Classification of stationary neuronal activity according to its information rate

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Abstract

We propose a measure of the information rate of a single stationary neuronal activity with respect to a template. The measure is based on the Kullback-Leibler distance between two interspike interval (ISI) distributions. The selected activity is compared with the state of null information described by the Poisson model with the same mean firing frequency. Then, the information rate quantifies the Poisson character of the chosen ISI descriptor (or data): the rate is zero if, and only if, the ISIs are distributed according to the reference model (in our case the Poisson process). This measure represents an alternative to the standard statistical methods, e.g., Kolmogorov-Smirnov test, as it reflects different aspects of the activity. We also show when the approach is related to the notion of specific information and that the method allows to judge the relative encoding effectivity.

Two classes of neuronal activity models are classified according to their information rate: the renewal process models and the first-order Markov chain models. The renewal process is fully described by its ISIs probability density function $f(t)$. The gamma, inverse Gaussian, lognormal and Pareto distributions are related to the template and we show that information can be transmitted changing neither the spike rate nor the coefficient of variation (CV). On the other hand, the Markov chain is fully described by the joint ISIs probability density function $f(t_1, t_2)$ and we analyze especially the effect of the ISIs correlation on the information rate. We show, that the increase in correlation does not necessarily increase the information gain.

The key point of the method is the differential entropy rate computation (estimation). We employ a simple but powerful Vasicek's estimator to illustrate an application on the experimental data coming from olfactory sensory neurons of rats.