Decoding Spike Ensembles: Tracking a Moving Stimulus

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How to read out the information from spike train ensembles is a long-standing issue in Neuroscience. Assuming that neurons *in vivo* operate as stochastic units, this issue is naturally addressed within the context of the statistical inference theory. Based upon our earlier work [1], we develop here a maximum-likelihood estimate (MLE) to decipher the activity of a network of I&F neurons.

In particular, we consider the following issue, which was left unresolved in [1]. To promptly respond to a time-dependent input the nervous system has to read out the information within short time windows. As a result, any decoding scheme based on the distribution of the interspike intervals will naturally face the problem of *censored* observations, i.e. any interspike interval longer than the decoding window will never be observed under such circumstances. In many cases, there may be even be no more than one spike observed within each time bin, hence there may be no 'proper' interspike intervals available for decoding. Under such circumstances, a standard maximum-likelihood approach is bound to return a biased estimate, or it may even not applicable at all. Following ideas developed in dealing with censored data in statistics, we present a 'censored' MLE approach (CMLE) to tackle this problem. To compare the efficiency of maximum-likelihood with a classical rate-based estimate, we also derive a rigorous moment estimate (ME), based on the analytical calculation of the relationship between the output (the mean firing rate) and the input of an I&F neuron.

The CMLE and the ME are first tested on a population of spiking neurons with constant inputs. It is found that CMLE yields an unbiased estimate, even for short (50 ms) decoding windows. Also, we find that the CMLE is consistently more accurate than ME, as expected from theory. Then, we test our approach using dynamical input signals. It is found that the time-course of the input signal can be accurately retrieved, despite only about one spike per neuron is observed within each time window. These findings also demonstrate the ability of such a spiking neuronal network to rapidly respond to external inputs. Finally we considered a tracking task, in which a moving target is located by reading out the output activity of a network of spiking neurons. The latter was designed to resemble the typical columnar architecture found in the cortex, with neurons grouped in columns sharing the same response properties. In particular, we neurons were tuned to specific spatial locations, in such a way to create a topographical map. Our results demonstrate that such a system can perform the tracking task quite accurately. Also, by varying the number of columns used for decoding, we demonstrate that the stimulus readout is more accurate when all neurons are taken into account for decoding, as in the *response pooling* approach, than when only the most responsive neurons are used, as indicated by *lower envelope principle*.

References

[1] Feng, J., and Deng, M. (2004). Decoding spikes in a spiking neuronal network. *J. Phys. A: Math. Gen.*, **37**, 5713-5727.