BP 14: Posters: Neurophysics

Time: Monday 17:30–19:30 Location: Poster A

BP 14.1 Mon 17:30 Poster A

Frequency modulated signal transmission in neurons — •Tim Herfurth and Tatjana Tchumatchenko — Max Planck Institute for Brain Research, Max-von-Laue-Str. 4, 60438 Frankfurt/M

During information/signal processing in neural networks aside from the actual signal background activity is always present and is commonly denoted as noise. Mechanisms of neural coding and decoding have to account for that and still reliably transmit information within the network. Traditionally, spontaneous synaptic and background activity have been treated as additive noise. Alternatively, amplitude modulations of the noise by the signal have been proposed, effectively coding in the variance channel. In this work we suggest and present closed form expressions for another kind of signal modulation: frequency modulation (FM). Here, the signal modulates the noise by linear frequency modulation. The concept is well known, e.g. from communication techniques. However, we present a representation that incorporates arbitrary forms of input signals and noise, define a signal-to-noise ratio and show consequences for statistics and mutual information of the FM channel.

BP 14.2 Mon 17:30 Poster A

Activity propagation in feed-forward neuronal networks described by reaction-diffusion like equations — •Dmytro Grytskyy[1], Markus Diesmann[1,2], and Moritz Helias[1] — [1]INM6&IAS6, Juelich Research Centre and JARA, Jülich, Germany — [2]Medical Faculty, RWTH Aachen, Germany

We investigate feed-forward neuronal networks of linear-nonlinear rate neurons with synaptic plasticity. For systems without plasticity or near to criticality, layers can be mapped onto states in time. We treat the K nearest neighbor coupling in diffusion approximation to obtain equations for the activity evolution from layer to layer. The equations are similar but not identical to those describing reaction-diffusion systems. We develop an appropriate solution scheme also applicable to generalized systems with several synapse or neuron types. We obtain the critical border separating ultimately decaying activity from possible activity explosion. On the border (requiring exact parameter tuning) and in its subcritical vicinity we analytically find long-living dissipative solitons with a plateau of arbitrary width with the decay velocity proportional to the distance to criticality. Two bumps can unite or remain disjoint within their lifetime depending on the distance in-between. For the united bump the same scenarios exist, so a kind of association tree can appear in this way.

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BP 14.3 Mon 17:30 Poster A

Mechanotransduction in the pentamere organ of the Drosophila larva — •Achintya Prahlad[1], Ben Warren[2], Martin Göpfert[2], and Christoph Schmidt[1] — [1]Drittes Physikalisches Institut, Georg-August-Universität, Göttingen — [2]Schwann-Schleiden Research Centre, Georg-August-Universität, Göttingen

The fruit fly Drosophila melanogaster uses mechanosensation for several purposes. One class of specialized organs are the chordotonal organs, such as the antennal auditory organ of the adult, and the larval pentamere organ (or lch5). The sensory neurons at the core of these organs have one dendrite, which terminates in a cilium. The cilia are believed to be the main mechanotransducers. The lch5 organ aids in locomotion by giving feedback to the central nervous system. We focus on this organ because its sensory neurons are well accessible to manipulation under the microscope.

Some molecular and anatomical aspects of these organs have been studied. However, an understanding of the internal transduction mechanics and the manner in which membrane channels are activated upon deflection of the cilium is still elusive. We are using a preparation of the larva under buffer solution that allows us to directly contact the sensory neurons of the lch5 after removing 2-3 layers of muscles. Our approach is to provide controlled mechanical stimuli to the cilia and measure the mechanical and electrical response.

