Potential Control Implications of the Inferior Olive→Deep Cerebellar Nuclei pathway in a Distributed Plasticity Cerebellar Model

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Abstract. Biological control systems evolving along ages have become the paradigm to emulate in robotic control. It is well-known that the cerebellum is involved in the control and learning of smooth coordinated movements, therefore an accurate understanding of how this advanced control engine works should have a strong impact in controlling biomorphic robots. To that aim, we have studied the potential control implications that the inferior olive→deep cerebellar nuclei cell connections (IO→DCN) may present in a distributed synaptic plasticity cerebellar model (it has been revealed, that the deep cerebellar nuclei cells could be activated, through this connection). Our working hypothesis tries to lay down how this connection may enhance the performance of a manipulation robotic task based on the potential heterosynaptic phenomenon that may occur in relation to long-term depression (LTD) and long-term potentiation (LTP) synaptic plasticity mechanisms of our cerebellar model. The Marr and Albus cerebellar model already hypothesized that parallel fibers(PFs) presented both LTP and LTD synaptic mechanisms so as to correlate the activity at parallel fibers with the incoming error signal through climbing fibers. Nevertheless, in subsequent studies it has been demonstrated that nearly all cerebellar connections show traces of being affected by plasticity. If so, without stabilizing mechanisms operating at neural circuit level, forms of plasticity, such as LTP and LTD based on local activity levels, may drive neural activity towards instability due to an over-excitation or saturation. In previous work , we have developed a firing-rate cerebellar model which includes plasticity mechanisms not just at parallel fibers but also at deep cerebellar nuclei synaptic inputs (from Mossy Fibers and Purkinje Cells) Here, we present a model where the IO→DCN pathway may play a fundamental role enhancing the cerebellar capability to tune accuracy in the framework of manipulation tasks. By means of control learning, this neuronal connection may adjust its electrical excitability and the overall strength of deep nuclei cell synaptic connections. This close loop pathway may be seen as a built-in stabilization mechanism towards rapid control corrections.

The obtained results suggest that, the cerebellar gain control is a consequence of the mossy fiber→deep cerebellar nuclei (MF→DCN) and Purkinje cell→deep cerebellar nuclei (PC→DCN) synaptic plasticity mechanisms working in balance with IO→DCN connection. The homeostatic mechanisms that allow this balance are implemented by using different learning rules which indirectly drive the cerebellar model to improve its learning accuracy. IO→DCN connection ensures stability in the very early learning stages while MF→DCN and PC→DCN strength connections are not settled down through the learning process. Once the learning process is finished, the IO→DCN connection strength is self-neglected, but remains keeping on waiting for new unexpected patterns to be learnt.

Keywords: Computational Cerebellar Model, Motor Learning, Synaptic Plasticity, Robot Arm Control, Inferior Olive.

1. F. Bengtsson and G. Hesslow, "Cerebellar Control of the Inferior Olive," *The Cerebellum*, **review article**, 1-8, (2006).
2. T.J.H. Ruigrok and J. Voogd, "Organization of Projections from the Inferior Olive to the Cerebellar Nuclei in the Rat," *J. Comp. Neurol*., **426**, 209-228, (2000).
3. D. Marr, "A Theory of Cerebellar Cortex," *J. Physiol*., **202**, 437-70, (1969).
4. J.S. Albus, "A Theory of Cerebellar Function," *Math Biosci.,* 10, 25-61, (1971).
5. C. Hansel, D.J. Linden, and E. D'Angelo, "Beyond Parallel Fiber LTD: the Diversity of Synaptic and Non-Synaptic Plasticity in the Cerebellum," *Nat. Neurosci*., **4**, 467–475, (2001).
6. G. G. Turrigiano and S.B. Nelson, "Homeostatic Plasticity in the Developing Nervous System," *Nat. rev. Neurosci*., **5**, 97-107, (2004).
7. J.A. Garrido, N.R. Luque, D'Angelo E., and E. Ros, "Enhancing Learning Precision at Parallel Fiber-Purkinje Cell Connections Through Deep Cerebellar Nuclei LTD and LTP," in *FENS Forum*, Barcelona, (2012), p. Abstract n.**950**.

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