Coursework 3

Write a brief report, no longer than two pages, probably shorter, including the figures and the comments specified above; submissions exceeding the page limit will be rejected, I will take a dim view of super-narrow margins or tiny fonts. Submit it in the pdf format together with the Python or Julia code by the deadline. Remember, provided it is in good time, I am happy to answer questions about Python and to help debug faulty code. Submit the report as pdf; make sure to set the size of the graphs in your plotting programme, not by shrinking the graph to fit in the report, this makes the figure legends and axis numbers tiny and is super annoying. You don't have to plot in Python or Julia, it is fine to output a data file and plot using gnuplot or whatever.

Question 1

Simulate an integrate and fire model with the following parameters for 1 s: $\tau_m = 10$ms, $E_L = V_r = -70$ mV, $V_t = -40$ mV, $R_m = 10$ MΩ, $I_e = 3.1$ nA. Use Euler's method with timestep $\delta t = 1$ ms. Here E_L is the leak potential, V_r is the reset voltage, V_t is the threshold, R_m is the membrane resistance, that is one over the conductance, and τ_m is the membrane time constant. Plot the voltage as a function of time. For simplicity assume that the neuron does not have a refractory period after producing a spike. You do not need to plot spikes - once membrane potential exceeds threshold, simply set the membrane potential to V_r.

Question 2

Simulate two neurons which have synaptic connections between each other, that is the first neuron projects to the second, and the second neuron projects to the first. Both model neurons should have the same parameters: $\tau_m = 20$ ms, $E_L = -70$ mV $V_r = -80$ mV $V_t = -54$ mV $R_m I_e = 18$ mV and their synapses should also have the same parameters: $R_m \bar{g}_s = 0.15$, $P = 0.5$, $\tau_s = 10$ ms; don't get confused by being given $R_m \bar{g}_s$ rather than $\bar{g}_s$ on its own, to get τ_m rather than the capacitance on the left hand side of the integrate and fire equation everything is multiplied by R_m. For simplicity take the synaptic conductance

$$g_s = \bar{g}_s s \tag{1}$$

to satisfy

$$\tau_s \frac{ds}{dt} = -s \tag{2}$$

with a spike arriving causing s to increase by P. This is equivalent to the simple synapse model in the lectures. Simulate two cases: a) assuming that the synapses are excitatory with $E_s = 0$ mV, and b) assuming that the synapses are inhibitory with $E_s = -80$ mV. For each simulation set the initial membrane potentials of the neurons V to different values chosen randomly from between V_r and V_t and simulate 1 s of activity. For each case plot the voltages of the two neurons on the same graph (with different colours).

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1. Compute analytically the minimum current I_e required for the neuron with the above parameters to produce an action potential.

2. Simulate the neuron for 1 s for the input current with amplitude I_e which is 0.1 [nA] lower than the minimum current computed above, and plot the voltage as a functions of time.

3. Simulate the neuron for 1s for currents ranging from 2 [nA] to 5 [nA] in steps of 0.1 [nA]. For each amplitude of current count the number of spikes produced, that is the firing rate. Plot the firing rate as the function of the input current.