Universität Bremen

M.Sc. Neurosciences

Module MN-F3: Theoretical Neuroscience

Exercises #2 / Tutorial on 4.12.2025

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1 Spike statistics and correlations

a) How are the coefficient of variation and signal-to-noise ratio related to each other?

b) Why is the Fano-factor important, and what does a value of 1 suggest for an observed stochastic process?

c) What is the difference between correlation and covariance?

2 Temporal structure within and among spike trains

We have recorded two neurons with an average firing rate of 42 Hz. Sounds boring, but maybe there is more to these units than just having the same average activity. Let us have a look at their auto- and cross-correlograms!

a) Implement a function `correlogram` which takes two `numpy`-vectors s_1, s_2 of same length, and a maximum delay $\tau_0 > 0$, and computes the following function $c(\tau)$ for $-\tau_0 \leq \tau \leq +\tau_0$:

$$c(\tau) = \frac{1}{T - |\tau|} \begin{cases} \sum_{t=\tau}^{T} s_1(t-\tau) s_2(t) & \text{if } \tau > 0 \\ \sum_{t=0}^{T+\tau} s_1(t-\tau) s_2(t) & \text{if } \tau < 0. \end{cases} \tag{1}$$

The function shall return $c(\tau)$, and the range of values τ within $[-\tau_0, +\tau_0]$.

b) For testing your code, plot $c(\tau)$ over τ for $\tau_0 = 3$ for the example spike trains `s1 = np.array([0, 0, 0, 0, 1, 0, 0, 0, 0])` and

- `s2 = np.array([0, 0, 1, 0, 0, 0, 0, 0, 0])` and
- `s2 = np.array([0, 0, 0, 0, 0, 0, 1, 0, 0])` .

c) Load file `exercise2.npz` and investigate the three spike arrays `s_one`, `s_two_A`, and `s_two_B`; they have the shapes `(n_trials, n_timesteps)`. Compute and plot auto-correlograms and cross-correlograms, and interpret your findings!

3 Statistics and Reality

For conducting an experiment, it is good practice to evaluate how much data you need if you expect a certain effect size. In this example, consider recording neurons being active according to a Poisson statistics, with rates between r_{min} and r_{max}.

a) Assuming your recording time T in one trial is limited, how many trial repetitions n would you need for determining the average/mean firing rate r (over time and trials!) with a standard deviation of p percent from the mean? Give an equation!

b) Test your equation by writing a `numpy`-function which generates n repetitions of trials with length T, simulating a Poisson process with rate r. Call this function multiple times and assess the statistics of the mean firing rates you obtain and compare with your analytical result.