BP 14.4 Mon 17:30 Poster A

Stochastic thermodynamics of biological information processing — •Sebastian Goldt and Udo Seifert — II. Institut für Theoretische Physik, Universität Stuttgart

We consider the stochastic thermodynamics of neural information processing in the presence of noise. Defining what we mean by noise in this problem is non-trivial, since it inevitably requires the definition of a signal, which is often hard to identify in neural systems. We therefore turn to general information theoretic measures to describe neural information processing, motivated by the fact that neurons in different organisms from fruit flies to primates display strikingly similar values for several of these parameters. This allows us to neglect the precise form of stimulus and response. Our focus is on single neurons, given the strong evidence for the impact of individual neurons on a behavioural level even in complex nervous systems, *e.g.* in perceptual decisions of primates.

Here we apply recent results in the theory of small systems [1], specifically at the boundary to information theory [2], to gain a better understanding of both the principles underlying the generality of neural properties and the limits that the inherent stochasticity of neural hardware places on computational strategies in the brain.

1 U. Seifert, Rep. Prog. Phys. **75**, 126001 (2012).

2 A. C. Barato and U. Seifert, Phys. Rev. Lett. **112**, 090601 (2014).

BP 14.5 Mon 17:30 Poster A

An objective function for Hebbian self-stabilizing neural plasticity rules — •Rodrigo Echeveste and Claudius Gros — Institute for Theoretical Physiscs, Goethe University Frankfurt, Germany

Objective functions provide a useful framework for the formulation of guiding principles in dynamical systems. In the case of information processing systems, such as neural networks, these guiding principles can be formulated in terms of information theoretical measures with respect to the input and output probability distributions. In the present work, a guiding principle for neural plasticity is formulated in terms of an objective function defined as the Fisher information with respect to an operator that we denote as the synaptic flux[1]. By minimization of this objective function, we obtain synaptic plasticity rules that both account for Hebbian/anti-Hebbian learning and are self-limiting to avoid unbounded weight growth.

As an application, the non-linear bars problem[2] is studied, in which each neuron is presented with a grid of inputs, depicting the superposition of a random set of bars. We show that, under the here presented rules, the neurons are able to learn single bars or points (the independent components of the input), even when these are never presented in isolation.

[1] Echeveste, R., & Gros, C. (2014). Generating functionals for computational intelligence: The Fisher information as an objective function for self-limiting Hebbian learning rules. Front. Robot. AI, 1, 1.

[2] Földiak, P. (1990). Forming sparse representations by local anti-Hebbian learning. Biological cybernetics, 64(2), 165-170.

BP 14.6 Mon 17:30 Poster A

Patterning and Interfacing of Biological Neural Networks — •Norman Shepheard[1,2], Stefan Niehörster[1], Matthias Schürmann[3], Savio Fabretti[1], Barbara Kaltschmidt[3], Christian Kaltschmidt[3], Ulrich Rückert[2], Elisabetta Chicca[4], and Andy Thomas[1] — [1]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany — [2]Cognitronics and Sensor Systems, Bielefeld University, Germany — [3]Cell Biology, Bielefeld University, Germany — [4]Neuromorphic Behaving Systems, Bielefeld University, Germany

The scale of neural networks reaches from large structures such as the whole human nervous system down to small single neurone networks. To examine the small types of single neurone networks we use a bottom up approach, which consist of two important parts. The first part is the pattern of the cell adhesion layer. The second part is the interface to the network.

To achieve self grown networks we produce an adhesion layer stack made of (3-aminopropyl)triethoxysilane (APTES), glutaraldehyde and poly-lysine. This adhesion layer is patterned via the uv-lithographic "lift-off" technique. The hyppocampal mouse neurones are cultured

on top of the adhesion layer. Our results show that the neurones adhere to the poly-lysine and aligning themselves with the pattern. The adhesion pattern is designed to fit to the electrode layout of a multi electrode array, which interfaces the networks.

