

DYNAMIC PROPERTIES OF SIMULATED LARGE-SCALE NEURAL NETWORKS

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ABSTRACT

Synfire chains are diverging/converging chains of neurons discharging synchronously to sustain the propagation of the information through a feed-forward neural network[1]. The observation of recurring spatiotemporal patterns of activity in multi-site single unit recordings[2] has been considered an indirect evidence of the existence of synfire chains. However, the detailed connectivity pattern of synfire chains embedded in brain circuits has remained an open question. In particular the question is raised about the random occurrence of synfire chains within very large interconnected circuits. The main goal of this study is to determine the dynamic properties of simulated large-scale Spiking Neural Networks (SNN) over a long time scale, in the order of 10^6 time steps. The network itself is composed by some probabilistic law of an extensively interconnected mix of excitatory and inhibitory units. The spiking point neuron model is simple yet biologically inspired. It has learning capabilities[3], and is compatible with a hardware implementation[4].

The simulated network is a 2D lattice in which borders are folded to form a torus to limit the border effect produced by the topology. The dimensions of the network are limited by the amount of memory available on the computer on which the simulations are run. Squares of 100×100 units with about 200 projections per unit are expected to be simulated. The network is composed of 80% excitatory and 20% inhibitory units randomly distributed over the simulated surface according to a space-filling quasi-random Sobol distribution[5]. Excitatory-excitatory, excitatory-inhibitory, inhibitory-excitatory, and inhibitory-inhibitory connections are established according to a two-dimensional Gaussian density function before the start of the simulation, and persist until the simulation is completed, though their synaptic weights are dynamically adapted.

The complete network activity is recorded as a multivariate time series from which only a few units are randomly picked up for further offline analyses, mimicking the random positioning of the electrodes in electrophysiological experiments. Apart from standard statistical methods, complex pattern search algorithms[6, 7] are applied to the extracted dataset to detect precisely timed spatiotemporal patterns of activity between units. One of the advantages of the simulation is that the observed patterns can be used as a seed to search for a possible synfire chain generating them in the complete network record. Several types of noise functions are applied to the same network, and the impact on the dynamics of the recorded units are quantified by statistical methods.

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Keywords: synfire chain, spatiotemporal pattern, spiking neural network, large-scale simulation, learning.

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