Poster Session 2

Commons East, Easel 71

12:45 PM to 2:15 PM

Heterogeneous Firing Rates in Densely Connected Recurrent Neural Networks

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Mentor: Eric Shea-Brown, Applied Mathematics
Mentor: Yu Hu, Dept. of Applied Math

Understanding the heterogeneity in neural activity will help develop theories in neural dynamics and coding - how sensory information is encoded via spike times and patterns. For example, the correlation structure of spiking activity in neural populations, which affects the collective coding capacity, is heavily dependent on the heterogeneous distribution of firing rates across neural networks. A natural cause of heterogeneity in a network arises from the non-regular connectivity between neurons. To capture this natural heterogeneity, we used an adapted Erdos-Renyi node-probability model to construct random architectures for both purely excitatory and excitatory-inhibitory networks of different sizes. The Erdos-Renyi model flips a weighted coin defined by a probability parameter to determine whether a path between nodes exists. However, we need to construct directed graphs, so we adapted the Erdos-Renyi model to construct directed paths based on the probability parameter. For each randomly generated network we examined the coherent structure of the steady-states that persist as the connection strengths between neurons are uniformly increased. In purely excitatory networks, we saw that the steady-state growth is very linear with respect to the connection strength of the network. As a result, stronger connection strengths lead to stronger heterogeneity between the firing rates within the network. We are using the coefficients in the linear approximations to steady-state growth to define the coherent structure of each network. We are continuing towards finding a relationship between the frequencies of three-cell connectivity motifs and this coherent structure since realistic neural network connectivity patterns are not purely random, but have significantly prevalent motifs that define neural architecture. We are specifically looking at how different frequencies of chain, divergent and convergent three-cell motifs affect the first and second order moments of the coherent structure that represents the heterogeneity.

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Homeostatic and Spike Time Dependent Plasticity Tune Feed-Forward Neural Networks

Yoni Ivens (Yoni) Browning, Senior, Applied & Computational Mathematical Sciences (Biological & Life Sciences)
Mentor: Eric Shea-Brown, Applied Mathematics
Mentor: Natasha Cayco Gajic, Applied Mathematics

Synapses, the connections between neurons, are not constant in strength but instead are plastic, adjusting due to various biophysical rules. While various types of plasticity have been identified, the interaction of different plasticity rules in a network of neurons in not well understood. We consider the behavior of two experimentally observed forms of synaptic plasticity, homeostatic and spike time dependent plasticity (STDP), and seek to exploit these rules to tune a model neural network towards a state in which activity throughout the network maintains dependence on its inputs. Our network consists of firing neurons arranged in layers connected in a sparse, feed-forward manner. Reliable propagation of layer-wide firing rates without all neurons firing together (synchrony) is required to achieve graded transmission of input rates, that is, signal transmission. Plasticity is introduced to our network through mathematical learning rules. One of our learning rules, STDP strengthens causal linkages by increasing or decreasing synaptic weights depending on the timing of pre- and postsynaptic activity. STDP by itself is often unstable, causing synaptic weights to grow without bound. We therefore attempt to stabilize STDP with a homeostatic rule, adjusting the weights of all of a neuron's incoming synapses in order to achieve some intrinsic firing rate. While current literature has focused primarily on the behavior of these rules in single neurons or in rate-based systems, we examine the interactions between these rules in a spiking, stochastic system with dynamic inputs, and their effectiveness in tuning such a network towards reliable rate propagation. Our hope is to shed light on the development of cortical networks able to perform successful computation.