BP 14.7 Mon 17:30 Poster A

Can compartmentalization explain fast population coding? — •David Hofmann[1,2], Andreas Neef[1,2], and Fred Wolf[1,2] — [1]Max Planck Institut für Dynamik und Selbstorganisation, Göttingen — [2]Bernstein Center for Computational Neuroscience, Göttingen

Cortical neurons, driven by noisy current injections, change their firing rate within 1 ms of a small step in the current average. This sets the speed of cortical information processing. Theoretical and experimental evidence points at the rapidness of the action potential (AP) onset as the key determinant of the fast neuronal response. However, the biophysical basis of this onset rapidness is unclear and a matter of current debate.

Recently, a minimal multi-compartment model was presented that produces a rapid onset in the somatic AP waveform (Brette *PloS Comp. Neuro.* 2013). This occurs by electric decoupling of the soma from the site of AP initiation (compartmentalization).

Here we investigate whether the electric decoupling mechanism can also explain the fast neural response. Specifically, we tested whether the model reproduces two robust experimental observations, a) the high cut-off frequency of the dynamic gain function in the range of 200 Hz b) the increasing cut-off frequency for increasing input current correlation time which is called the Brunel effect.

We find that the gain function is dominated by a single pole low pass filter around the membrane time constant independent of the electric decoupling. Hence, the model is not able to explain fast population responses. In addition, the model does not display a Brunel effect.

BP 14.8 Mon 17:30 Poster A

Computer generated holography for optogenetic modulation of neural network activity in vitro — •Manuel Schottdorf[1,2], Hecke Schrobsdorff[1], Walter Stühmer[2] und Fred Wolf[1] — [1]MPI für Dynamik und Selbst-Organisation, Göttingen — [2]MPI für Experimentelle Medizin, Göttingen

A randomly plated culture of neurons resembles to some extend *in-vivo* neural tissue in structural features, activity and development [Chiappalone et al. 2006, Huettner & Baughman 1986, Cohen et al. 2008] and has been used for various studies of learning, memory, plasticity, connectivity, and information processing. The activity of neurons in a culture can be measured with multi-electrode arrays. However, providing the cell culture with precise and spatially complex input patters is limited, most obviously by current diffusion from the electrodes. Here, we address this problem using holography [Golan et al. 2009]. A laser and a spatial light modulator, assembled in the beam path of an inverted microscope, are used to generate holographic interference patterns in the object plane. These precise and spatially complex patterns excite a cell culture of optogenetically modified cortical neurons of a rat. The neural responses are monitored with a multielectrode array. We present a performance assessment of our setup. We show that cultured neurons react well to external stimuli and we present some preliminary results on the modulations in network activity by the spatially complex optical excitation.

BP 14.9 Mon 17:30 Poster A

Switching dynamics in subnetworks of spiking neural networks — •Fereshteh Lagzi and Stefan Rotter — Bernstein Center Freiburg and Faculty of Biology, Freiburg, Germany

The network under study is comprised of three subnetworks of either excitatory or inhibitory leaky integrate-and-fire neurons. The excitatory and inhibitory weights are arranged to establish and maintain a balance between excitation and inhibition for a constant external drive. Each subnetwork has a random connectivity with fixed in-degree and fixed out-degree for all neurons belonging to a particular population. Neurons in different subnetworks are also randomly connected with the same probability; however, depending on their identity, the connection weight is scaled by a factor. We observed that for a certain regime of ratios of the "within" versus "between" connection weights (bifurcation parameter), the network activation spontaneously switches between the two subnetworks of the same identity (winnerless competition). In our model, this phenomenon is explained by a set of coupled stochastic differential equations of Lotka-Volterra type that exhibit a competition between the subnetworks. The deterministic phase portrait is characterized by two attractors and a saddle node, its stochastic component is essentially given by the multiplicative inherent noise of the system.

