Biol635 / Math635 / Biol432 / Math430
Fall 2025

.

Assignment 3

Answer the following questions.

- Justify your answers.

- Explain your results.

- Provide the necessary calculations in a clear way.

- Provide the necessary supporting graphs and codes.

- Make sure the graphs are properly labeled and include the information (title and parameter values) necessary to understand your explanations.

- You may write your own code or adapt the template code provided in class.

Consider the following passive membrane equation

$$\tau \frac{dV}{dt} = -(V - E_L) + R\,I_{app}(t) \tag{1}$$

with $E_L = -60$ mV, $C = 1$ μF/cm^2, $G_L = 0.1$ mS/cm^2, Write a Matlab code (or use the template code) to solve eq. (1). Use $V(0) = -60$ mV and the following units for V, t and I_{app} respectively: $[V] = $ mV, $[t] = $ msec, $[I_{app}] = \mu$A/cm^2.

1. Build a leaky integrate-and-fire (LIF) model using $V_{th} = -50\,mV$, $V_{rst} = -65\,mV$ and the parameters values for the passive membrane equation above.

   (a) Simulate the model for the following values of I_{app} and plot the solutions.

       i. $I_{app} = 0.5$

       ii. $I_{app} = 1$

       iii. $I_{app} = 1.01$

       iv. $I_{app} = 2$

   (b) Calculate (analytically) the interspike-interval (ISI) firing rate (r_{isi}), if possible, for the values of I_{app} above

(c) Consider the following oscillatory current

$$I_{app}(t) = I_0 \ \sin(2\pi f t/1000).$$

with $I_0 = 0.5$. The input frequency f is given in Hz (number of cycles per second) and the units of time are msec.

Simulate the model for the following values of I_{app} and plot the solutions.

   i. $I_{app} = 0.5$

   ii. $I_{app} = 1$

   iii. $I_{app} = 1.01$

   iv. $I_{app} = 2$

2. (Graduate level) Extend the integrate-and-fire model (question1) to include spike rate adaptation using $V_{th} = -50\,mV$, $V_{rst} = -65\,mV$ and the parameters values for the passive membrane equation above.

(a) Compute the numerical solutions and plot the corresponding graphs for for $I_{app} = 2$, $E_k = -85$, $\Delta g_{sra} = 0.1$ and

   i. $\tau_{sra} = 10\,msec.$

   ii. $\tau_{sra} = 100\,msec.$

(b) Based on the literature, speculate on what are possible roles of spike-rate adaptation?

(c) Find examples of adaptation in other biological systems.

(d) Consider the following oscillatory current

$$I_{app}(t) = I_0 \ \sin(2\pi f t/1000).$$

with $I_0 = 0.5$. The input frequency f is given in Hz (number of cycles per second) and the units of time are msec.

Simulate the model for the following values of I_{app} and plot the solutions.

   i. $I_{app} = 0.5$

   ii. $I_{app} = 1$

   iii. $I_{app} = 1.01$

   iv. $I_{app} = 2$

Choose (b) **or** (c)