University of Lincoln Assessment Framework Assessment Briefing Template 2024-2025

1. Module code & title	CMP9783M – Neural computing
2. Assessed learning outcomes	• [LO1]: Understanding of the principles of artificial and biological neuronal models and knowledge of their main areas of application in vision sciences • [LO2]: Demonstrate the ability to design, implement and analyse the behaviour of simple neural models
3. Assessment title	Assessment 1
4. Contribution to final module mark (%)	**50%**
5. Description of assessment task	This is Assessment 1 and is an **individual** assignment. **Overview** This set of exercises will take you through modelling a. An I&F neuron with adaptation b. A Hodgkin-Huxley model as an oscillator using MATLAB. You are required to write and submit a report where you need to provide all requested graphs, discuss how you completed the tasks, and provide snippets of MATLAB code you've developed for these tasks. You are expected to go into sufficient depth to demonstrate knowledge and critical understanding of the relevant processes involved. 50% of available marks are through the completion of the written report, with clear and separate marking criteria for each required report section. **Report Guidance** You must supply a written report containing **two** distinct sections that provide a full and reflective account of the processes undertaken. You are expected to answer all questions in each step in each section in detail and perform all analysis on your own.

Section 1 – LIF neuron model with adaptation (50%)

Neuroscience goal: Understand the reciprocal impacts of adaptation currents on spike trains and spike trains on adaptation currents; understand how limits on the firing rate and mean membrane potential depend on the spiking mechanism.

Computational goal: Simulate coupled differential equations with two variables; analyze simulation results and plot appropriate features of the simulation, for example, depending on the number of spikes produced.

In this exercise, you will analyse the impact of adaptation currents on the f-I curve of a neuron.

1. Write code to simulate the LIF model with an adaptation current so that the full model becomes:

$$C_m \frac{dV}{dt} = \frac{E_L - V}{R_m} + G_{SRA}(E_k - V) + I_{app}$$

and

$$\frac{dG_{SRA}}{dt} = -\frac{G_{SRA}}{\tau_{SRA}}$$

With the rule that if $V > V_{th}$ then $V \rightarrow V_{reset}$ and $G_{SRA} \rightarrow G_{SRA} + \Delta G_{SRA}$.

Use the parameters: E_L = -75mV, V_{th} = -50mV, V_{reset} = -80mV, R_m = 100MΩ, C_m = 100pF, E_k = -80mV, ΔG_{SRA} = 1 nS, and τ_{SRA} = 200ms. Initially set V = E_L and G_{SRA} = 0. (**5 points**)

   A. Simulate the mode neuron for 1.5s, with a current pulse of I_{app} = 500 pA applied from 0.5 s until 1.0 s. Plot your results in a graph, using three subplots with the current as a function of time, the membrane potential as a function of time and the adaptation conductance as a function of time stacked on top of each other. (**10 points**)

   B. Now simulate the model for 5 s with a range of 20 different levels of constant applied current such that the steady state firing rate of the cell varies from zero to 50Hz. For each applied current calculate the first interspike interval and the steady-state interspike interval. On a graph, plot the inverse of the steady-state interspike interval against applied current to produce an f-I curve. On the same graph plot as individual points (e.g. as crosses or squares) the inverse of the initial interspike interval. Comment on your results. (**10 points**)

2. Write a code to simulate the Adaptive Exponential Leaky Integrate-and-Fire (AELIF) neuron

$$C_m \frac{dV_m}{dt} = G_L \left[E_L - V_m + \Delta_{th} exp\left(\frac{V_m - V_{th}}{\Delta_{th}} \right) \right] - I_{SRA} +$$

and

$$\tau_{SRA} \frac{dI_{SRA}}{dt} = a(V_m - E_L) - I_{SRA}$$

while

if $V_m > V_{max}$, then $V_m \rightarrow V_{reset}$ and $I_{SRA} \rightarrow I_{SRA} + b$

