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Properties of synaptic plasticity rules implementing actor-critic temporal-difference learning

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There is considerable interest in establishing a link between system-level learning and synaptic plasticity [1-3]. In a previous study [4] we presented a specific set of biologically plausible synaptic plasticity rules implementing temporal-difference (TD) learning in a spiking neuronal network inspired by the actor-critic architecture [5]. We showed the equivalence between the plasticity rules and the traditional discrete-time TD(0) algorithm and demonstrated that the network learns a complex task with a similar speed to its discrete time counterpart and attains the same equilibrium performance. However, the set of learning rules represents only one possible way in which actor-critic TD learning could be implemented in the brain, and so the model has only limited predictive power for experimental work.

Here, we extract properties of synaptic plasticity rules that suffice to implement actor-critic TD(0) learning, under the assumption that states are represented by elevated rates in disjunct sets of neurons. On this basis we define generalized classes of continuous time synaptic plasticity rules that implement value function and policy updates. The main property is that the amount and sign of the weight update depends on a characteristic change in the activity of the critic module combined with a global reward signal. We present concrete examples belonging to the defined class and demonstrate that they are able to solve a non-trivial task. We further analyze to what extent the defined class of plasticity rules are compatible with experimental findings of synaptic plasticity [6,7].

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