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Poster presentation

Serial interspike interval correlations of excitable neurons with memory

Tilo Schwalger* and Benjamin Lindner

Address: Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany

Email: Tilo Schwalger* - tilo@pks.mpg.de

* Corresponding author

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Many theoretical studies of spiking neurons rely on the simplifying renewal assumption, meaning that interspike intervals (ISIs) of a spike train are statistically independent. Experimental measurements of serial ISI correlations have revealed, however, that the renewal assumption is violated in various systems. For instance, strong but short-lived, negative correlations have been reported for P-units of weakly electric fish [1,2] and for pyramidal neurons in rat entorhinal cortex [3]. For a review, see [4]. Positive correlations that extend over many ISIs have been observed in [5]. Neurons exhibiting spike-frequency adaptation typically display negative serial correlations, whereas slow input variations typically induce positive serial correlations [6].

Theoretical work has gained much insight into the beneficial role of serial correlations for signal transmission [7]. In that case, the calculation of the serial correlation coefficient (SCC) could be accomplished by the use of a particularly simple neuron model that operates in the oscillatory regime and features a dynamic firing threshold. In general, however, the SCC is difficult to access analytically, which is due to the non-Markovian nature of non-renewal neuron models. Here, we present a novel technique that allows us to calculate the SCC of a large class of non-renewal neurons operating in the excitable regime. Specifically, we consider neurons with discrete internal states or discrete states of the external driving function. The analytical approach is based on a generalization of the discrete kinetic scheme used to investigate residence time correlations in driven bistable systems [8,9].

Having established the general method to obtain the SCC for arbitrary lags between ISIs, we consider two special cases that are of particular interest. The first case mimics a leaky integrate-and-fire (LIF) neuron with dynamic threshold, which has been proposed as a model for spike-frequency adaptation. By discretizing the threshold into three states, we find a negative SCC at lag one and vanishing correlations at higher lags. In the second case, we consider a neuron that participates in a network that switches between Up and Down states. The theory reveals positive serial correlations that decay exponentially with the lag. Interestingly, for slow two-state synaptic input the SCC at lag one is maximized at an optimal amplitude of the two-state driving. Our theoretical expressions agree well with extensive simulations of noisy LIF neurons. Finally we mention, that an analytical formula for the SCC could be useful to model measured data by tuning the parameters of the discrete neuron model.

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