Assignment 1: Synaptic input in noisy neurons

Neural Computation 2018/19

September 27, 2018

Practical info

Due: 4pm Thursday 18 October, 2018

We may not be able to provide full feedback on assignments submitted after this date.

This assignment is for formative feedback only and not marked, hence will not form any part of your final grade. Feel free to work together in pairs or groups, and to discuss this assignment freely with anyone in class. You can ask clarifying questions on the class Piazza forum.

Organize your answers according to the questions; don't merge them. Plots should include axis labels and units. Some answers may require units as well. You will find that some questions are quite open-ended. In order to receive full marks for those you will need to do more than running a simulation and making a plot. Instead, you should justify your choices, and substantiate your explanations and claims, for instance by doing additional simulations or mathematical analysis. Just writing down all you can think of is discouraged, and incorrect claims can reduce marks. It should not be necessary to consult scientific literature, but if you do use additional literature, cite it. Add your code as an appendix to allow the marker identify problems, but note this can not replace an answer to a question. We will examine code as far as possible, but will be unlikely to trace back every bug.

For policies on late submissions, see the School Late coursework & extension website:

`https://bit.ly/1Jy2YyV`

Please note that the University has very strict guidelines on plagiarism, which apply for all marked coursework. You should not copy results, code or text from others. For information, please consult the School Academic misconduct website:

`https://bit.ly/2PTUH3A`

A real neuron receives inputs from many synapses on complicated dendritic trees. Here we model a very simplified case and examine the effect of a single input on a single dendrite using the NEURON simulator, both with and without noisy background activity.

Create a passive dendritic cable of 1μm diameter and 1000μm length using NEURON's defaults parameters (`insert pas`). Set `nseg` appropriately. Connect this to a cylindrical soma with a diameter of 10μm and length of 10μm with default Hodgkin-Huxley spike generation channels (`insert hh`).

Create an exponential synapse along the dendritic cable with the following parameters: a reversal potential 0mV, a maximal conductance of 0.1 μS, and a 5 ms time-constant.

Question 1 (5 points) Voltage clamp the soma at -70mV and measure the clamp current as you move the location of the synapse (the EPSC). Plot the peak clamp current vs the location of the synapse.

Question 2 (5 points) Explain the shape of the distance dependence found in question 1.

Question 3 (10 points) Now remove the voltage clamp and examine the voltage excursion in the soma caused by the synaptic activation while you vary the synaptic location. List and explain the differences with Question 1 in, for instance, the shape of the event and its location dependence.

Next, we mimic a condition where the neuron is under continuous bombardment of synaptic input. Rather than simulating all those extra synapses, we inject an ongoing noisy current into the soma and periodically stimulate the synapse (see notes below). Set the standard deviation of the noise to 1nA.

Locate the synapse on the dendrite, $200\mu m$ from the soma. To collect statistics, repeatedly stimulate the synapse. Make sure that the stimulation frequency of the synapse is fairly low to prevent interactions between the stimuli (say, intervals of 100ms).

Question 4 (5 points) Plot the probability that the synaptic input evokes a spike as a function of the strength of the synapse both in the absence and the presence of the noise. What happens if the synapse is located further away from the soma?

Question 5 (10 points) Measure the latency (time between activation of the synapse and the spike) and the precision of the spike time (the standard deviation in the latency) as a function of strength in presence and absence of the noise. Ignore events that did not cause a spike. Explain the findings.

Notes

1. Instead of running a different simulation for every synapse location, simulations for question 1-3 can be simplified by creating an array of synapse regularly spaced along the dendrite and stimulating each of them in succession. E.g.:

   ```
   Ni=10
   objref Espikesource[Ni]
   objref esyn[Ni]
   objref nc[Ni]
   access den
   for i=0,Ni-1{
   Espikesource[i] = new NetStim(0.5)
   Espikesource[i].number =1
   Espikesource[i].start = 100*(i+1)
   ....
   ```

2. To make the module for the noise injection download `noisy_iclamp.mod` from the course website, and compile it using:

   ```
   nrnivmodl noisy_iclamp
   ```

   It can then be used in a .hoc file as:

   ```
   access soma
   objref vce
   vce= new IClampNoise(0.5)
   vce.bias=0
   vce.std=1 // std.dev. in nA
   ```

3. For question 4 and 5, analysis of the simulation is easiest outside of NEURON, using matlab or similar. You can write out the spike times as using:

   ```
   objref ncsp, nil
   objref spiketimes
   spiketimes = new Vector()
   ncsp = new NetCon(&soma.v(.5), nil)
   ncsp.threshold = 0
   ncsp.record(spiketimes)
   run()
   objref fout
   fout= new File()
   fout.wopen("sptimes.dat")
   spiketimes.printf(fout)
   fout.close()
   quit()
   ```

4. Also voltage/current traces can be saved. For that use constructions like

   ```
   objref data
   data = new Vector();
   data.record(&vce.i) // this statement for the clamp current
   data.record(&soma.v(0.5)) // this for voltage in soma
   ```