Simulating and Decoding Neuronal Spike Trains Millisecond-By-Millisecond

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One view of the brain is that it is an information processing machine with neurons as critical building blocks. The neurons themselves are complicated elements. At the level of systems neuroscience they are simplified into elements that carry information via their spike trains. The spike trains arise from the integration of the many inputs (some estimates are that there are 10^4 inputs per cortical neuron) leading to excitation of the neuron to generate an output spike train.

It is in this information processing view that we study the brain as the substrate for behavior. Immediately we are faced with what the neural code might be. Unlike the genetic code that has a fixed frame length of 3 base pairs, and a nearly universal meaning, a neural response unfolded in time and is evanescent. Once a specific spike train has been emitted, an exact replicate seems unlikely ever to reappear.

It is obvious that the number of spikes can be treated as a code with the modulation of the number as the code elements. In the visual system for example, the number of spikes might be related to the orientation of a bar or edge. Looking at spike trains it is inevitable that we wonder whether or to what degree the pattern of spikes over time and across neurons acts as a code. This issue has fascinated neurophysiologists for nearly 100 years, with heated debates continuing to this day about the role of these spike patterns, especially when they arise within the networks of patterns and not from some external drive. Here I will present data and support a view that the patterns of spikes arise from stochastic sampling of an underlying deterministic temporally modulated rate function. The approach is based straightforward application of order statistics, and using this approach I will demonstrate that we can construct spike trains in single neurons and pairs of neurons that are indistinguishable from the experimentally recorded ones, and that this approach can be used to decode spike trains as the unfold millisecond-by-millisecond.