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Models of Neural Systems, WS 2009/10
Project 4: Adaptive exponential integrate-and-fire model
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Background

Detailed neuron models offer much biological realism and good agreement with experimental findings. On the other hand, they are often very complex, which makes parameter fitting, simulation and theoretical analysis of such models very difficult. Therefore, quite often simplified neuron models are used to simulate neuronal dynamics. One class of such models are based on integrate-and-fire approach. How good are these models in comparison with detailed conductance-based neuron models? Here you will study the expressive power of an adaptive exponential integrate-and-fire neuron (AdExp).

Problems

1. *Literature review.* Study the paper of Brette and Gerstner, J Neurophysiol 2005. Focus on the figures and the method section. What is the hypothesis? What are the main results and conclusions? What are the main assumptions of the model? What are the strengths and weaknesses of the paper?

2. Model the responses of Hodgkin-Huxley model to fluctuating synaptic inputs. To this end, add synaptic inhibitory and excitatory currents to the standard HHM:
$$I_{\text{syn}} = g_{\text{syn}}(E_{\text{syn}} - V) \tag{1}$$
where syn $\in \{\text{exc}, \text{inh}\}$ denotes excitatory or inhibitory currents. The respective reversal potentials are $E_{\text{exc}} = 0$ mV and $E_{\text{inh}} = -75$ mV. The synaptic conductance g_{syn} is time-varying – for the first approximation assume that they are independent Gaussian random numbers with mean $\overline{g}_{\text{syn}}$ and standard deviation σ_{sync}. Choose both parameters of the Gaussian distribution such that the neuron fires spontaneously with low firing rate (about 10 Hz). Consider both low-conductance (ratio total mean conductance to leak conductance 2:1) and high-conductance states (ratio 5:1).

3. Implement the exponential integrate-and-fire neuron with adaption (AdExp) as described in the method section of Brette and Gerstner (2005).

4. Fit the parameters of the AdExp model to data generated from HHM according to the procedure described in Brette and Gerstner (2005).
5. Compare the spike trains generated by AdExp and HHM models to the same time-varying synaptic conductances in terms of missing and extra spikes (see Method section of Brette and Gerstner, 2005).
6. Try to answer the following questions: Are the simplified models a good description of the experimental data? How well can AdExp model reproduce the spike trains generated by HHM? How could the performance be improved? How well would you expect AdExp to describe real experimental data? Why? A recent opinion on the issues can be also found in Gerstner, Naud, Science 2009.

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