BMEN90002 Neural Information Processing

Laboratory Assignment 3

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 on LMS by

11:59 pm, Friday, 4th October 2019.

Your report should be in PDF format, submitted via Turnitin on the "Workshops" link on LMS for your lab session, with file name:

```
Lab3_StudentNumber.pdf
```

where you substitute your student number in the file name.

Your MATLAB code should be contained in three m-files, submitted via the "Workshops" link on LMS for your lab session, that are named

```
Lab3_StudentNumber_Q1.m,
Lab3_StudentNumber_Q2a.m
Lab3_StudentNumber_Q2b.m
```

where you substitute your student number in the file names.

Each of your MATLAB m-file 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

Indicated marking scheme is out of a total of **20 marks**.

Question 1. (8 marks)

In this question, you will measure the frequency response function and rate-level function of a simulation of an auditory neuron.

The code for the auditory neuron is available on LMS in the Labs folder. It is called `auditory_nerve.m`. Download the file and save it to your MATLAB working directory. The function is called using the command

```
spikes = auditory_nerve(stimulus, dt)
```

The function simulates a single auditory nerve fibre, creating a sequence of spikes every `dt` seconds.
Input:

`stimulus`: sampled input stimulus, such as a sine wave
`dt`: sampling period in seconds

Output:

`spikes`: array of spike times in seconds

Be sure to include informative plots in your report.

(a) Your first task is to find the characteristic frequency (or best frequency) of the auditory neuron. To do this, create pure tone stimuli that span the range of frequencies between 100 Hz and 4000 Hz in 100 Hz steps. The following code will help get you started:

```
Fs = 10000;      % Sampling rate for the stimuli
dt = 1/Fs;       % Corresponding sampling period

f = 100;         % Stimulus frequency in Hz
t = 0:dt:1;      % Stimulation time in seconds

stimulus = 100*sin(2*pi*f*t);   % Pure tone stimulus
```

Create stimuli for frequencies in the range 100-4000 Hz and plot the number of spikes generated for each stimulus. You may need to increase the duration of the stimuli or present each stimulus multiple times to reduce the effect of noise. **(1 mark)**

Q1: Which frequency gives the greatest response? This is the characteristic frequency. Explain how you have found this frequency and why you think it is the best answer. **(3 marks)**

(b) Now give the neuron a zero stimulus with duration of one or more seconds.
Q2: What is the spontaneous rate of the auditory neuron? **(1 mark)**

(c) Plot a rate-level curve for the neuron at its characteristic frequency. This may be achieved by varying the amplitude of the stimulus at characteristic frequency. **(1 mark)**

Q3: What is the approximate "threshold" of the neuron? The "threshold" in this case is defined in this case as the point where the output rate is 10% greater than the spontaneous rate. **(1 mark)**

Q4: Approximately at what stimulus amplitude does the neuron's output rate saturate and what is the saturation firing rate of the neuron? **(1 mark)**

Question 2. (12 marks)

In this question, you will investigate the Hodgkin-Huxley neuron model.

(a) In MATLAB, create an ODE function `HH` in file `HH.m`

```
function xdot=HH(t, x, flag, Iapp);
% Variables...
V=x(1); m=x(2); h=x(3); n=x(4);
% Set constant parameters…
VNa=50; gNa=120;
VK=-77; gK=36;
VL=-54.4; gL=0.3;
C=1;
%
taum=1/(0.1*(V+40)/(1-exp(-(V+40)/10))+4*exp(-(V+65)/18));
minf=(0.1*(V+40)/(1-exp(-(V+40)/10)))*taum;
tauh=1/(0.07*exp(-(V+65)/20)+(1/(1+exp(-(V+35)/10))));
hinf=0.07*exp(-(V+65)/20)*tauh;
taun=1/(0.01*(V+55)/(1-exp(-(V+55)/10))+0.125*exp(-(V+65)/80));
ninf=(0.01*(V+55)/(1-exp(-(V+55)/10)))*taun;
%
xdot(1,1)=(Iapp - gNa*m^3*h*(V-VNa) - gK*(V-VK)*n^4 - gL*(V-VL))/C;
xdot(2,1)=-(m - minf)/taum;
xdot(3,1)=-(h - hinf)/tauh;
xdot(4,1)=-(n - ninf)/taun;
% End HH.m
```

Simulate and plot the membrane voltage using the following commands in `Lab3_StudentNumber_Q2a.m`

```
close all
duration = 100;     % duration of simulation in msec
Iapp = 0.0          % applied current injection
tInit = [0 duration];
xInit=[-65; 0.052; 0.059; 0.317];
[t, x] = ode23('HH', tInit, xInit, [], Iapp);
plot(t, x(:,1));
axis([0 duration -80 60]);
xlabel('time (ms)');
ylabel('voltage (mV)');
```

Repeat for increasing values of `Iapp` until you observe oscillations.
Continue repeating for increasing values of `Iapp` until oscillations disappear.
Include in your report representative simulation results in your report and describe what you have observed. **(2 marks for representative simulations, 2 marks for observations)**

(b) You will now do a fast-slow analysis, where the Na^+ dynamics are considered to operate instantaneously as they are much faster than the K^+ dynamics. Create an ODE function `HHFS` in file `HHFS.m`

```
function xdot=HHFS(t, x, flag, Iapp);
% Variables...
V=x(1); n=x(2);
% Constant parameters…
% Just set them here…
VNa=50; gNa=120;
VK=-77; gK=36;
VL=-54.4; gL=0.3;
C=1;
%
taum=1/(0.1*(V+40)/(1-exp(-(V+40)/10))+4*exp(-(V+65)/18));
minf=(0.1*(V+40)/(1-exp(-(V+40)/10)))*taum;
tauh=1/(0.07*exp(-(V+65)/20)+(1/(1+exp(-(V+35)/10))));
hinf=0.07*exp(-(V+65)/20)*tauh;
taun=1/(0.01*(V+55)/(1-exp(-(V+55)/10))+0.125*exp(-(V+65)/80));
ninf=(0.01*(V+55)/(1-exp(-(V+55)/10)))*taun;
%
xdot(1,1)=(Iapp - gNa*minf^3*hinf*(V-VNa) - gK*(V-VK)*n^4 - gL*(V-VL))/C;
xdot(2,1)=-(n - ninf)/taun;
% End HHFS.m
```

Simulate and plot the membrane voltage using the follow commands in `Lab4_StudentNumber_Q2b.m`

```
close all
duration = 100;     % duration of simulation in msec
Iapp = 0.0          % applied current injection
tInit = [0 duration];
xInit=[-65; 0.317];
[t, x] = ode23('HHFS', tInit, xInit, [], Iapp);
plot(t, x(:,1));
axis([0 duration -80 60]);
xlabel('time (ms)');
ylabel('voltage (mV)');
```

Repeat for increasing values of `Iapp` until you observe oscillations.
Continue repeating for increasing values of `Iapp` until oscillations disappear.
Include in your report representative simulation results in your report and describe what you have observed. **(2 marks for representative simulations, 2 marks for observations)**

(c) **Q5:** Discuss whether the HHFS model can be used to understand the HH model qualitatively. Explain your answer. **(2 marks)**

Q6: Discuss whether the HHFS model can be used to understand the HH model quantitatively. Explain your answer. **(2 marks)**