ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Bachelor/Master Thesis

Finding Sequence Ensembles in Random Structures

The last decades have seen the development of technological methods (EEG, fMRI, etc) and design of ingenious experiments that track the traces of conscious thoughts in our brain, see [2] for a nice overview. In particular, these experiments seem to suggest that we are able to pursue, at any given moment of time, only a single thought. Another line of research, this time due to a very unfortunate surgery, cf [2], showed that the hippocampus is absolutely essential to store any new memories. The starting point of this project is our paper [3] in which we showed that the use of so-called sequence ensembles in the hippocampus permits memorization of events in a one-shot fashion, cf. also [4]. In [3] we used the concept of synfire chains. The goal of this thesis is to show that actually this concept is not needed, but that (geometric) Erdős-Rényi random graphs are sufficient.

Concretely, consider a cylinder of radius R and length L, with $L \gg R$. We place neurons uniformly at random into this cylinder and connect neurons with probability p whenever their distance is at most r. Assuming that the number of neurons is large, Chernoff bounds tell us that number of neighbours is tightly concentrated. In the brain neurons come in two versions: excitatory and inhibitory. The first one give a positive signal, the latter one a negative one. Correspondingly, we assume that the neurons in our cylinder are of excitatory type with probability p_e. In addition, we assume that inhibitory neurons are asymmetrically connected: they are randomly connected to excitatory neurons within distance r_l to the left and within distance r_r to the right. The goal of this thesis is to show that such a cylindrical configuration allows to build a sequence ensemble as it was used in [3]. For the analysis you should proceed in various steps. First, compute the expected behavior and set up differential equations that describe the dynamics of your model. Then find parameters so that the dynamics of your model exhibits the desired behavior. Finally, use Chernoff bounds to show that the model behaves as expected. Due to various dependencies of the involved random variables the last step may not be feasible in full detail and, as often in computational neuroscience, a simulation will also be considered sufficient.

Prerequisites: A solid understanding of discrete probability theory, willingness to combine theoretical intuition, creativity, and simulations.

Contact Information: Xun Zou, CAB J 21.3, `xun.zou@inf.ethz.ch`

[1] S. Dehaene, *Consciousness and the Brain: Deciphering How the Brain Codes Our Thoughts*, Penguin, 2014
[2] S. Corkin, *Permanent Present Tense: The man with no memory, and what he taught the world*, Penguin, 2014
[3] F. Weissenberger, H. Einarsson, M. Gauy, J. Lengler, F. Meier, M. Yanik and A. Steger, *A hippocampal model for behavioral time acquisition and fast bidirectional replay of spatio-temporal memory sequences*, Frontiers in Neuroscience, 2018
[4] `https://www.dropbox.com/s/o8ryq5lb0kd8oiu/sequence_replay_video.mp4`