Use the parameters: E_L = -75mV, V_{th} = -50mV, V_{reset} = -80mV, Δ_{th} = 2mV, G_L = 10 nS, C_m = 100 pF, a = 2 nS, b = 0.02 nA and τ_{SRA} = 200 ms. Initially set V = E_L and I_{SRA} = 0. (**5 points**)

a. Simulate the model neuron for 1.5 s, with a current pulse of I_{app} = 500 pA applied from 0.5 s until 1.0 s. Plot your results in a graph, using two subplots with the current as a function of time plotted above the membrane potential as a function of time. (**10 points**)

b. Now simulate the model for 5 s with a range of 20 different levels of constant applied current such that the steady state firing rate of the cell varies from zero to 50Hz. For each applied current calculate the first interspike interval and the steady-state interspike interval. On a graph plot the inverse of the steady-state interspike interval against applied current to produce an f-I curve. On the same graph plot as individual points (e.g. as crosses or squares) the inverse of the initial interspike interval. Comment on your results. (**10 points**)

<u>Section 2 – Hodgkin-Huxley model as an oscillator (50%)</u>

Neuroscience goal: Gain appreciation of the Type-II properties of the Hodgkin-Huxley model

Computational goal: Careful transposition of mathematical formulae and parameters into computer code; practice of simulations with several interdependent variables

In this exercise, you will simulate a full four-variable model similar to the original Hodgkin- Huxley model (though using modern units). The four variables, sodium activation, *m*, sodium inactivation, *h*, potassium activation, *n*, and membrane potential, *V*, will all be updated on each timestep, since they depend on each other. Initial conditions should be 0 for all gating variables, and E_L for the membrane potential, unless otherwise stated.

1. Set up a simulation of 0.35 sec duration of the Hodgkin-Huxley model as follows:

$$C_m \frac{dV_m}{dt} = G_L(E_L - V_m) + G_{Na} m^3 h(E_{Na} - V_m) + G_k n^4 (E_k - V_m) + I_{app}$$

$$\frac{dm}{dt} = \alpha_m(1-m) - \beta_m m$$

$$\frac{dh}{dt} = \alpha_h(1-h) - \beta_h h$$

$$\frac{dn}{dt} = \alpha_n(1-n) - \beta_n n$$

where the parameters are given in table 1 and the rate of constants are the instantaneous functions of membrane potential given in table 2.

Table 1. Parameter values for HH model

Parameter	Symbol	Value
Leak conductance	G_{Leak}	30 nS
Maximum sodium conductance	G_{Na}	12 µS
Maximum delayed rectifier conductance	G_k	3.6 µS
Sodium reversal potential	E_{Na}	45 mV
Potassium reversal potential	E_k	-82 mV
Leak reversal potential	E_L	-60 mV
Membrane capacitance	C_m	100 pF
Applied current	I_{app}	Variable

Table 2 Gating variables of the HH model

Gating variable	Steady state	Time constant	Rate constants
m	$\frac{\alpha_m}{\alpha_m + \beta_m}$	$\frac{1}{\alpha_m + \beta_m}$	$\alpha_m = \frac{10^5(-V_m - 0.045)}{\exp[100(-V_m - 0.045)] - 1}$
			$\beta_m = 4x10^3 * \exp[\frac{(-V_m - 0.070)}{0.018}]$
h	$\frac{\alpha_h}{\alpha_h + \beta_h}$	$\frac{1}{\alpha_h + \beta_h}$	$\alpha_h = 70 * \exp[50 * (-V_m - 0.070)]$
			$\beta_h = \frac{10^3}{1 + \exp[100(-V_m - 0.040)]}$
n	$\frac{\alpha_n}{\alpha_n + \beta_n}$	$\frac{1}{\alpha_n + \beta_n}$	$\alpha_n = \frac{10^4(-V_m - 0.060)}{\exp[100(-V_m - 0.060)] - 1}$
			$\beta_n = 125 * \exp[\frac{(-V_m - 0.070)}{0.08}]$

Initially set the applied current to zero and check the membrane potential stabilizes at -70.2mV. (**5 points**)

