Norwegian University
of Life Sciences

Solution to Exercise 5: Multicompartmental neuron model with synaptic input

A Python file making the figures given here is available as `exercise_5_solution.py`.

(i) For the simplest example of a single spike, see Figure 1.

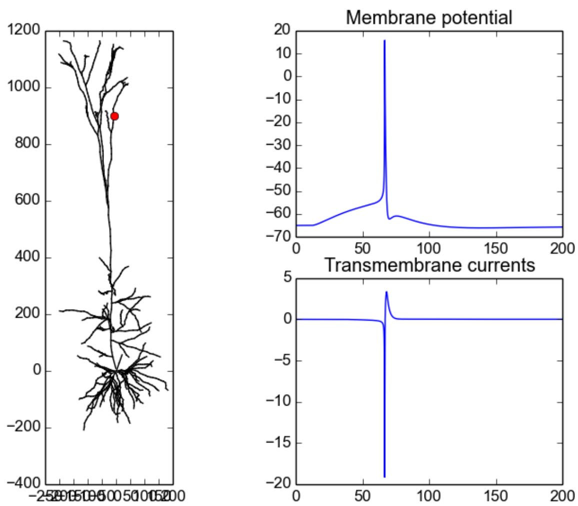

Figure 1: Result of (i), showing a single spike.

(ii) In Figure 2 the somatic response to increasingly distant apical synaptic input is plotted both for the passive model (top) and for the full active model. Notice how the width of the synaptic response increase with distance for the passive case, but not (or much less) for the active case. For the active model, you can also see that the somatic voltage trace resulting from a distal apical input contains a hyperpolarized overshoot (or 'undershoot') after the initial depolarization. This is caused by the I_H conductance, and you can read more about it in the reference of this footnote[1].

(iii) In Figure 3 we see that when three consecutive spikes arrives at a synapse (marked by red dot on morphology) with an inter-spike interval of 30 ms, the

[1]Williams SR, Stuart GJ (2000) *Site Independence of EPSP Time Course Is Mediated by Dendritic Ih in Neocortical Pyramidal Neurons.* J Neurophysiol 83: 3177–3182.

membrane potential in the compartment where the input arrives has three distict peak. For the passive model (top) these inputs are seen to sum a single wide and smeared potential-hump in the soma compartment due to temporal summation and filtering by the passive dendrites. For the case with active conductances this is somewhat different (bottom), and the voltage response in the soma has similar temporal width as at the compartment where the spike input arrives. Thus the active conductances compensate for the temporal blurring imposed by the passive dendrites and 'sharpens' up the signal. In this way the active conductances makes the cell more sensitive to detecting coincident synaptic inputs, and it has been speculated that this is the primary role of the I_H current[2,3].

[2] Migliore M, Messineo L, Ferrante M (2004) *Dendritic Ih selectively blocks temporal summation of unsynchronized distal inputs in CA1 pyramidal neurons.* J Comput Neurosci 16: 5–13.

[3] Vaidya SP, Johnston D (2013) *Temporal synchrony and gamma-to-theta power conversion in the dendrites of CA1 pyramidal neurons.* Nat Neurosci 16: 1812–1820.

