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Using cerebellar Purkinje cell models at different levels of abstraction as a read-out mechanism for pattern recognition in a biologically detailed granular layer model.

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The cerebellum is thought to be essential for our adaptive control. Its anatomy, physiology, circuitry and functionality have been well-studied [1--3], and several biologically detailed models of cerebellar neurons [4--9] and microcircuits [10,11] have been proposed. However, most existing network models that include the input layer (granular layer) and the output cell (Purkinje cell, PC) are based on simplified neuronal models [12--15]. Here, hybrid network models of cerebellar cortex were constructed based on a realistic granular layer model [11] and one of two kinds of abridged PC models: an inner product of synaptic weights and parallel fibre (pf) inputs [16,17], and an integrate-and-fire unit [13,14]. The granular layer model consisted of detailed granule and Golgi cell (GC and GoC) models, mossy fibres (mfs) and glomeruli (glom) (panel A). The PC received synapses from pfs (GC axons) originating within a 4,000 μm transversal $\times$ 250 μm sagittal $\times$ 100 μm vertical volume of granular layer comprising about 192,000 GCs. The models were implemented and simulated with NEURON (version 7.4) and Python (version 3.7.0) and studied in the context of a pattern recognition tasks. During this task, mfs were spontaneously active at 5 Hz and, in addition, a mf patch of 100 μm radius was activated at 200 Hz for 50 ms (panels B,C). At the offset of the mf patch stimulus, climbing fibre (cf) input induced long-term depression (LTD) of synapses from active pfs to the PC. After training, the two types of PC models showed distinct responses to learnt and novel patterns of stimulated mfs, both in their inner product and in their number of spikes during the stimulated 50 ms (red and green traces in panels D,E). The increase in inner product and firing rate in response to burst activity of mfs were absent in response to input to the learnt patch, but were still present in response to novel input, which implies that the transformation of stimuli in the granular layer does not prevent learning with pfs-PC LTD. As a next step, more realistic PC models [4,5,9] will be used as read-out neurons, and the effect of sparseness and clustering on pattern recognition will be studied.

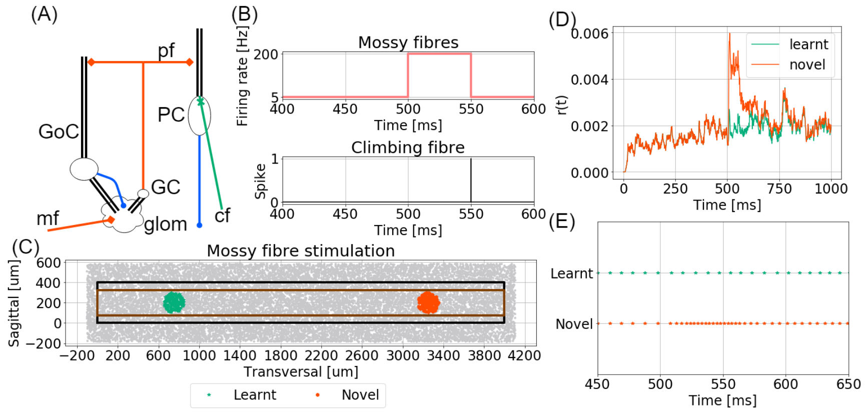

Figure 1: (A) Model circuit. GC, GoC, PC: granule, Golgi and Purkinje cells. mf, pf, cf: mossy, parallel, and climbing fibres. glom: glomeruli. (B) Timing of mfs and cf stimulation. (C) Stimulated patches of mfs. (D) Dot products of synaptic weight and pfs. (E) Spike sequences of the integrate-and-fire unit.

Acknowledgements

The first author appreciates the help of Dr. Tadashi Yamazaki at University of Electro-Communications, Tokyo and fruitful discussions with Dr. Sergio Solinas at the Institute of Neuroinformatics, Zurich. This work made use of the University of Hertfordshire's high-performance computing facility.

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- Citation: Katakura O, Maex R, Davey N, Kadir S, Steuber V (2019) Using cerebellar Purkinje cell models at different levels of abstraction as a read-out mechanism for pattern recognition in a biologically detailed granular layer model.. Bernstein Conference 2019. doi: 10.12751/nncn.bc2019.0043 (http://doi.org/10.12751/nncn.bc2019.0043)