Modeling Membrane Potentials in Motoneurons by time-inhomogeneous Diffusion Leaky Integrate-and-Fire Models

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Abstract

A commonly used model for membrane potentials in neurons is the diffusion leaky integrate-and-fire model, where the membrane potential $(X_t)_{t\geq 0}$ is assumed to be a solution of a time-homogeneous SDE with linear drift

$$\mathrm{d}X_t = (a - \frac{1}{\tau}X_t)\mathrm{d}t + \sigma(X_t)\mathrm{d}B_t,$$

where $(B_t)_{t\geq 0}$ is a standard Brownian motion and $\sigma(\cdot)$ the diffusion coefficient. However, real data contains very often time-inhomogeneous patterns. Moreover, we can observe from data that the time-constant τ decreases when neuronal activity increases. Further, $\sigma^2(\cdot)$ turns out to be a linear function of X_t, which leads to the Feller neuronal model. The issue is to model the cycling behavior of membrane potentials in motoneurons from an active network during mechanical stimulation and to take a varying τ and a linear $\sigma^2(\cdot)$ into account. In a first step we use nonparametric methods in the data analysis which help to apply further regression methods in order to fit the model to data.