Predictive Coding Light+: learning to predict visual sequences with spike timing-dependent plasticity and synaptic delays

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The ability to predict the future is of great value for biological and artificial cognitive systems alike. For instance, the ability to predict future sensory inputs can be exploited to encode sensory information more efficiently, e.g., using fewer spikes. However, successfully predicting the future typically requires maintaining a short-term memory of the recent past. It is currently unclear how biological or artificial spiking neural networks can learn to maintain past sensory information to help predict the future [3]. To address this issue, we here propose Predictive Coding Light+ (PCL+), a spiking neural network architecture for unsupervised sequence processing that learns delayed recurrent excitatory connections to enable short-term retention of information. It expands the Predictive Coding Light model [2], a spiking neural network architecture that learns to efficiently encode visual input using only local synaptic learning rules. We show that the PCL+ network reproduces classic findings on sequence learning in visual cortex [4]. Furthermore, it learns to "fill in" missing input in a challenging gesture recognition task (Figure 1).

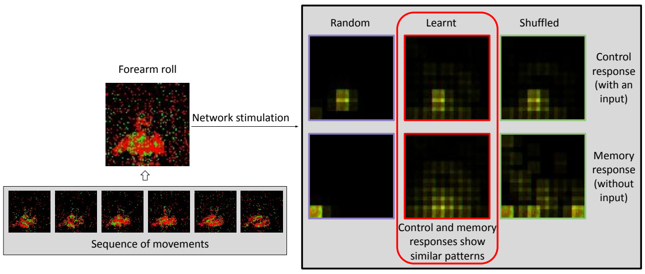

Figure 1: **Spiking patterns of a PCL+ network.** Top left shows an event-based input pattern representing a forearm roll gesture, with bottom left showing example movements composing this gesture. On the right side of the figure, the PCL+ network is stimulated with such event-based gestures and two response patterns: a control one in which the network is excited by an external input, and a recall response in which the network is active from its spontaneous activity alone, are shown. Three networks are considered with a random PCL+ network, a learned PCL+ network and a shuffled PCL+ network. Zones that exhibit neural activity are represented in the frames such that bright colors indicate strong network activity and dark colors indicate weak activity. The learned network exhibits similar patterns for both its control and recall responses.

In the PCL network, neurons suppress predictable spikes through feedback inhibition and reproduce various effects viewed as signatures of an efficient neural code. PCL+ keeps these functionalities and further incorporates a working memory using the concept of polychronization [1]. In PCL+ the network retains past information recurrent lateral and top-down excitatory connections with long delays. Each spike in a PCL+ network is thus sent out into the "future" using those delayed excitatory connections. Inhibition instead occurs instantaneously and removes immediate redundant spikes thus ensuring efficiency. Essentially, PCL+ offers a simple mechanism to instantiate a working memory in spiking neural networks by propagating spikes through time using long synaptic delays. Overall, our work shows how spiking neural networks can learn recurrent excitatory connections to maintain a record of the recent past and successfully predict the future.

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