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Models of Neural Systems, WS 2009/10
Project 2: Synfire chains
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Background

A popular view in neuroscience is that the information in the neural systems is encoded by the number of spikes (firing rate). Alternatively, the information could be encoded into precise timing of spikes thus increasing substantially the information capacity. For example, the information could be processed in so-called synfire chains – feedforward networks of sequentially and coherently active neural subpopulations. However, it has been argued that the background noise present in cortex would destroy all such temporal information. Here, you will test this hypothesis by checking if precise spike packets can reliably and stably propagate in model feedforward networks.

Problems

1. *Literature review.* Study the paper of Diesmann, Gewaltig, Aertsen, Science 1999. 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. Implement the leaky integrate-and-fire model discussed in the computer practical (Exercise Sheet 5) with the parameters given in Diesmann et al. (1999). Additionally, introduce the absolute refractory period during which the neuron does not respond to the incoming inputs. If required, add relative refractory period as described in the paper.

3. Model the background activity by injecting a random synaptic current whose values are normally distributed. Choose the mean and standard deviation of the current such that the neuron is spontaneously active with mean firing rate of 2 Hz and fires irregularly.

4. The feed-forward inputs are entering the neuron model by means of the conductance-based synapses discussed at the computer practical (Exercise Sheet 6). Choose the parameters of the alpha function such that the post-synaptic potential of one spike has the peak amplitude of 0.14 mV and time-to-peak of 1.7 ms.

5. Model the feed-forward inputs with packets of spikes, which are simulated by repeatedly drawing a_{in} spike times from Gaussian density with standard deviation σ_{in} and mean 0.

6. Simulate the response of the neuron. It should respond with at most one spike to the pulse packet (adjust the refractory periods and the membrane time constant if it does not). Repeat the simulation multiple times and calculate the distribution of the output spikes. Plot and compare the input and output distribution. Calculate the number of spikes a_{out} and standard deviation σ_{out} of the output spike times. Is the packet's propagation stable or unstable?

7. Simulate the propagation of the pulse packet in a fully connected synfire chain (10 successive groups, 100 neurons each). Plot the raster plots (see Diesmann et al. 1999, Figure 1).

8. *Phase-space analysis*. Calculate a_{out} and σ_{out} for different pairs of a_{in} and σ_{in}. Plot the results as a vector field. Can you reproduce the results of Diesmann et al. 1999 (Figure 3)? If not, describe and explain the differences.

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