Assignment 2: Rate based networks

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 or, if you are out of town, email me a PDF file. Late policies are strict and are stated at `http://www.inf.ed.ac.uk/teaching/years/msc/courseguide09.html#exam`.

Rate based networks

In this assignment we consider rate based networks that consist of separate excitatory and inhibitory populations of neurons. The neurons have a rectifying input-output relation.

The connections weights are given by w_{ee} (recurrent excitation), w_{ei} (connections from inhibitory to excitatory), w_{ie} (excitatory drive of the inhibitory population), and w_{ii} (recurrent inhibition). So that for the excitatory neurons

$$\tau \frac{dr_e(t)}{dt} = -r_e + \max(0, w_{ee} r_e(t) - w_{ei} r_i(t) + in_e)$$

and for inhibitory neurons

$$\tau \frac{dr_i(t)}{dt} = -r_i + \max(0, w_{ie} r_e(t) - w_{ii} r_i(t) + in_i)$$

Depending on the exact weights, the network has different dynamics. Recent studies have considered so called inhibitory dominant networks (IDN-network), where the inhibition is crucial in constraining the excitatory population [1]. (You are welcome to read that paper, although it should not be necessary). An example of such an IDN network is obtained with weights $w_{ee} = 2$, $w_{ii} = 3$, $w_{ie} = 8/3$, $w_{ei} = 3$. While a weakly inhibitory network (WIN-network) has for example $w_{ee} = 0.5$, $w_{ii} = 0$, $w_{ie} = 0.71$, $w_{ei} = 0.71$. In such a network, the excitatory population is modulated by the inhibition, but the inhibition is not crucial.

Question 1 (5 points) Implement the network in a language of choice (Matlab or Octave are obvious choices). [Please email me the code with subject `nc2code`]. Vary the input to the excitatory and inhibitory inputs to the populations and plot the resulting firing rates for both weight matrices. Explain the result.

Question 2 (5 points) Examine and explain the behavior when $w_{ii} = 0$ in the IDN network.

Question 3 (5 points) In setting possible weight configurations, we would like tune the gain of the network such that the output equals the input $r_e = in_e$ whenever $in_i = 0$ (as is the case for the given weights). Work this requirement out as a condition on general weights.

Next, we make the neurons noisy by adding noise to the input. There are some subtleties simulating white noise, but we will ignore those here; just add Gaussian noise to both inputs at every time-step.

Question 4 (5 points) Discuss the appropriateness of this noise model as a description for real neurons. Describe, but do not implement, alternatives.

Question 5 (5 points) Examine how the noise is processed by the network, either in simulation or analytically, or both.

References

[1] Hirofumi Ozeki, Ian M Finn, Evan S Schaffer, Kenneth D Miller, and David Ferster, *Inhibitory stabilization of the cortical network underlies visual surround suppression.*, Neuron 62 (2009), no. 4, 578–592.