Workshop 2013

in

Leucorea, Lutherstadt Wittenberg

28. – 30. August 2013

Workshop on Control of Self-Organizing Nonlinear Systems

Program

Organizing Committee
Judith Lehnert (chair, finances)
Josef Ladenbauer (academic program)
Leonard Lücken (academic program)
Christopher Prohm (academic program, flyers/handouts)
Sina Reichelt (social program, catering)
Anna Zakharova (catering)
Paul Geffert (website, name tags, audio-visual)
Roland Aust (advisor, audio-visual, catering)
Kai Pfenning (SFB office, catering)

Abstract Booklet for the SFB 910 Workshop 2013

"Workshop on Control of Self-Organizing Nonlinear Systems"

August 28th - August 30th, 2013, Wittenberg

Time schedule

Wednesday, 28.8.

08:30 - 10:30		*Bus travel Hardenbergplatz, Berlin - Wittenberg*
11:15 - 11:30		*Settling in, coffee*
Chairperson	Sabine Klapp	
11:30 - 11:50		Welcome address
11:50 - 12:40	Hugues Berry (**invited**)	Effects of Cellular Homeostatic Intrinsic Plasticity on Dynamical and Computational Properties of Biological Recurrent Neural Networks
12:40 - 14:00		*Lunch break (Leucorea)*
Chairperson	Roland Aust	
14:00 - 14:25	Philipp Hövel (B10)	Towards the control of networks with time-varying topologies: analysis of livestock trade
14:25 - 14:50	Nikos E. Kouvaris (A6)	Pattern formation and control in networks of bistable elements
14:50 - 15:15	Anna Zakharova (A1)	Controlling complex networks: interplay of structure, noise and delay
15:15 - 15:35		*Coffee break*
Chairperson	Thomas Isele	
15:35 - 16:00	Josef Ladenbauer (B8)	How neuronal adaptation shapes spiking and network dynamics
16:00 - 16:25	Bernold Fiedler (A4)	Regulatory networks: observation and control
16:25 - 16:40		*Coffee break*
16:40 - 19:00		Poster session
19:00 - 20:00		*Dinner (Leucorea)*

Thursday, 29.8.

8:00 - 9:00		*Breakfast (Leucorea / Hotel respectively)*
Chairperson	Pavel Gurevich	
9:00 - 9:50	Peter Ashwin (**invited**)	Phase response curves and emergent dynamics in oscillator networks
9:50 - 10:05		*Coffee break*
Chairperson	Franz Schulze	
10:05 - 10:30	Kathy Lüdge (B9)	Collective phenomena in laser networks with non identical units
10:30 - 10:55	Julia Kabuß (B1)	Control of single quantum excitations in cavities
11:55 - 11:20	Tobias Brandes (A7)	Feedback Control: quantum transport, thermodynamics, and phase transitions
11:20 - 11:40		*Coffee break*
Chairperson	Anna Zakharova	
11:40 - 12:15	Christopher Prohm (B4)	Optimal control of particle separation in inertial microfluidics
12:15 - 12:40	Sergio Alonso (B5)	Generic model of pattern formation in nonlinear systems with two spatial scales
12:40 - 14:00		*Lunch break (Leucorea)*
Chairperson	Leonhard Lücken	
14:00 - 14:50	Holger Kantz (**invited**)	Prediction of complex dynamics – who cares about chaos?
14:50 - 15:15	Christopher Ryll (B6)	Sparse optimal control of the Schlögl and FitzHugh-Nagumo system
15:15 - 15:30		*Coffee break*
15:30 - 17:20		Meeting of the principial investigators
17:30 - 18:30		Excursion
19:00		*Dinner at the restaurant "Haus des Handwerks"*

Friday, 30.8.

8:00 - 9:00		*Breakfast (Leucorea / Hotel respectively)*
Chairperson	Philipp Hövel	
9:00 - 9:50	Rajarshi Roy (**invited**)	Nonlinear Dynamics in Optical Networks: Patterns and Synchronization
9:50 - 10:05		*Coffee break*
Chairperson	Christopher Prohm	
10:05 - 10:30	Sina Reichelt (A5)	Homogenization of degenerated reaction-diffusion equations
10:30 - 10:55	Pavel Gurevich (A9)	Reaction-diffusion systems with hysteresis
10:55 - 11:15		*Coffee break*
Chairperson	Sina Reichelt	
11:15 - 11:40	Leonhard Lücken (A3)	Spatio-temporal dynamics of scalar delay differential equations
11:40 - 12:15	Phi Ha (A2)	Differential-algebraic equations with time-delay: solvability analysis and control
12:15 - 12:40	Robert Lasarzik (A8)	A closer look at liquid crystal displays
12:40 - 14:00		*Lunch break*
Chairperson	Eckehard Schöll	
14:00 - 14:25	Tarlan A. Vezirov (B2)	Manipulating transport phenomena of colloidal particles at surfaces
14:25 - 14:50	Julien Siebert (B7)	Nonlocal Control of Chemical Front Propagation in the Schlögl Model
14:50 - 15:00		*Closing remarks*
15:30		*Depature by bus*
17:00		*Arrival in Berlin*

Abstracts

Wednesday, 28.08.

