"A novel multi-class logistic regression algorithm to reliably infer network connectivity from cell membrane potentials."

by dr. Thierry Nieus, Università degli Studi di Milano

In neuroscience, the structural connectivity matrix of synaptic weights between neurons is one of the critical factors determining the overall function of a network of neurons. The mechanisms of signal transduction have been intensively studied at different time and spatial scales and at both the cellular and molecular level. While a better understanding and knowledge of some basic processes of information handling by neurons has been achieved, little is known about the organization and function of complex neuronal networks. Experimental methods are now available to simultaneously monitor neural activities from a large number of sites in real time.
Here, we present a methodology to infer the connectivity of a population of neurons from their voltage traces.
At first, spikes and putative synaptic events are detected. Then, a multi-class logistic regression is used to fit the putative events to spiking activities. The fit is further constrained, by including a penalization term that regulates the sparseness of the inferred network. The proposed weighted Multi-Class Logistic Regression with L1 penalization (MCLRL) was benchmarked against data obtained from in silico network simulations.
MCLRL properly inferred the connectivity of all tested networks (up to 500 neurons), as indicated by the Matthew correlation coefficient (MCC), already with small samples of network activity (5 to 10 seconds). Then, we tested MCLRL against different conditions, that are of interest in concrete applications. First, MCLRL accomplished to reconstruct the connectivity among subgroups of neurons randomly sampled from the network. Second, the robustness of MCLRL to noise was assessed and the performances remained high (0.95) even in extremely high noise conditions (95% noisy synaptic events). Third, we devised a data driven procedure to gather a proxy of the optimal penalization term, thus envisioning the application of MCLRL to experimental data. The proposed approach is ideally suited for populations recordings, where spikes and post-synaptic recordings can simultaneously be recorded (e.g. genetic encoded voltage indicators). Yet, the main message here is that a small fraction (5%) of genuine synaptic events is sufficient to properly infer the underlying connectivity of a network.

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