Title: Spatio-Temporal Patterns Revealed by a Large-Scale Model of the Hippocampal Entorhinal-Dentate-CA3 System: Emergence of Clustered Activity

Presenter: Gene J. Yu

Description:

A significant unknown in neuroscience is an understanding of how ensemble network activity, e.g. a spatio-temporal pattern, is expressed in a neural system as a whole. However, most studies investigating the population dynamics have been restricted to the smaller, incomplete networks on the order of thousands of neurons. To study spatio-temporal patterns at a large-scale network level, we have developed a parallelized, neural network model of rat hippocampus which is comprised of 112,000 entorhinal cortex cells, 1,200,000 dentate granule cells, and 330,000 CA3 pyramidal cells, contains over 4 billion synapses that are modeled using a simple synaptic model, and uses a connectivity derived from the anatomical topography of the neuronal projections, which represents the full number of principal neurons and corresponding synapses in a single hemisphere of the entorhinal-dentate-CA3 system of rat hippocampus. The characterization of network activity at a large-scale allows the identification of potential intermediary phenomena between the cellular and higher levels that can serve as a bridge linking the two disparate scales. Using the large-scale model, we have identified one possible intermediate phenomenon representative of a fundamental unit of population activity that we refer to as spatio-temporal clusters of activity.

The clusters, initially discovered while studying the entorhinal-dentate system, were found to be a network level expression of a weak spatio-temporal correlation that was shared throughout the granule cell population. Subsequent analysis revealed that the predominant mechanism that contributed to clustered activity was the topography describing the entorhinal-dentate connectivity. Clusters could only be observed due to the combination of the number of neurons that were represented in the network and topographic connectivity and would otherwise not be observed by typical neural network studies which are limited to upwards of thousands of neurons and use a random connectivity.

The robustness of the dentate clusters was studied by observing its propagation to and transformation by the CA3/4 subfield. Simulations of the entorhinal-dentate-CA3 system demonstrate the viability of clusters as a possible unit of population activity as entorhinal activity was disynaptically propagated to the CA3 via the dentate mossy fiber system. The CA3 generated transformed patterns clustered of activity that maintained a level of correlation with the dentate activity.

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