Assignment 1: Electrically coupled cells

Neural Computation 2007-2008. 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, for instance by 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.

Copying results is not allowed. It's OK to ask for help from your friends. However, this help must not extend to copying code 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.

Email me the .hoc file that you used for question 2, I will not assess the programming style, but I might check it if results are unexpected. I can also run plagiarism detectors on them. Email it to mvanross@inf.ed.ac.uk and the subject should contain 'nc1-2008' (all lowercase).

Deadline is Monday March 3 at noon (late policy are stated at `http://www.inf.ed.ac.uk/teaching/years/msc/courseguide07.html#exam`). Hard-copies preferred, but if you are out of town an email to me is OK (pdf or postscript format). Hand in to Pat Ferguson, Rm. D-10 in Forrest Hill.

Model of electrically coupled neurons

In this assignment we consider two cells that are coupled electrically. Such coupling is known to exist in a number of cases, for instance between cells in the retina and between inhibitory neurons in the hippocampus. Although in biology such coupling occurs via so called gap-junctions, the coupling is here modelled as a cable between the two cells. The cells are modelled as single compartments.

In Neuron create a model consisting of two cells: a large one modeled as a cylinder with a length 10 and diameter 20 μm, and a smaller one with length 10 and diameter 5μm. Connect the cells with a passive cable of $100\mu m$ length, (`insert pas`) but with $g_{pas} = 0.00005 S/cm^2$. You can connect compartments with:
`connect soma1(0), dend(0)` and `connect soma2(0), dend(1)`.
(Note, the order of the arguments matters in Neuron; the wrong order can lead to errors).

Question 1 (5 points) Set `nseg` for the cable correctly, knowing that we will vary the diameter between 0.01 and 1 μm. Each segment should be shorter than $\lambda/20$, where λ is the electrotonic length. This is usually a decent choice the get sufficient numerical accuracy. Show the calculation that you used.

Question 2 (10 points) At first make the largest cell active (`insert hh`), while the other is passive (`insert pas`, default value for g_{pas}). Start with a cable diameter of 0.1 μm. Stimulate the active cell with a current injection, so that it spikes. This spike will not fully propagate to the second cell, but will lead to some small voltage excursion. Measure and plot the delay between the peak of the spike and the peak of the voltage peak in the second cell while varying the cable diameter.
How does this compare to the theory? What assumptions does the theory make that are not met? Examine which assumptions are important.

Question 3 (10 points) Make now both cells active (remove the passive parameters by either restarting or `uninsert pas`). Stimulate one of the cells.
What is the delay between the spikes? How does it depend on the cable diameter? Make a plot.
What does theory predict for the delay in this case? Compare to your simulations.

Question 4 (15 points) Next, inject both cells with various supra-threshold currents. Examine and describe the possible firing patterns in the cells, as you vary the cable diameter and the stimulus currents. Discuss possible biological relevance of the different firing modes.