HOMEOSTATIC MECHANISMS AT CEREBELLAR PARALLEL FIBER – PURKINJE CELL CONNECTIONS THROUGH DEEP CEREBELLAR NUCLEI LTD AND LTP

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The cerebellum is one of the most influential centers controlling motor task performance. Traditional cerebellar theories by (Marr, 1969) and (Albus, 1971) in the early 70s anticipated the main role of plasticity at the parallel fibers (PF) → Purkinje cell (PC) synapses, where motor skills are learnt by storing memory traces. However over the last decades, several studies have shown that the whole cerebellum operates as an eminently plastic circuit (Hansel et al, 2001). Neurophysiological evidence has been provided about long-term depression (LTD) (Zhang and Linden, 2006) and long-term potentiation (LTP) (Pugh and Raman, 2006) at the connections afferent to the deep cerebellar nuclei cells (DCN) from mossy fibers (MF). Furthermore, LTD (Morishita and Sastry, 1996) and LTP (Ouardouz and Sastry, 2000) have been reported at DCN→PC connections.

In this work, a linear firing rate cerebellar model has been developed. This model includes: climbing-fiber-driven LTD and LTP at PF→PC connection, PC-driven LTD and LTP at MF→DCN synapses, and PC-driven LTD and LTP at PC→DCN connection. These adaptation mechanisms proved effective in previous simulations addressing the vestibulo-ocular reflex (VOR) (Masuda and Amari, 2008). In our model, the influence of these plasticity mechanisms on precise trajectory execution with robotic arms has been evaluated by using different loads applied at the end of the arm (thus modifying the intrinsic dynamic model of the arm+object entity).

Our model suggests that these learning mechanisms at MF→DCN and PC→DCN connections support the homeostasis at the PF→PC connections, and as a consequence, some other predicted functionalities, such as gain control and learning consolidation. This allows absorbing part of the information initially stored at the PF→PC connections. Moreover, learning mechanisms at MF→DCN and PC→DCN connections, in turn, help PCs to maintain their firing within the appropriate activity range, thereby enhancing learning precision at PF→PC connections.

Keywords: Computational Cerebellar Model, Motor Learning, Synaptic Plasticity, Homeostasis, Deep Cerebellar Nuclei.