Assignment 1

Simulate a leaky integrate-and-fire model neuron with a resting potential of $V_{\text{rest}} = -65\text{mV}$ and a spiking threshold of -50mV. The input current is $I(t)$. The membrane has a decay constant of $\tau = 20\text{ms}$:

$$\frac{\mathrm{d}V(t)}{\mathrm{d}t} = -\frac{1}{\tau}\left[V(t) - V_{\text{rest}}\right] + I(t)$$

Add the assumption that the membrane potential cannot decrease below the reset potential, i.e. whenever an input pushes V to below the reset potential, reset it to -70mV.

Simulate your model neuron with excitatory and inhibitory inputs of varying magnitude and variance. Plot the interspike interval (ISI) distribution and compute the mean spike rate. Plot the coefficient of variation (CV) of the ISI distribution as a function of the standard deviation of the input current. What do you find and why?

Approach:

1. Implement a function that returns the membrane potential for arbitrary inputs. Discretize time into 0.1ms time bins. (Matlab: function) [1pt]

2. Test your function using inputs for which you know the correct results from the class, e.g. for $I(t) = 0$ starting with different intitial conditions, $V(0) = -70\text{mV}$ or $V(0) = -60\text{mV}$. Plot the computed membrane potential as a function of time. (Matlab: plot) [2pts]

3. Compute and plot $V(t)$ for a constant $I(t) = I_0$ where you vary I_0. What is the minimum value for I_0 for which $V(t)$ reaches the spiking threshold? Compute the time between two spikes and from that, compute the spike rate (number of spikes per second). Now make a plot of the spike rate as a function of I_0 ranging from $I_0 = 0$ to whatever current at which the spike rate is about 100 spikes/sec. [2pts]

4. Fixing I_0 at a value at which the rate is about 50 spikes/sec, now introduce variability into $I(t)$ by drawing I in each time bin from a Gaussian distribution around I_0 with standard deviation σ_I (Matlab: normrnd or randn). Compute the inter-spike-interval (ISI) distributions (Matlab: diff). Plot membrane potentials and ISI distributions (histograms) for three different values of σ_I for which membrane potential traces and ISI distributions are noticeably different from each other. In order to plot the membrane potentials, choose example runs that show the generation of 3-5 spikes. In order to plot an ISI distribution, run the simulation for long enough to generate 100 to 1000 spikes (Matlab: hist, ksdensity). Compute the coefficient of variation (CV) for each ISI histogram (standard deviation of the ISI divided by the mean of the ISI). [3pts]

5. Vary σ_I and plot the CV and spike rate as a function of σ_I. Choose a range of σ_I that includes values for which the CV is approximately one. [2pts]

At each step, summarize your observations in a couple of sentences, and include your predictions for each before you ran the simulations.

Note:

Please combine code, output and verbal answers into one compact PDF document. Please comment your code.