Assignment 1: Voltage clamp

Neural Computation 2009-2010. Mark van Rossum

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Practical info

You will find that some questions are quite open-ended. A particularly well-researched answer can receive additional points, but core-dumping (just writing down all you can think of) does not. Ideally you substantiate your explanations and claims, for instance by doing additional simulations.

Plots should include axes labels and units (either on the plot, or mentioned in the text), see my web page link.

There might a to be determined normalization factor between the number of points scored and the resulting percentage mark.

It should not be necessary to consult scientific literature. If you do use additional literature, cite it.

Copying results is absolutely not allowed and can lead to severe punishment. It's OK to ask for help from your friends. However, this help must not extend to copying code, results, or written text that your friend has written, or that you and your friend have written together. I assess you on the basis of what you are able to do by yourself. It's OK to help a friend. However, this help must not extend to providing your friend with code or written text. If you are found to have done so, a penalty will be assessed against you as well.

Deadline will be announced via email and the website. Hand in a paper copy to ITO. Late policies are strict and are stated at `http://www.inf.ed.ac.uk/teaching/years/msc/courseguide09.html#exam`.

Voltage clamp

In normal situation the voltage in a neuron reflects synaptic and other input currents that it receives. In voltage clamp, the membrane voltage at the site of the electrode is controlled via an electronic feedback circuit. The circuit injects current, the clamp current, so that the voltage is the desired one. (The NEURON simulator actually simulates such a circuit). Voltage clamp can both prevent the activation of voltage dependent mechanisms, as in the Hodgkin-Huxley model, as well as reduce cable filtering.

Here we examine the basic properties of voltage clamping in a cable. We'll be working with a cable of 1μm thickness and 1000 μm length, with standard passive parameters (`insert pas`), but use $r_m = 10k\Omega\, cm^2$.

Question 1 (5 points) Create voltage clamp halfway along the cable (see below) and plot the clamp current. Explain the shape of the current. Also explain how you set `nseg`.

Question 2 (10 points) Simulate and calculate how much current you need to inject to obtain a membrane voltage of 0 mV at the site of the electrode in the steady state. Compare both results and explain differences.
Note: there was a typo in the lecture notes in the cable equation on page 19. This is corrected in the online version.

Now create an exponential synapse at one end of the cable, reversal potential 0mV, maximal conductance of 0.01 μS, and 5ms timeconstant. Stimulate this synapse once when the voltage clamp has been reached its steady state (see earlier practicals).

Question 3 (5 points) Plot the peak clamp current caused by the synaptic input as a function of the clamping voltage. Explain the result.

For the remainder, we clamp the voltage at the resting voltage (-70mV) only.

Question 4 (10 points) Explore the shape and the amplitude of the clamp current, as a function of synaptic conductance and distance between the synapse and the electrode. Explain your findings.

Apart from the amplitude of the clamp current, one can also measure the charge, which is defined as $q = \int dt\, I(t)$.

Question 5 (10 points) Explore the charge for different sized synapses and with different timeconstants. Explain your findings.

Practical information

Voltage clamp can be defined in the GUI of NEURON (tools-> Point processes -> Electrode), or in the .hoc file, using a construction such as

```
load_file("electrod.hoc")
objref vce
vce= new VClamp(0.5) // in the middle of the cable
vce.dur[0]=10 // 10 ms, at -70 mV
vce.amp[0]=-70
vce.dur[1]=20 // 20 ms, at +10 mV
vce.amp[1]=10
vce.dur[2]=10 // 10ms at -70mV
vce.amp[2]=-70
```

In analogy with typical experiments, there are three voltage clamp levels: first to condition the neuron, second to test, and the last one to return to conditioning level. The clamp current can be plotted via the GUI, or when using the above command, using the `vce.i` variable. Of course, you might need to change the parameters for this work.

In this assignment can also useful to write out data to a file, that can then be read by matlab.

```
objref data // create a vector to store the data
data = new Vector()
data.record(&vce.i) //The sample time for record statement is by default
   set to dt, which is 0.025 ms
run()
objref fout
fout= new File() // create file pointer
fout.wopen("data.dat")
data.printf(fout)
quit() // only after quiting neuron, all remains of the file are written
   and it is closed.  You might find you need this.
```

In Matlab or Octave you can then use

```
load -ascii 'data.dat'
```

to read the file, which will give you an array with name `data`.