

# COSYNE 2010

7th Computational and Systems Neuroscience Meeting

Main Conference • 25–28 February 2010

Salt Lake City, Utah

Workshops • 1–2 March 2010

Snowbird, Utah



Research Results  
of the BCF  
presented at:



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## Microcircuits of stochastic neurons

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Multiplicatively interacting point processes and applications to neural modelling Stefano Cardanobile & Stefan Rotter BCCN  
Mathematical analysis of complex neural network dynamics is both challenging and important for research in neuroscience. current approaches, though, rely on mean-field approximations, which have difficulties to evaluate the influence of network structure on its spiking dynamics. We exploit the stochastic nature of neuronal firing and set up a point process framework, the observation that the escape noise of real neurons is exponential with respect to their membrane voltage [1]. Assuming linear integration of inputs, this translates into a multiplicative interaction rule on the level of instantaneous firing rates: each incoming spike effectively multiplies the instantaneous firing rate by a fixed "synaptic weight". This approach is in contrast to Hawkes' model [2], where the instantaneous firing rate is given by a convolution of the input spike rate with a linear temporal filter. This effectively prevents the implementation of inhibition in this model. We proved that the equations governing the dynamics of expected firing rates in our multiplicative system are of Lotka-Volterra type, if one ignores covariances [3]. Based on numerical simulations, we show that this approximation works quite well under very general conditions. Asymptotically, the observed rates coincide with the solutions of the associated rate equations even in cases where the rates do not converge to a fixed point or exhibit transient dynamics. Multiplicatively interacting point processes offer an interesting novel framework for the study of neural network dynamics. To illustrate this claim, we finally describe some structured networks that are able to process information and discuss specifically competing neural populations to describe experiments where rivaling features are perceived. Our model qualitatively replicates the unimodal distribution of dwell times as observed in experiments, and it leads to an intuitive explanation of the switching dynamics. The project has been supported by BMBF grant 01GQ0420 to the BCCN Freiburg.

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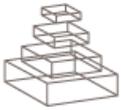
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# Beyond linear perturbation theory: the instantaneous response of integrate-and-fire model

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The integrate-and-fire neuron model with exponential postsynaptic potentials is widely used in analytical work and in simulations of neural networks alike. For Gaussian white noise input currents, the membrane potential distribution is known exactly. The linear response properties of the model have successfully been calculated and applied to the dynamics of recurrent networks in the diffusion limit [2]. However, the diffusion approximation assumes the effect of each synapse on the membrane potential to be infinitesimally small. Here we present a novel hybrid theory that takes finite synaptic weights into account. We show, that this approximation considerably alters the absorbing boundary condition at the threshold: the probability density increases just below threshold. As a result, the response of the neuron to a fast transient input is enhanced much in the same way as found for the case of synaptic filtering [3]. However, in contrast to this earlier work relying on linear perturbation theory [4], we quantify to all orders an instantaneous response that is asymmetric for excitatory and inhibitory transients and exhibits a non-linear dependence on perturbation amplitudes. Furthermore we demonstrate that in the pooled response of two neuronal populations to antisymmetric transients the linear components exactly cancel. In this scenario the macroscopic network dynamics is dominated by the instantaneous non-linear components of the response. These results suggest that the linear response approach neglects important features of the rectifying nature of threshold units with finite jumps even for small perturbations. We provide an analytical framework to go beyond [5]. Partially funded by BMBF Grant 01GQ0420 to BCCN Freiburg, EU Grant 15879 (FACETS), DLR Helmholtz Alliance on Systems Biology, and Next-Generation Supercomputer Project of MEXT.

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