2. Produce a vector for the applied current that has a baseline of zero and steps up to 0.22 nA for a duration of 100 ms beginning at a time of 100 ms. Plot the applied current on an upper graph and the membrane potential's response on a lower graph of the same figure. (you should see subthreshold oscillations, but no spikes). (**5 points**)
3. Alter your code so that the applied current is a series of 10 pulses, each of 5 ms duration and 0.22 nA amplitude. Create a parameter that defines the delay from the onset of one pulse to the onset of the next pulse. Adjust the delay from a minimum of 5 ms up to 25 ms and plot the applied current and membrane potential as in question 2 for two or three examples of pulse separations that can generate spikes. Be careful (especially if using the Euler method) to repeat your simulation with your time step reduced by a factor of 10 to ensure you see no change in the response, as a sign you have sufficient accuracy in the simulation. (A timestep of as low as 0.02 µs may be necessary.). Describe and explain your findings. (**10 points**)
4. Now set the baseline current to be 0.6 nA. Set the initial conditions as $V_m(0)$ = -0.065V, m(0) = 0.05, h(0) = 0.5, n(0) = 0.35. (Note that the "0" in parenthesis indicates a time of t = 0, which corresponds to element number 1 in an array.) Apply a series of 10 inhibitory pulses to bring the applied current to zero for a duration of 5 ms, with pulse onsets 20 ms apart. Plot the applied current and the membrane potential's response as in questions 2 and describe and explain what you observe. (**10 points**)
5. Now set the baseline current to 0.65 nA. Set the initial conditions as $V_m(0)$ = -0.065 V, m(0)
= 0.05, h(0) = 0.5, n(0) = 0.35. Increase the excitatory current to 1 nA for a 5 ms pulse at the time point of 100 ms. Plot the applied current and resulting behavior in the same manner as in questions 2, 3, and 4. Describe what occurs and explain your observation. (**10**

	points) 6. Repeat 5 with the baseline current of 0.7 nA, but set the initial conditions as $V_m(0) = -0.065V$, $m(0) = 0$, $h(0) = 0$, $n(0) = 0$. As in question 5, increase the excitatory current to 1 nA for a 5 ms pulse at the time point of 100 ms. Plot the applied current and resulting behavior in the same manner as in questions 2-5. Describe what occurs and explain your observation, in particular by comparing with your results in question 5. (**10 points**)
3. Assessment submission instructions	The submission deadline of this assignment is included in the School Submission dates on Blackboard. You must make an electronic submission of your presentation report to the Turnitin upload area for Assessment 1. The report must: • Contain your name, student number, student email address, and module name • Be in PDF • Be formatted single-spaced with 11pt font size • Do not include this briefing document If you are unsure about any aspect of this assessment component, please seek the advice of the module co-ordinator **Dr. Zied Tayeb** <ztayeb@lincoln.ac.uk>
4. Date for return of mark and feedback	Please see the **Hand In Dates.xls** spreadsheet. Note: *all marks awarded are provisional until confirmed by the Board of Examiners.*
5. Feedback format	Summative feedback will be provided on BlackBoard according to CRG criteria (see CRG file). You will be given formative verbal feedback during the workshop sessions.
6. Use of Artificial Intelligence (AI) in this assessment	The use of AI tools to generate all or part of your assessment submission is **not** permitted unless specifically mentioned below.
7. Marking criteria for assessment	A Criterion Reference Grid (CRG) is used to evaluate your learning against a set of pre-defined criteria.
8. Additional informatio	

n (support, advice, tips etc)	Students are encouraged to use any lecture and their own personal notes to assist them with the completion of the assessment. Also, students are allowed to use any library and/or online resource as a guide on how to solve the assessment problems. Students are encouraged to seek assistance from any member of the delivery team and particularly from the module coordinator as means to complete the assessment.
9. Important Information on Dishonesty, Plagiarism and AI Tools	University of Lincoln Regulations define plagiarism as *'the passing off of another person's thoughts, ideas, writings or images as one's own...'*. Examples of plagiarism include the unacknowledged use of another person's material whether in original or summary form. Plagiarism also includes the copying of another student's work'. Plagiarism is a serious offence and is treated by the University as a form of academic dishonesty. For more information on examples of Academic Offences, please see the **Academic Offence Guidance**. Please note, if you use AI tools in the production of assessment work **where it is not permitted**, then it will be classed as an academic offence and treated by the University as a form of academic dishonesty. Students are directed to the University Regulations for details of the procedures and penalties involved. For further information, see www.plagiarism.org