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Neuronal jitter: can we measure the spike timing dispersion differently?

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To measure the spike timing precision is a tedious task. First, spike trains may be interleaved by bursts and interpreting their information content is difficult [1]. Second, input-output neuronal transfer functions are nonlinear, depend on many synaptic inputs and it is also difficult to track the source of variability in experimental data. We propose an information-theoretic quantity, entropy-based dispersion (ED), to measure dispersion of a continuous spike-timing probability distribution. The method is based on the notions of differential entropy and asymptotic equipartition property [2]. The ED is conceptually similar to the traditionally used standard deviation (SD) and coefficient of variation (CV). However, we show that the properties of SD and ED are different: while SD is a second-moment characteristics measuring the dispersion relative to the mean value, ED measures the absolute effective spread of the probability distribution and is more closely related to the concept of randomness [3].

We apply both measures to analyze the temporal precision of neuronal spiking activity of the perfect integrate-and-fire model [4], which is a plausible neural model if the synaptic activity is high enough. The synaptic activity is described by several frequently used models, namely, the inter-spike interval (ISI) probability distribution of presynaptic neurons is either exponential, gamma, inverse Gaussian or bimodal lognormal.

We show that SD and ED behave similarly for simple models of presynaptic activity (Poisson, gamma and inverse Gaussian) when the CV of input spike trains inter-spike intervals is not greater than 1. However, for bimodal lognormal or overdispersed input spike trains (CV > 1) the results obtained by SD and ED differ strikingly. We discuss these differences and argue, that contrary to ED, SD may overestimate or underestimate the variability of output spiking activity. We show on several examples, how the ED might pinpoint some optimal regimes or parameter values of spike trains.

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