Learning biological-like sequential responses in a Drosophila-inspired spiking neural network with the e-prop algorithm

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Biological decision-making is known to rely on different mechanisms [1, 5]. Interestingly, Drosophila have also been shown to also exhibit such capabilities. For instance, when excited with a simple sensory stimulus, Drosophila larvae surprisingly perform a sequence of actions (e.g. a hunching behavior followed by a bending behavior). The emergence of such sequential behaviors is thought to rely on competitive interactions within Drosophila sensorimotor neural circuits [2, 4]. Taking inspiration from Drosophila neural circuits to simulate their behavior might thus help us understand better how decision-making occurs in biological systems, considering the reduced complexity of their neural circuits compared to mammals. In this work, based on the neural circuit proposed by [2], we propose to reproduce the emergence of Drosophila behavioral choice using spiking neural networks. Figure 1 depicts the simulated neural circuit.

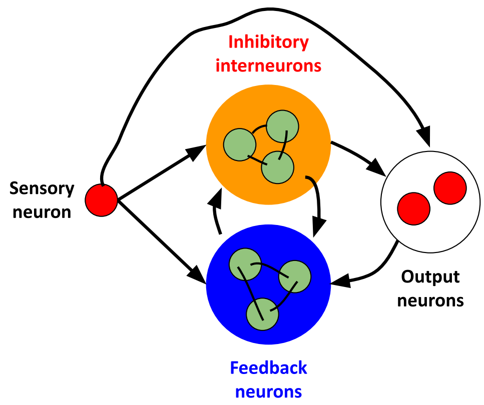

Figure 1: **Architecture of our Drosophila inspired spiking neural network.** Red circles denote excitatory neurons and green circles denote inhibitory neurons. Lines denote synapses.

Using the e-prop algorithm, and an inhibitory and excitatory recurrent spiking neural network, we mimic the sequential hunching-bending behavior of Drosophila larvae. Interestingly, our simulations make use of different delays between recurrent and feedforward connections to enhance the dynamical capabilities of the neural circuit [3]. We systematically study the interplay of those delays in our model, as well as the role of the different recurrent (and feedback) connections. Our results suggest that: 1) these behaviors can be learnt with e-prop even though they are innate in Drosophila, 2) competition between inhibitory neurons is necessary for the emergence of sequential responses, which is in line with results obtained with the rate-based model proposed in [2], 3) larger delays in recurrent (and feedback) synapses might be necessary for spiking networks to exhibit such complex dynamics. Overall, our study demonstrates how decision-making could be performed in simple spiking neural networks.

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