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Session 1: Open Talk

On the ubiquity of Gibbs distributions in spike train statistics

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In this talk we shall argue that Gibbs distributions, considered in more general setting than the initial concept coming from statistical physics and thermodynamics, are canonical models for spike train statistics analysis. This statement is based on the three following facts, developed in the talk.

1. The so-called *Maximum Entropy Principle* allows one to propose models for spike statistics based on empirical observations, providing constraints for the model. Although this approach has been initially devoted to show the role of weak instantaneous pairwise correlations in the retina [7], it has been recently applied to investigating the role of more complex events such as instantaneous triplets [4] or spatio-temporal events [8]. Probability distributions arising from the Maximum Entropy Principle are Gibbs distributions. The main strength of this method is to be able to include any type of spatio-temporal correlations as constraints for statistical estimations. Its mean weaknesses are (i) It assumes stationarity; (ii) It does not tell how to select constraints among the huge set of possibilities.

2. Other approaches such as the Linear-Non Linear (LN) or Generalized Linear Models (GLM) propose an ad hoc form for the conditional probability that a neuron fires given the past network activity and given the stimulus. Those models have been proven quite efficient for retina spike trains analysis [6]. They are not limited by the constraint of stationarity, but they are based on a questionable assumption of *conditional independence between neurons*. As we show, the probability distributions coming out from those models are also Gibbs distributions, although in a more general sense than 1.

3. Recent investigations on neural network models (conductance based IF with chemical and electric synapses) show that statistics of spike trains generated by these models are Gibbs distributions reducing to 1 when dynamics is stationary, and reducing to 2 in specific cases [1, 2, 3]. In the general case, the spike trains produced by these models have Gibbs distributions *which neither match 1 nor 2*. Additionally, spike correlations are not only produced by a shared stimulus: they have a strong dynamical component due to neurons' interactions.

We shall also briefly discuss a software implementation, designed at INRIA, for MEA spike train analysis using Gibbs distributions [5].

- [1] Cessac B. A discrete time neural network model with spiking neurons ii. dynamics with noise. *J. Math. Biol.*, 62:863-900, 2011
- [2] Cessac B. Statistics of spike trains in conductance-based neural networks: Rigorous results. *J Mathem Neurosci*, 1, 2011.
- [3] Cofré R, Cessac B. Dynamics and spike trains statistics in conductance-based integrate-and-fire neural networks with chemical and electric synapses. *Chaos, Solitons and Fractals*, 2012. submitted.
- [4] Ganmor E, Segev R, Schneidman E. The architecture of functional interaction networks in the retina. *J Neurosci*, 31:3044-3054, 2011.
- [5] Nasser H, Marre O, Cessac B. Spatio-temporal spike trains analysis for large scale networks using maximum entropy principle and monte-carlo method. *J Statist Mech*, submitted, 2012.
- [6] Pillow JW, Ahmadian Y, Paninski L. Model-based decoding, information estimation, and change-point detection techniques for multineuron spike trains. *Neural Comput.*, 23:1-45, 2011.
- [7] Schneidman E, Berry MJ, Segev R, Bialek W. Weak pairwise correlations imply strongly correlated network states in a neural population. *Nature*, 440:1007-1012, 2006.
- [8] Vasquez JC, Marre O, Palacios AG, Berry MJ, Cessac B. Gibbs distribution analysis of temporal correlation structure on multicell spike trains from retina ganglion cells. *J. Physiol. Paris*, 2012. in press.