

Model of a single neuron

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Due No due date **Points** 0 **Submitting** a file upload

1. Simulate an integrate and fire model with the following parameters (notation as in the slides) for 1s:

$\tau_m = 10$ [ms] (i.e. τ_m is the time constant of the membrane)

$E_L = V_{\text{reset}} = -70$ [mV]

$V_{\text{th}} = -40$ [mV]

$R_m = 10$ [M Ω]

$I_e = 3.1$ [nA]

$DT = 1$ [ms]

And 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_{reset} .

2. Compute analytically the minimum current I_e required for the neuron with the above parameters (τ_m , E_L , V_{reset} , V_{th} , R_m) to produce an action potential.
3. Simulate the neuron (for 1s) for the input current with amplitude I_e which is 0.1 [nA] lower than the minimum current computed in part a), and plot the voltage as a function of time.
4. 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 (i.e. the firing rate). Plot the firing rate as the function of the input current.
5. Simulate two neurons which have synaptic connections between each other, i.e. 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]

$V_{\text{reset}} = -80$ [mV]

$V_{\text{th}} = -54$ [mV]

$R_m I_e = 18$ [mV]

and their synapses should also have the same parameters:

$R_m G_s = 0.15$

$P_{\text{max}} = 0.5$

$\tau_s = 10$ [ms].

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_{reset} and V_{th} and simulate 1s of activity. For each case plot the voltages of the two neurons on the same graph (with different colours). You should observe differences between the two cases. Comment these differences, and why they occur.

6. OPTIONAL: To get a mark above 60% from this assignment you have to do something beyond the topics discussed during the lectures. Here are some suggestions of things you may try:
- Look at more complex models of neurons described in Dayan & Abbott “Theoretical Neuroscience” and simulate Hodgkin & Huxley model, or model with bursting.
 - Read some papers in which multiple integrate and fire neurons were connected into a network (type into Google Scholar "integrate and fire neurons"), and simulate such a network.
 - Download some software for neural simulation (e.g. Neuron), figure out how to use it, and simulate something in it.
 - Let your imagination fly high, and do something amazing.

Write a brief report including the above mentioned figures and the comments specified above. All the plots should have axes labels, and if there are multiple graphs on a plot, the legend (or key) should be included. Submit it in the pdf format together with the Matlab code.