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Inferring Neural Network Connectivity from Dynamical Response Measurements

Neural networks show a large variety of phenomena that arise from the interactions between single neurons. While the observation of the behavior of a network is often easy, the interactions are generally not easily accessible.

The work proposes a method for deriving the connectivity of spiking neural networks from measuring the collective responses in spike times to changes in external driving currents.

When driving a homogenous neural network of spiking neurons with oscillatory dynamics, all neurons of the neural network will fire in synchrony under certain condition. Disturbing this synchronous state by small variations in the driving currents gives a near-synchronous state where the difference between the spiking time of any two neurons is smaller than the delay. The relation between differences in driving currents and resulting differences in spiking times of two driving conditions depends on the coupling strengths between the neurons. This gives rise to a set of equality constraints for each pair of driving conditions that restricts the space of possible connections of the network. With a sufficient number of constraints, a solution to the system of equations reveals the interaction matrix of the neural network. By this the topology of the neural network is derived from the dynamical responses to different driving conditions.

A sufficient number of measurements under independent driving conditions lead to fully determined systems of linear equations that is solved easily with standard algorithms. But the large number of measurements needed for this may be costly and time-consuming. Under the assumption that neurons are typically sparsely connected, meaning that most of the potential connections between any pair of neurons is not present, the space of possible solutions yields a faithful reconstruction of the real coupling matrix by maximizing the number of zero entries.