Transmission of Signals from Neuron to Neuron

Project Module Associated with
2nd Edition, Introduction to Computational Science:
Modeling and Simulation **by**

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Prerequisites: "Transmission of Nerve Impulses: Learning from the Action Potential Heroes" from Module 7.9 on "Transmission of Nerve Impulses: Learning from the Action Potential Heroes" and Modules 9.5 on "Random Walk" and 10.2 on "Diffusion: Overcoming Differences"

Introduction

Projects in this module involve modeling the transmission of signals from neuron to neuron in the brain. We focus on the axons, which can have multiple terminals. Each axon terminal can transmit a signal to a dendrite on a different neuron. The brain has approximately 80% excitatory neurons and 20% inhibitory neurons (Carnegie Mellon News 2013). An excitatory neuron can transmit a received signal, while an inhibitory neuron does not forward such a message.

As simplifying assumptions, we model the brain in 2D and ignore the impact of supporting cells on signal propagation. Figure 1 presents one possible depiction of signal propagation (yellow) with a grid of excitatory (pink) and inhibitory (black) neurons. Additionally, we assume a signal moves in random direction, whereas in reality signals usually travel along established network paths.

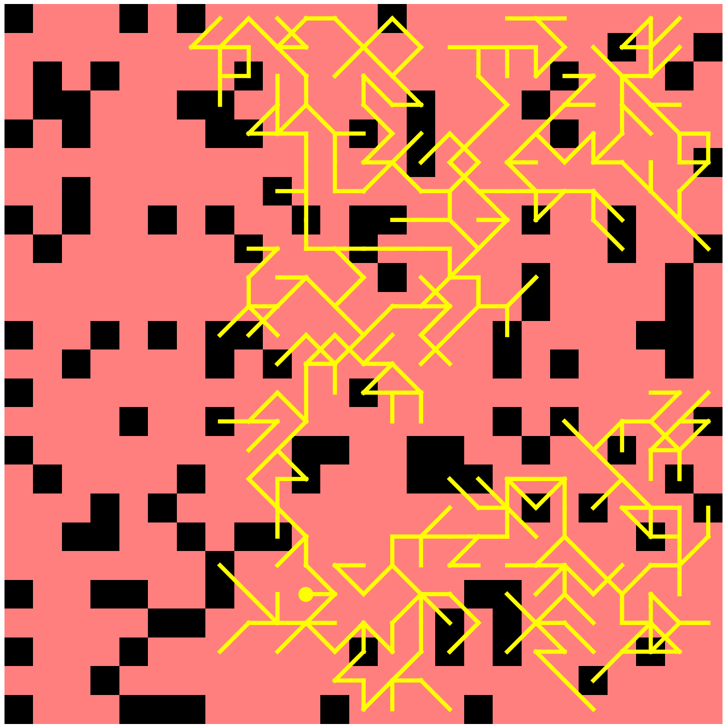

Figure 1 Possible depiction of signal (yellow) propagation with a grid of excitatory (pink) and inhibitory (black) neurons

Projects

1. **a.** In this project, model the transmission in the brain of a signal that starts from one random excitatory neuron. For this part, simplify the problem by allowing an excitatory neuron to transmit a signal to exactly one random neighboring neuron. Consider the brain to be a 2D grid of neurons with randomly distributed excitatory (80%) and inhibitory (20%) neurons, depicted with different colors. Show the path of the signal from neuron to neuron.

b. Without visualizations, adjust the program from Part a to run the simulation at least 100 times and to calculate the average path length.

2. Develop Project 1a where an axon can have more than one axon terminal. Thus, an excitatory neuron can propagate the signal to multiple neighboring neurons. Do not allow more than one signal to go to the same neighbor. Moreover, assume that once an excitatory neuron has been stimulated, it cannot be stimulated again.

3. Develop Project 1a or 2 allowing for multiple initial signals.

4. Develop Project 1a or 2 allowing a signal to propagate to a random neighbor or to jump to the neighbor of a neighbor.

References

Carnegie Mellon News. 2013. “Press Release: Researchers Discover How Inhibitory Neurons Behave During Critical Periods of Learning.” Carnegie Mellon University. 26 Aug 2013. http://www.cmu.edu/news/stories/archives/2013/august/aug26_inhibitoryneurons.html (Accessed 15 Jan 2015)

Williams, Alissa. 2015. NetLogo model *neurons.nlogo*.