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BP 14.10 Mon 17:30 Poster A

Neuronal avalanches in a self organizing recurrent neural network — •Bruno Del Papa[1,2], Viola Priesemann[3], and Jochen Triesch[1] — [1]Frankfurt Institute for Advanced Studies — [2]Max Planck Institute for Brain Research — [3]Max Planck Institute for Dynamics and Self-Organization

A large number of experiments have suggested that the brain operates close to criticality, but in a subcritical regime, based on power-law distributions of neuronal avalanches. Although several critical neural network models have been studied before, they typically show simplified connectivity structures and no advanced information processing or learning abilities. Here, we investigate neuronal avalanches in spontaneous activity of a self organizing recurrent neural network (SORN), which exhibits spatio-temporal pattern learning and reproduces experimentally observed fluctuations of synaptic efficacies. The network consists of excitatory and inhibitory threshold units with connection weights and firing thresholds evolving based on a combination of spike-timing dependent plasticity rules and homeostatic mechanisms. We observe power-law distributed neuronal avalanches, suggesting that the SORN self-organizes to a critical state, and find a strong dependence on the neurons' target firing rates and membrane potential noise, which indicates these are essential to maintain the critical phase. Our results show, for the first time, that signatures of criticality are present in the spontaneous activity of a self-organizing network model that has advanced learning abilities and reproduces central findings on the fluctuations of synaptic connection strengths in cortex and hippocampus.

BP 14.11 Mon 17:30 Poster A

Spectral properties of excitable systems subject to colored noise — Jannis Schuecker[1], Markus Diesmann[1,2], and •Moritz Helias[1] — [1]Institute of Neuroscience and Medicine (INM-6) and Institute for Advanced Simulation (IAS-6), Jülich Research Centre and JARA — [2]Medical Faculty, RWTH Aachen University

Many phenomena in nature are described by excitable systems driven by colored noise. Studying the response properties of these systems comes along with considerable difficulties, due to the non-vanishing correlation time of the noise. For systems with noise fast compared to their intrinsic time scale, we here present a general method of reduction to a lower dimensional effective system, respecting the details of the noise in the boundary conditions. Static boundary conditions were derived earlier by a perturbative treatment of the arising boundary layer problem [1,2]. Here we extend this scheme to the dynamic case [3]. We apply the formalism to the leaky integrate-and-fire neuron model, revealing an analytical expression for the transfer function valid up to moderate frequencies. This enables the assessment of the stability of networks of these excitable units.

[1] Klosek MM, Hagan PS. J Math Phys 1998, 39:931-953
[2] Doering CR, Hagan PS, Levermore CD. PRL 1987, 59:2129-2132
[3] Schuecker J, Diesmann M, Helias, M. 2014, arXiv:1411.0432

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BP 14.12 Mon 17:30 Poster A

Die E8-Gruppe, eine Theorien zum Verständnis des Gehirns. — •Sadler Norbert — Wasserburger Str. 25a: 85540 Haar

Wird das Gehirn als ein komplexes, kollektives System aufgefasst, kann durch Anwendung der Exzeptionellen E8-Gruppe, der Explorativen Faktorenanalyse und Methoden der Statistischen Physik eine neue Theorie zum Verständnis des Gehirns gefunden werden. Für das Human Brain Projekt kann die E8-Gruppe die Grundlage für ein neues Simulationsmodell des Gehirns dienen.

Die Algebren der E8-Gruppen Simulation:
(Träger-Matrix;453060**2)x(Anz.Verknüpf.2**22)=8.61x10**17

In der Simulation erhält jedes der 8.9x10**10 Neuronen des Gehirns eine Identität, die synaptischen Verknüpfungen, die spezifischen Sinnesmodalitäten, die gemessenen Reizintensitäten und die Entropie der Reizstärken bzw. den Energieumsatz des Gehirns.

Das Simulationsmodell:
(453060**2)x(e**Ry(13.6eV))/(QCD)x(log(QCD)))=E8xlog(QCD)
Ry=13.6eV, das photo-elektrische Intensitätszunahme-Quant zur

Registrierung eines Sinnenreizes und QCD =0.192 die Starke Wechselwirkung und Intensität der spez. Sinnenreize. Die spezifischen Sinnarten, Modalitäten sind Vielfache des Intensitätszunahme-Quants.

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