A spiking neuron model of movement and pre-movement activity in M1

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We present a spiking neuron model of the primary motor cortex (M1) in the context of a reaching task for a 2-link arm model on the horizontal plane. The M1 population is embedded in a larger scale, hierarchical optimal control model of the motor system called NOCH (DeWolf & Eliasmith, 2010). NOCH characterizes the overall functioning of the motor system, and has been shown to reproduce natural arm movements, as well as movements resulting from perturbations due to motor system damage from Huntington's, Parkinson's, and cerebellar lesions. Here, we demonstrate that the observed dynamics of spiking neurons in awake behaving animals can be accounted for by the NOCH characterization of the motor system.

To do so, the M1 neural population is provided with target information and proprioceptive feedback in end-effector space, and outputs a lower-level system command, driving the arm to the target. The implemented neural population represents a single layer of the M1 hierarchy, transforming high-level, end-effector agnostic control forces into lower-level arm specific joint torques. The population is preferentially responsive to areas in space that have been well explored, providing more exact control for movements that can be executed using learned movement synergies. In this way the motor cortex performs component based movement generation, similar to recent Linear Bellman Equation (Todorov 2009) and Hidden Markov Model (Schaal 2009) based robotic control systems displaying high levels of robustness to complicated system dynamics, perturbations, and changing environments.

We compare neural activity generated from our model of M1 to experimental data of movement and pre-movement recordings in monkeys (Churchland 2010), providing support for our model of the primary motor cortex, and to the methods underlying the more general NOCH framework.