Analysis of Multielectrode Data from CPG Networks Using a Stochastic Framework

Maryam Abolfath-Beygi[1], Terence D. Sanger[1], and Simon F. Giszter[2]
[1] Department of Biomedical engineering, University of Southern California, Los Angeles, CA
[2] Department of Neurobiology, Drexel University College of Medicine, Philadelphia, PA

We are developing a new stochastic framework using stochastic dynamic operators (SDO) in order to quantify the inter-relations of neural dynamics and neural connectivity in motor control, and to develop predictive models suitable for neuroprostheses. Our goal is to construct a framework that is capable of capturing uncertainty in the high-level network behavior as well as connectivity patterns that are difficult to discover via current neural analysis techniques. The advantages of the SDO framework over current neural analysis and predictive models include: 1) its ability to describe state-based probabilistic dynamic effects of neurons, 2) its methodolgy to embed nonlinear dynamics in a linear frameork in the probability domain, and 3) its capacity to extend pair-wise neural analysis to multi-neural analysis through linear superpositions. In the SDO framework, each spike triggers a differential Markov operator mapping probability of current state of movement variables to the probability of next state in a continuous-time Markov dynamic model. An SDO thus represents both sensory (current state) and motor (mapping to the next state) effects in the neuron. The SDO model can be best compared with likelihood point process models such as the generalized linear model (GLM), since it describes the probability of firing rate of one neuron in terms of history of firing of itself and other neurons. The important differences are that firstly the SDO model can represent the pure nonlinear interactions, and secondly the SDO model has the potential to discover uncertainty in the realization of disparate possible outcomes. We use real neural data collected in spinal frogs, and artificial data from a simulated spinal network as a 'ground truth' network of known connectivity and hierarchy, driven by Hodgkin-Huxley dynamics. This network has been developed by Rybak, Shevtsova, and Markin for spinal cord simulation of populations of pattern generation neurons. The 'fictive' simulated network generates rhythms, deletions, and motor pool spiking which can be integrated to simulate electromyographic (EMG) recordings. First tests have built SDO-based predictive models of EMG as well as interneuron firing activities, validating SDO use in predictive control. The analysis demostrates that the SDO framework allows us to test SDO patterns for differentiating between central rhythm generation layer and pattern formation generation layer. We seek to predict the effect of small perturbations to the network from spike train recordings using appropriate SDO analyses. In this direction, we aim to combine neural perturbation techniques with the capability of SDO analysis in describing state-based dynamics, to discover neural hierchy and connectivity. Further, we seek to compare the SDO results with the resuls of GLM framework for EMG prediction and neural connectivity analysis in these experiments.