Effects of Cellular Homeostatic Intrinsic Plasticity on Dynamical and Computational Properties of Biological Recurrent Neural Networks

Hugues Berry

Project-Team Beagle, INRIA Rhône-Alpes, Université de Lyon, France

Homeostatic intrinsic plasticity (HIP) is a ubiquitous cellular mechanism regulating neuronal activity, cardinal for the proper functioning of nervous systems. In invertebrates, HIP is critical for orchestrating stereotyped activity patterns. The functional impact of HIP remains more obscure in vertebrate networks, where higher-order cognitive processes rely on complex neural dynamics. Here, we assess how cellular HIP effects translate into collective dynamics and computational properties in biological recurrent networks. We develop a realistic multi scale model including a generic HIP rule regulating the neuronal threshold with actual molecular signaling pathways kinetics, Dale's principle, sparse connectivity, synaptic balance and Hebbian synaptic plasticity (SP). Dynamic mean-field analysis and simulations unravel that HIP sets a working point at which inputs are transduced by large derivative ranges of the transfer function. This cellular mechanism insures increased network dynamics complexity, robust balance with SP at the edge of chaos, and improved input separability. Although critically dependent upon balanced excitatory and inhibitory drives, these effects display striking robustness to changes in network architecture, learning rates and input features. Thus, the mechanism we unveil might represent a ubiquitous cellular basis for complex dynamics in neural networks. Understanding this robustness is an important challenge to unravel principles underlying self-organization around criticality in biological recurrent neural networks.

Towards the control of networks with time-varying topologies: analysis of livestock trade

Philipp Hövel

Institut für Theoretische Physik, Technische Universität Berlin

We give an overview of a number of models where hysteresis plays a role of a feedback control in a reaction-diffusion system and gives rise to spatio-temporal patterns. In particular, hysteresis on the boundary of a spatial domain may lead to time-periodic solutions, while hysteresis inside the domain may lead to spatial concentric-rings or sign-changing patterns. From the mathematical point of view, the challenge is that we have to deal with discontinuous and non-variational objects, where not only a long-term dynamics but even the well-posedness is a nontrivial issue.

We will also discuss spatially discretized reaction-diffusion systems (dynamical systems on lattices or, more generally, on graphs) and see how hysteresis may lead to a certain self-organization. This will indicate a way to quantitatively describe the dynamics of a corresponding continuous model.

Questions to be addressed in the next funding period include delay control of periodic solutions, traveling-wave solutions in "hysteretic" slow-fast systems, and discrete-vs-continuous issues.

Pattern formation and control in networks of bistable elements

Nikos E. Kouvaris

Abteilung Physikalische Chemie, Fritz-Haber-Institut, Berlin

Traveling fronts and stationary localized patterns in bistable reaction-diffusion systems have been broadly studied for classical continuous media and regular lattices. Analogs of such non-equilibrium patterns are also possible in networks. Here, we consider traveling and stationary patterns in bistable one-component systems on random Erdös-Rényi, scale-free and hierarchical tree networks. As revealed through numerical simulations, traveling fronts exist in network-organized systems. They represent waves of transition from one stable state into another, spreading over the entire network. The fronts can furthermore be pinned, thus forming stationary structures. While pinning of fronts has previously been considered for chains of diffusively coupled bistable elements, the network architecture brings about significant differences. An important role is played by the degree (the number of connections) of a node. For regular trees with a fixed branching factor, the pinning conditions are analytically determined [2]. Furthermore, effects of feedbacks on self-organization phenomena in bistable networks are investigated [2]. For regular trees, an approximate analytical theory for localized stationary patterns under application of global feedbacks is constructed. Using it, properties of such patterns in different parts of the parameter space are discussed. Numerical investigations are performed for large random Erdös-Rényi and scale-free networks. In both kinds of systems, localized stationary activation patterns have been observed. The active nodes in such a pattern form a subnetwork, whose size decreases as the feedback intensity is increased. For strong feedbacks, active subnetworks are organized as trees. Additionally, local feedbacks affecting only the nodes with high degrees (i.e. hubs) or the periphery nodes are considered.

[1] N. E. Kouvaris, H. Kori and A. S. Mikhailov, *Traveling and pinned fronts in bistable reaction-diffusion systems on networks*, PLoS ONE **7(9)**: e45029 (2012).
[2] N. E. Kouvaris and A. S. Mikhailov, *Feedback-induced stationary localized patterns in networks of diffusively coupled bistable elements*, Europhysics Letters **103**, 16003 (2013).

