a graph of the stimulus orientation vs. time on one plot (`subplot(5,1,1)`).

Plot a graph of the firing rate vs. time on another plot (`subplot(5,1,2)`).

Set up the stimulus orientation and firing rate curves using the commands below, ensuring that you choose an **appropriate** time step size, `dt`.

Q6: Explain your choice of value for `dt`.

```
t = [0:dt:(0.5-dt)];                          % time axis
stimulus = -40+floor(t/0.1)*20;               % orientation angle
rate = 50*exp(-0.5*(stimulus/15).^2);         % rate of firing
```

(b) Generate a sequence of spikes over 500 ms based on the firing rate function. Store these as spike times in an array called "`spikes`". Plot the spikes on one plot (`subplot(5,1,3)`) as unit bars.

Q7: Comment on how the resulting set of spikes differs from or resembles the firing rate function of `subplot(5,1,2)`. Would one set of spikes such as this be sufficient to determine the function of the V1 neurons? Why or why not?

Hint: Use the Poisson spike generator routine on slide 16 of Lecture Week 3 "Neural Coding 2" plus the following code…

```
spikes=[];     % Initialise an array of spikes
% Create a for loop to generate spikes
% Each time a spike is created use...
  spikes=[spikes new_spike_time]; % append a new spike to the array
  plot([new_spike_time new_spike_time], [0 1]); % Plot new spike
```

(c) Simulate repeated presentations of the stimuli to the neuron by generating 50 sequences of spikes, each over 500 ms, based on the firing rate function. Store these as spike times in a one-dimensional array, `spikes50()`, appending each sequence to the end of the previous sequence.

Plot these spikes on one plot (`subplot(5,1,4)`) as unit bars, producing a raster plot.

Q8: Comment on how the resulting set of spikes resembles the firing rate function of `subplot(5,1,2)`. Is this representation better than the one set of spikes in part (b) for determining the function of the V1 neurons? Why or why not?

Hint: To separate the 50 spike iterations, plot the spikes using

```
plot([new_spike_time new_spike_time], [n-1 n]);
```

where "`n`" is the sequence number.

(d) Generate a peri-stimulus time histogram (PSTH) with time bin widths of 10 ms and plot this on the last subplot (`subplot(5,1,5)`). Ensure that you scale the histogram appropriately.

Q9: Compare the PSTH to the firing rate plot (subplot(5,1,2)) and comment on similarities and differences. Why is the PSTH useful for characterising the response of a neuron?

Q10: Investigate the use of other bin widths, such as 1 ms or 100 ms. What key features do you see and why?

Hints: Use the commands

```
[n,xout]=hist(spikes50,num_bins);     % generate PSTH
bar(xout,n,1);                        % plot the PSTH
axis([0 0.5 0 max(n)]);               % set the axes
```