Sequence learning in spiking winnerless competition networks.

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The learning and the reproduction of sequences is a key requirement for many feats of cognitive systems, such as motor planning, speech and audio-visual scene analysis.

Most attempts to model the process of learning spatiotemporal patterns in the brain are based on attractor networks. In this type of model, the stability of storage and recall is not assured because noise and input variability can easily cause the state to move into basins of the wrong attractors.

One solution to this problem is to use winnerless competition dynamics, where the stability of the transitions between fixed points is ensured by the existence of a Stable Heteroclinic Channel (SHC) [1]. We present a spiking neural network based on an inhibitory Hodgkin-Huxley-type neuron model [2] capable of learning sequences autonomously. The network starts in a state that is statistically homogeneous. As sequences of patterns are presented, the network associates a small subset of the neurons to each pattern. Simultaneously and on a slower time scale, an asymmetric and bistable rule adjusts the weight of the inhibitory connections between the neurons to store the order of the presented patterns.

Robustness is guaranteed through the learning of a SHC in the phase space of the neural system, where each fixed point of the channel corresponds to a burst of spikes. Unlike in attractor networks, the fixed points are unstable in the direction leading to the subsequent pattern of the sequence. This way, the network is capable of reproducing the sequence with high fidelity.

The existence of heteroclinic orbits in a microcircuit of Hodgkin-Huxley-like neurons was shown previously [2], but learning them in a biologically inspired fashion is novel. Our results thus offer a non-linear dynamical systems perspective on how the brain may organize the learning of long sequences of neural activity.

References

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