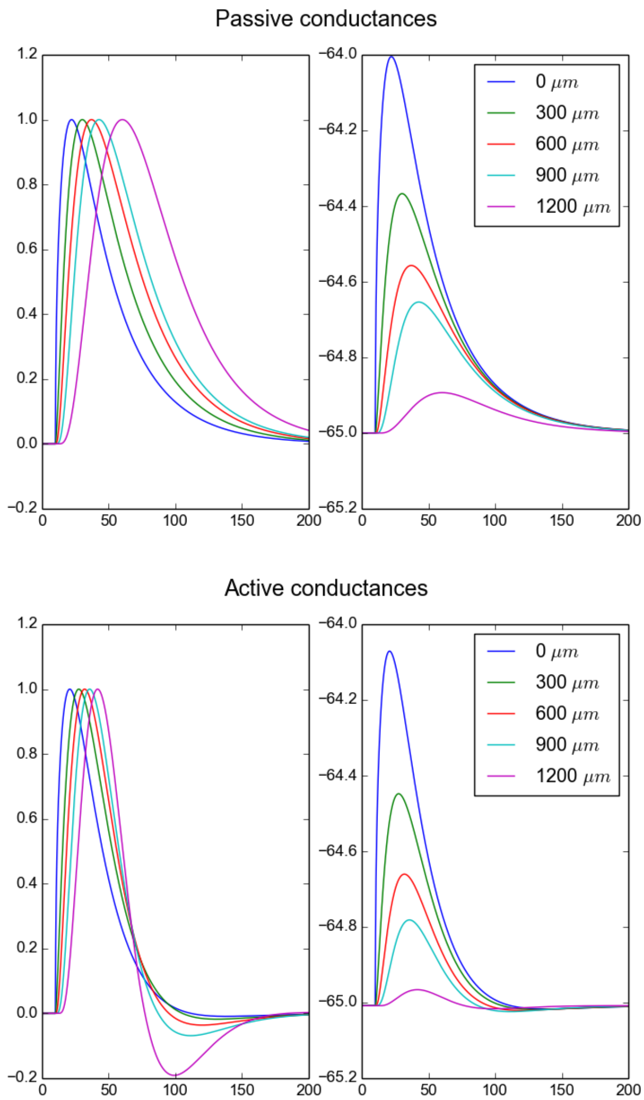

Figure 2: Result of (ii) showing voltage response in the soma for synaptic input at different distances. In the two panels in the top row the cell model is passive, while in the bottom row it it active, i.e. it contains all the original ion-channels. Right panels show 'raw' (un-normalized) results, left panels show normalized results.

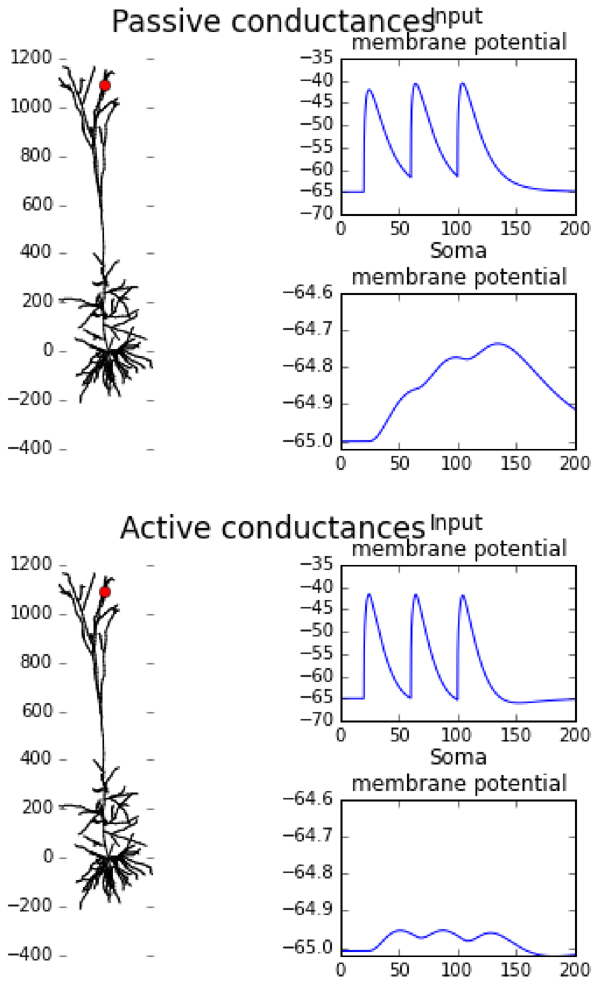

Figure 3: Result of (iii). In the top row, the cell model is passive, while in the bottom it is active, i.e. it contains all the original ion-channels.