Assignment 2: Learning of feed-forward and lateral connections

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 Matlab file that you used for question 4, 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 'nc2-2008' (all lowercase).

Deadline is April 4th at noon. Late policy is stated at `http://www.inf.ed.ac.uk/teaching/years/msc/courseguide07.html#exam`; no late submission is allowed except for special circumstances. 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.

Lateral learning

In this assignment we consider a rate based neural network, with $n = 4$ units. This network is supposed to model a tiny piece of the early visual system, although it is not meant to be very specific. The units are decribed by their firing rate $r(t)$; they receive feed-forward inputs x through weights v and lateral inputs through weights w; they obey

$$\tau \frac{dr_i(t)}{dt} = -r_i(t) + g[\sum_{j=1}^{n} v_{ij} x_j(t) + \sum_{j=1}^{n} w_{ij} r_j(t)]$$

where g implements a smooth thresholded linear function, $g(x) = 0$ for $x < 0$, $g(x) = 10$ for $x > 10$ and $g(x) = x(1 - \exp(-x))$ otherwise.

We first study conditions on the lateral connections. The self connection lateral weights are kept at zero $w_{ii} = 0$. The input weights v are fixed to be equal to the identity matrix.

Question 1 (10 points) Assume that all the weights in the weight matrix (except the self connections) have reached a maximum value w_{max} and assume for now that g is linear, $g(x) = x$. Show that if $w_{max} < 1/(n-1)$, the network will have no sustained activity (activity in the absence of input). What is the general condition on the weight matrix for the absence of sustained activity?

Question 2 (5 points) Discuss (dis)advantages and possible applications of a regime with and without sustained activity when the network is used to model the visual system.

Plasticity

The plasticity rule we implement is as follows:

- If pre- and postsynaptic activity are both larger than θ, $w \rightarrow w + \eta$ (where η is a small number),
- If pre- and postsynaptic activity are both smaller than 0.1, the weight remains the same,
- in all other cases $w \rightarrow w - \eta$.

In order to apply the plasticity rules, 1) apply the input to the network (which stays on the whole time), 2) next, evolve the network to equilibrium and 3) then apply the plasticity rule based on the equilibrium activity. Limit all weights to $0 \leq w_{ij} \leq w_{max}$.

Question 3 (5 points) Implement the network reverting back to the full definition of g. Use $w_{max} = 0.3$ and $\theta = 1$. Train the network with alternating stimuli (1,1,0,0) and (0,0,1,1) until the weights no longer change. Examine the resulting weight matrix and the response to the patterns for a variety of initial conditions on the weight matrix.
Explain the results.

Next, we also make the feed-forward connections plastic. They are subject to the same rules as the lateral connections, but $0 \leq v \leq v_{max}$ with $v_{max} = 1$ and $\theta = 0.5$.

Question 4 (10 points) Repeat the simulation of question 3 but now with plastic feed-forward connections. Explain the result.

Question 5 (5 points) We model now low contrast versions of the stimuli as (c,c,0,0) with $0 \leq c \leq 1$. After training with the normal contrast versions of the stimulus, turn all plasticity off and explore the response to low contrast versions of the stimuli. If you found different possible solutions in question 3&4, compare them.

Question 6 (5 points) Discuss possible problems and advantages of the network as a model for visual processing. You can also comment on its coding capabilities, and its realism.

Question 7 (5 points) In light of your answers to the previous question, suggest and possibly implement improvements to the network.