Intrinsically bursting neurons enlarge timescales of fluctuations in firing rates

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Timescales of fluctuations in single-neuron spiking activity are reported to vary depending on cortical areas in a resting-state macaque brain, implying that the timescales contribute to areal functional specialization [1]. However, it remains unclear what intrinsic neural properties cause the various timescales. The purpose of this study is to identify the key parameter of a spiking neural network model to determine the timescale. We focus on the intrinsically bursting (IB) neurons that have a shorter refractory period than the regular spiking (RS) neurons. The IB neurons, if injected dc current, fire burst of spikes, in contrast, the RS neurons fire a few spikes with short interspike period, i.e. refractory period. We evaluated the timescales in neural networks consisting of one thousand Izhikevich's spiking neurons [2], where the ratios of the number of the IB neurons to that of the RS ones were varied. The timescale T was evaluated using the decay of the spike-count autocorrelation R for pairs of time bins (currently, 150ms) based on the equation (1) in Fig. 1, which shows the timescales averaged over all neurons in networks with various ratios of the number of the IB neurons to that of the RS ones. When the timescale becomes large, neurons tend to maintain the number of spikes per bin. Only within the range of the ratio, from 0.95 to 1.35, the exponential decays of the autocorrelation, which were observed in macaque brain [1], were observed. The median of the timescale for 10 trials became large as increase in the number of the IB neurons. This trend indicates that the IB neurons contributes to the maintenance of their firing rates rather than the RS neurons. We speculate that difference of refractory period between RS and IB neuron lead this result. As we mentioned above, refractory period of RS neuron is larger than IB neuron (i.e. the time to next spike is long), therefore, fluctuation of firing rate of RS neuron within each bin is larger than IB neuron.

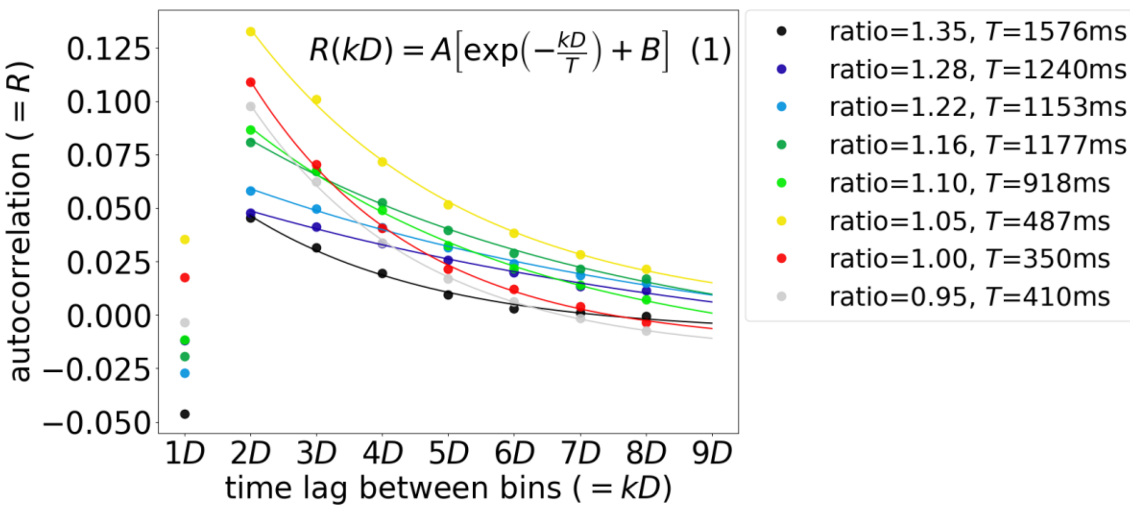

Figure 1. Spike-count autocorrelation was computed with time bins (D=150ms) for each ratio of the number of the IB neurons to that of the RS ones. Each color corresponds to the ratio. The timescale T is defined as an exponential decay of the autocorrelation R with a coefficient A and an offset B. Solid lines show the exponential fit as a function of time lag kD between bins. The value of the timescale is the median for 10 trials.

Future issues

The current model had random connectivity, although the existing computational study figured out that the biologically realistic connectivity, e.g., layer-specific connectivity, also contributes to reproduce the various timescales [3]. We plan to investigate how these factors, i.e., the intrinsic properties of an individual neuron and connectivity between neurons have impact on the timescales. Furthermore, how the various timescales yield functional differentiation is an interesting question.

References

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