Research Results of the BCF presented at: 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

Invited Speakers • Keynote Clay Reid (Harvard Medical) • Ophne Baxtiller (Rochester) • Howard Berg (Harvard) • Adrienne Feinberg (University of Washington) • John Lisan (Brandeis) • Eve Marder (Brandeis) • Tim Moore (Stanford) • Michael Pletz (Duke) • Nicholas Schiff (Cornell Medical) • Jackie Schiller (Techne) • Anthony Zador (Cold Spring Harbor)
Special Symposium honoring Horace Barlow • Horace Barlow (Cambridge) • David Field (Cornell) • William Grisler (Texas) • Geoffrey Hinton (Toronto) • Simon Aughton (Cambridge)
Organizing Committee • General Chair Monash School (University College London) • Program Chair Anne Churchland (University of Washington) and Barbara Miller (University of Southern California) • Workshop Chair Ado Kahn (Nester) and Mark Lauscher (Yale) • Communications Chair Dyrce Yu (Carnegie Mellon)
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Microcircuits of stochastic neurons

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Multiplicatively interacting point processes and applications to neural modelling

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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 input 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. It 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 but 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.

References


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 simu-

The linear response properties of the model have successfully been calculated and applied to the dynamics of recurrent net-

this diffusion limit [2]. However, the diffusion approximation assumes the effect of each synapse on the membrane potenti-

We consider the absorbing boundary condition at the threshold: the probability density increases just below threshold.

The response of the neuron to a fast transient input is enhanced much in the same way as found for the case of synap-

during filtering [3]. However, in contrast to this earlier work relying on linear perturbation theory [4], we quantify to all orders an

features of the rectifying nature of threshold units with finite jumps even for small perturbations. We provide an analytical

macroscopic network dynamics is dominated by the instantaneous non-linear components of the response. These results suggest that the linear response approach neglects imp-

Partial funding by BMBF Grant 01GQ0420 to BCCN Freiburg, EU Grant 15879 (FACETS), DfG Helmholtz Alliance on Systems Biology, and Next-Generation Supercomputer Project of MEXT.

References

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