An integrative neuromorphic approach to modeling of voluntary motor function

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In Niu, et al. (2017) we implemented a realtime Field-Programmable Gate Array (FPGA)-based simulation of neuromorphic models of monosynaptic stretch reflex circuitry of an agonist-antagonist muscle-pair. We then characterized the system in Jalaleddini, et al. (2017) by coupling the simulation to the flexor digitorum profundus and the extensor carpi radialis longus tendons of the MCP joint of a cadaveric hand preparation to show that such systems can indeed evoke human-like stretch reflexes as in the work of Edin and Vallbo (1990).

We now present improvements to that system such as including Golgi tendon organs, Renshaw cells, and polysynaptic interneuronal pathways to form a system akin to a simplified spinal-like regulator as in Raphael et al. (2010). Nonlinear adaptive controls and simple neural networks allow us tune the descending commands (pulse trains) to both fusimotor and alpha motoneuron pools. We use such time-based running of descending commands to demonstrate the ability to produce “voluntary” movement. We find that realistic models of muscle mechanics, force-velocity properties in particular, are critical to produce stable movements. By selectively adding/removing components and interconnections, we are also able to show the sufficiency of the same for enabling voluntary movement. Future extensions will include homonymous and heteronymous sensorimotor pathways to control more muscles and produce motor function in cadaveric human fingers.

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