Parameter inference from hitting times for perturbed Leaky Integrate and Fire neuronal models

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In neuroscience, the interval between two consecutive action potentials is often studied being related to information transfer in neurons. Leaky Integrate and Fire (LIF) models are often chosen to describe the subthreshold membrane potential evolution of the neuron [1] and parameter estimation has been investigated [2]. In many experiments, a stimulation (the intervention) such as a sound or a visual image is presented and the changes in electrical activity of the neuron is measured. Estimation from observations of the last action potential before the intervention and the next following it, also in presence of delayed response to the stimulus and background noise, has been recently investigated [3, 4]. But how can we evaluate whether the intervention had an effect?
To answer this question we describe the effect of the intervention through parameter changes of the underlying LIF model. Then, the time interval between the start of the process and the final event is divided into two subintervals: the time from the start to the instant of intervention, denoted by S, and the time between the intervention and the threshold crossing, denoted by R. The first question studied here is: What is the joint distribution of (S, R)? The theoretical expression is provided and serves as a basis to answer the main question: Can we estimate the parameters of the model from observations of S and R and compare them statistically? Maximum likelihood estimators are illustrated on both simulated and real data under the assumption that the process before and after the intervention is described by the same type of model, i.e. either a Brownian motion [5] or an Ornstein-Uhlenbeck process, but with different parameters. The proposed model can be used as a model of latency and it is able to cover both excitatory and inhibitory responses.

References

[1] L. Sacerdote, M.T. Giraudo. Leaky Integrate and Fire models: a review on mathematical methods and their applications, in *Stochastic biomathematical models with applications to neuronal modeling*, volume 2058 of Lecture Notes in Mathematics, pp. 95–148. Springer, 2013.

[2] P. Lansky, S. Ditlevsen. A review of the methods for signal estimation in stochastic diffusion leaky integrate-and-fire neuronal models. *Biological Cybernetics*, 99, pp. 253–262, 2008.

[3] M. Tamborrino, S. Ditlevsen, P. Lansky. Identification of noisy response latency, *Physical Review E* 86:021128, 2012.

[4] M. Tamborrino, S. Ditlevsen, P. Lansky. Parametric inference of neuronal response latency in presence of a background signal. *BioSystems* 112, pp. 249–257, 2013.

[5] M. Tamborrino, S. Ditlevsen, P. Lansky. Parameter inference from hitting times for perturbed Brownian motion. To appear in *Lifetime Data Analysis*, DOI 10.1007/s10985-014-9307-7, 2015.