CN510 Assignment 4: Shunting Networks

Due Tuesday Oct. 8, 2013

Please note that you do not need to submit your source code for this assignment.

The Network Equations

In this assignment you will analyze and simulate the following networks:

$$\frac{dx_i}{dt} = -Ax_i + BI_i - \sum_{j \neq i} I_j \quad \text{(Additive)}$$

$$\frac{dx_i}{dt} = -Ax_i + (B - x_i)I_i - x_i \sum_{j \neq i} I_j \quad \text{(Shunting)}$$

$$\frac{dx_i}{dt} = -Ax_i + (B - x_i) \sum_{k \in D} D_{ki} I_k - (C + x_i) \sum_{l \in E} E_{li} I_l \quad \text{(Distant-Dependent Shunting)}$$

The first two equations are intended for analysis only, while the third equation is for simulations. You are free to try and simulate the first two equations as you code the third one to verify your analysis and ensure the parts of your code work properly, but this is not required.

Analysis of Network Equations `(30 points)`

Determine the equilibrium solutions the additive and shunting (not distance-dependent) network equations, as well as for distance-dependent equation.
Using parameters $A = 0.1$ and $B = 1$, and your equilibrium solution, calculate the values of x_i in the first two networks for ten neurons using input array $I = \{1.0, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1\}$
Plot the resulting x_i as well as pattern variables $X_i = \frac{x_i}{\sum_{k=1}^{10} x_k}$. Use the cell index as x axis.
Repeat for $I = \{10, 9, 8, 7, 6, 5, 4, 3, 2, 1\}$

Computational Work `(40 points)`

For the simulations of distant-dependent network use your previously designed Euler integration code, the parameters $A = 1$, $B = 10$, $C = 1.5$, and the network size of 100 neurons. Compute excitatory and inhibitory weights as

$$D_{ki} = e^{-\frac{(k-i)^2}{F^2}} \quad (1)$$

$$E_{li} = 0.5e^{-\frac{(l-i)^2}{G^2}} \quad (2)$$

and use two sets of parameters: $F = 2$, $G = 4$, and $F = 4$, $G = 8$. In all cases, disregard all weights that are smaller than 0.01. You have to pick how you want to handle boundary conditions in your network. Wrap-around, padding with boundary value, and padding with zeros are three common methods. Given the inputs below, one of these will create artifacts on the edges, while the other two will not.

Simulate the network responses to the four inputs:

- $I = 10$ for the first and last 25 cells, $I = 80$ for the middle 50 cells

- $I = 1$ for the first and last 25 cells, $I = 8$ for the middle 50 cells
- $I = 10$ for the first and last 45 cells, $I = 80$ for the middle 10 cells
- $I = 1$ for the first 10 cells, 82 for the last 10 cells, I goes from 2 to 81 (2, 3, 4, ... 80, 81) for the middle 80 cells creating a smooth ramp

Determine the simulation time experimentally: monitor the activity of one of the cells (preferably with large input) until it settles. Provide well-labeled, captioned figure with plots of the inputs and the equilibrium responses of the network to all inputs: one for each input and parameter set combination, eight plots total. Note again, that here we are interested in equilibrium activity through space, not the development of the response through time, so use cell index as your x axis.

Discussion `(30 points)`

Discuss the difference in response between additive and shunting network computed in part 1
For both additive and shunting network of part 1, compare the responses to two different input intensities
For distance-dependent network compare the results for the first two inputs and discuss how well it factorizes pattern from energy
Compare the results for inputs 1 and 3 and discuss how the width of the high step in the input affects the output
Compare the response to input 4 with the part 1 shunting net response to a similar ramp
Discuss the effect of the width of Gaussian kernels in the distance-dependent network on the output. Tie it up to a suppression of uniform inputs discussed in class