Learning the Structure of Local Neural Circuits in Mouse Ectorhinal Cortex

Scott Brookes and Derek Racine

May 19, 2014

Introduction

The brain is structured such that local networks of neurons can perform distinct, modular, tasks. For example, the ectorhinal cortex is known to receive the majority of its input from visual sensory areas and is involved in visual memory and object recognition. However, the network structure is not well understood. Training an animal to recognize certain images, such as through visual paired-associate learning, might also affect the network dynamics. In particular, one might hypothesize that this training could cause neurons to become tuned to images that the mouse has seen before, but not others. That is, the activity of neurons would be well correlated with stimuli used during training. Yet, this relationship hasn't been explored.

Simplified neurons can be described as being in one of two states: resting or firing. When a neuron fires, calcium ions flow into it from the extracellular fluid. As such, fluorescence observed from calcium sensors can serve as a proxy for neural activity.

The recent discovery of an ultrasensitive family of fluorescent calcium sensors has caused an explosion in the availability of time-series data based on the use of this technique.[1] Whereas previous recording methods were limited to only a few cells, fluorescent imaging techniques can measure the activity of an entire region of neurons simultaneously. This data offers an opportunity to learn the structure of local neural circuits through statistical methods. Indeed, previous work has addressed this problem by modeling fluorescent imaging data as a collection of coupled Hidden Markov chains, one for each neuron.[2]

Dataset

We have obtained data sets corresponding to four recording sessions. The first data set consists of activity of neurons in the primary visual cortex that are well coordinated and known to respond to oriented gratings which are presented to the mice during the session, and thus will be a useful control for testing our methodology. The remaining data sets track the activity of neurons in the ectorhinal cortex during period of no stimulus, new stimulus, and known stimulus. Inferring both network structure and edge weights will allow us to determine how the neurons react to new stimulus, and whether or not the neurons become tuned to stimuli that the mouse has learned.

Method

We propose to model the local neural circuits as a Bayesian network and infer the edges from the correlations of the activity of individual neurons, which we will treat as binary random variables firing or not firing. In order to learn the structure, we plan to discretize our continuous series into buckets that each represent a single instance of the overall network.

Measuring Success

We expect that the model we learn on the first data set of highly correlated activity in the primary visual cortex will align well with the theoretical expectation. To clarify, we plan on using the same methods that we test on this first data set in order to verify their correctness/applicability, on the others.

References

[1] Tsai-Wen Chen and et al. Ultrasensitive fluorescent proteins for imaging neuronal activity. *Nature*, 499.7458:295–300, 2013.

[2] Yuriy Mishchenko, Joshua T. Vogelstein, and Liam Paninski. A bayesian approach for inferring neuronal connectivity from calcium fluorescent imaging data. *The Annals of Applied Statistics*, 5.2B:1229–1261, 2011.