Three Neurorobotic Testing Paradigms for a Cerebellar Spiking Neural Network with Distributed Plasticity

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Neurorobotics is a useful tool to challenge neural models in closed-loop tasks in a noisy world. We present three neurorobotic paradigms to test a cerebellar spiking neural network model. It was composed of 2160 Integrate&Fire specific neurons that replicated the cerebellar structure, with firing rates of each cells population within neurophysiological ranges. The learning mechanisms involved three different synaptic connections: Parallel Fibers-Purkinje Cells (cortical plasticity), Mossy Fibers-Deep Cerebellar Nuclei and Purkinje Cells-Deep Cerebellar Nuclei (nuclear plasticities). Neurophysiologists suggest that different time-scales of cerebellar learning depend on different mechanisms. In particular, the cortical plasticity is supposed to correspond to a fast learning, whereas the other two nuclear plasticities correspond to a slower adaptation and modulation of the output activity. We embedded the cerebellar model within a robot controller and we tested it in three sensorimotor tasks: a Pavlovian timing association between two stimuli, a combined learning of timing and gain in the vestibulo-ocular reflex and in a voluntary arm reaching perturbed by a viscous force-field. The model parameters were the same, whereas the input and output signals were protocol-dependent. Each task consisted of two sessions of 80 trials of acquisition, where the model had to learn the appropriate response, and 20 trials of extinction, where the model had to extinguish the previously acquired behaviour. We compared the performances of two models: one equipped with the distributed plasticity and the other with only the cortical plasticity. Both models were able to learn and extinguish the proper response in all the three tasks, proving the generalizability of the proposed neural network. The model with distributed plasticity demonstrated better performances than the other one; it was able to modulate the output activity, with a synergic action of the three plasticities, and to transfer information from the cortical to the nuclear plasticities, exhibiting memory consolidation.