Sequence Learning through Spike Timing Dependent Plasticity

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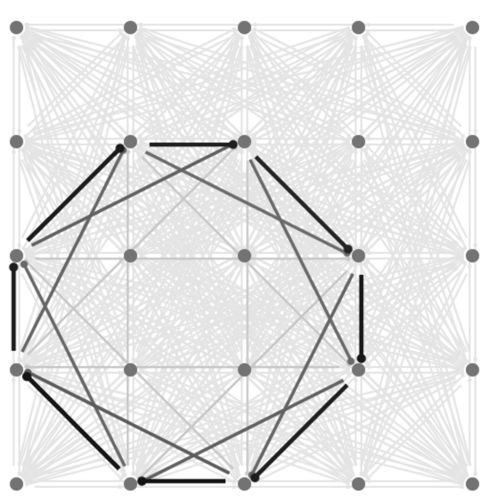
The representation of time in neural systems is a frequently addressed problem of broad interest. Three main mechanisms of such representation have been proposed: through delays and filters, by feedback or by transforming temporal information into spatial information. In this work we suggest a mechanism to transform temporal sequences into spatial patterns of strengthened synaptic connections based on Spike-Timing Dependent Plasticity (STDP). This mechanism allows storage, retrieval and prediction of temporal sequences. We demonstrate it in a model system of realistic Hodgkin-Huxley type neurons densely connected by STDP synapses. All synapses are modified according to the so-called normal STDP rule which leads to potentiation of synaptic strength if the post-synaptic spike occurs after the pre-synaptic one and to depression if the order is reversed. In our simplified setup each neuron receives isolated input spikes to which it responds with single spikes. The system is globally inhibited if its activity exceeds a given threshold. This is necessary to enforce meaningful activity in the densely connected and therefore highly excitable system. After conditioning through repeated input of a limited number of temporal sequences of inputs the system is able to complete each temporal sequence upon reception of the input of a fraction of it. The learning success is measured in terms of the number of spiking neurons belonging to a sequence in reaction to the input of a fraction of that sequence. We investigate the dependence of learning success on entrainment time, the number of input sequences and system size. Possible applications include learning of motor sequences, recognition and prediction of temporal sensory information in the visual as well as the auditory system and late processing in the olfactory system.



Example of a pattern storing temporal information. The neurons at the corners of the octagon have been repeatedly excited in clockwise order. The width and greyscale of the connections encodes the strength of the corresponding synapses and the small circles at the end show their direction. As one can clearly see the temporal pattern is transformed into an ordered spatial pattern by STDP.