International Institute of Information Technology, Hyderabad

CSE486 (Spring 2020) MID-SEM EXAM-1 (22-Feb-2020)

Introduction to Neural and Cognitive Modeling (INCM)

Time: 1.5 Hours **Max. Marks: 60**

INSTRUCTIONS:

Scientific Calculators are allowed. Please be as concise as possible in your answers.

Please start each question at the top of a page, indicating the question and sub-part numbers clearly.

If there is any ambiguity, make best assumptions and proceed but please state them.

Answer all the FOUR Questions.

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1. Answer the following: [6 + 9 = 15 Marks]

   A. What are Marr's three levels of analysis? Illustrate these levels using one concrete example.

   B. Write down the *Cable Equation* for passive dendrite and derive it.

2. Answer the following: [8 + 7 = 15 Marks]

   A. Indicate TRUE or FALSE for these questions and give suitable brief explanation.

   (i) In the subthreshold regime, excitatory synapses *always* depolarize the membrane, i.e, shift the membrane potential to more positive values.

   (ii) In the subthreshold regime, inhibitory synapses *always* hyperpolarize the membrane, i.e, shift the membrane potential to more negative values.

   Consider the equation $\frac{dx}{dt} = -\frac{x}{\tau} + c\sum_k \delta(t - t^k)$ for parts (iii) and (iv). Here $\delta(\cdot)$ is the dirac delta function and with a suitable interpretation of the variable x and the constant c:

   (iii) Equation describes a passive membrane voltage $u(t)$ driven by spike arrivals.

   (iv) Equation describes the conductance $g(t)$ of a simple synapse model.

B. Derive the expression for the time evolution of membrane voltage from a suitably defined equation for time-rate-of-change equation for the membrane potential, for the case of step current injection at time t_0 and with an initial membrane potential at u_{rest}) at time t_0. Assume a passive membrane model and also that $I(t < t_0) = 0$.

3. Answer the following: [8 + 7 = 15 Marks]

A. Describe the complete sequence of events that take place at the action potential initiation site, including the nature of ion flows at different stages of the action potential generation.

B. Write down the model for exponential integrate-and-fire (EIF) model. Explain how the threshold of firing changes when there is no external stimulating current as well as when there is a step current. Use graphs of $\frac{du}{dt}$ versus t and u versus t to illustrate the behaviour.

4. Answer the following: [8 + 7 = 15 Marks]

A. State the set of four differential equations that constitutes Hodgkin-Huxley equations. Label all the terms clearly and briefly explain what they stand for. Now, derive the equation for the membrane potential from the first principles.

B. Write down the *Nernst equation*, please label all the terms of the equation clearly. Now, assuming the Boltzmann constant $k = 1.4 \times 10^{-23} J/K$, the absolute temperature to be $T = 300K$, electron's charge to be $e = 1.60 \times 10^{-19} C$, calculate the reversal potential for Na^+, K^+, and Cl^- in millivolts (mV) assuming the following extracellular and intracellular concentrations: $C_{int}[K^+] = 140$, $C_{ext}[K^+] = 5$; $C_{int}[Na^+] = 12$, $C_{ext}[Na^+] = 145$; $C_{int}[Cl^-] = 5$, $C_{ext}[Cl^-] = 125$.