Controlling complex networks: interplay of structure, noise and delay

Anna Zakharova

Institut für Theoretische Physik, Technische Universität Berlin

We investigate both deterministic and stochastic dynamical systems with different types of coupling including time-delay. In particular, we study noise-induced phenomena such as stochastic bifurcations, coherence resonance, stochastic synchronization as well as a special type of oscillation suppression - oscillation death. The systems we consider in the present study are the paradigmatic models of nonlinear dynamics: generalized Van der Pol system and Stuart-Landau oscillator. We perform analytical calculations, numerical simulations and relate these to the experiments on an electronic circuit. In particular, we show both experimentally and numerically that stochastic oscillations that appear due to noise in a system with a subcritical Hopf bifurcation, can be partially synchronized even outside the oscillatory regime of the deterministic system. Moreover, for a model of coupled Stuart-Landau oscillators we show that symmetry-breaking oscillation death can occur in time-delayed systems.

How neuronal adaptation shapes spiking and network dynamics

Josef Ladenbauer, Moritz Augustin and Klaus Obermayer

Institut für Softwaretechnik und Theoretische Informatik, Technische Universität Berlin
Bernstein Center for Computational Neuroscience Berlin

Many types of neurons exhibit spike rate adaptation, a gradual decrease in spiking activity following a sudden increase in stimulus intensity. This phenomenon is typically produced by slowly deactivating transmembrane potassium currents, which effectively inhibit neuronal responses and can be controlled by neuromodulators [1]. Here we examine (i) how these adaptation currents change the relationship between in-vivo like fluctuating synaptic input, spike rate output and the spike train statistics of single neurons and (ii) how they contribute to spike rate oscillations and resonance in recurrent networks of excitatory and inhibitory neurons. We consider (networks of) threshold-model neurons which include two types of adaptation currents and can well reproduce the activity of cortical neurons. To calculate the neuronal spike rates and inter-spike intervals we use a mean-field approach based on the Fokker-Planck equation. We show that adaptation currents differentially change the neuronal response properties, depending on the type of current activation. Adaptation currents which are driven by the subthreshold membrane voltage increase the threshold for spiking and the inter-spike interval variability. Suprathreshold (spike-dependent) adaptation currents, on the other hand, decrease the spike rate gain and high spiking variability caused by strongly fluctuating inputs [2]. For recurrent networks we find that neuronal adaptation (i) can mediate slow oscillations for sufficiently strong recurrent synaptic excitation, (ii) promotes fast oscillations originating from recurrent excitation-inhibition loops and (iii) amplifies the network response to oscillatory external inputs for a narrow band of frequencies [3]. Our results therefore identify the different roles of adaptation currents for controlling neuronal response properties and rhythms in recurrent networks.

[1] D.A. McCormick: Progr. Neurobiol. 39:337-388 (1992)
[2] J. Ladenbauer, M. Augustin and K. Obermayer: (submitted)
[3] M. Augustin, J. Ladenbauer and K. Obermayer: Front. Comput. Neurosci. 7:9 (2013)

Regulatory networks: observation and control

Bernold Fiedler

Institut für Mathematik, Freie Universität Berlin

Gene regulation gives rise to regulatory networks. The mathematical framework, however, reaches far beyond biological examples. Based on the network structure alone, we study which nodes are sufficient to faithfully and reliably monitor all long-term dynamics of the network. We also discuss open-loop control of the network, through the same set of nodes.

Aspects like feedback-control and delays should be addressed in the next funding period.

This is joint work with Atsushi Mochizuki at RIKEN, Tokyo.

Thursday, 29.08.

Phase response curves and emergent dynamics in oscillator networks

Peter Ashwin

Centre for Systems, Dynamics and Control, University of Exeter, U.K

It is well known that coupled dynamical systems can self-organize into a variety of synchronized or partially synchronized states via the emergent dynamics of their interaction. Clearly the topology of the interactions and their strengths are important for what emerges. This talk will examine the influence not only of the topology and strength of the coupling but also of the exact functional form of the phase response curve for phase oscillator networks. For these networks a lot can be understood using analytical tools from symmetric dynamics. In the case of all-to-all coupled networks, clustered attracting and repelling behaviour can be characterised in terms of local properties of a phase response curve - there can exist arbitrarily complex clustered attractors for appropriate choice of phase response curve. In addition to these dynamically simple attractors there can be a wide range of chaotic and/or heteroclinic network attractors in such systems. This talk will review some exampl es of these as well as highlighting some open problems in this area.

Collective phenomena in laser networks with non identical units

Kathy Lüdge

Institut für Theoretische Physik, Technische Universität Berlin

The aim of the project is to study the nonlinear dynamics of delay-coupled lasers forming a complex network made of nonidentical units. In a first step the bifurcation scenarios of a limited number of lasers coupled with a common mirror will be studied. The main questions will be which kind of synchronization patterns exist and how the stability may be controlled. In a second step the ability to use these laser networks for applications like "reservoir computing" will be explored. This method of training a network to perform computation is inspired by the brain and may be highly efficient for technological implementations.

To describe the laser network, Lang-Kobayashi equation for the local dynamics wil be used. This model system for a laser with self-feedback was already subject to intensive investigations and thus its bifurcation structure as well as its regimes of chaotic behavior are known. Starting from there the emerging dynamics when coupling more than 2 lasers will be explored, with a special focus on phase-locking effects that may occur if, e.g. lasers with different properties are coupled.

Depending on the coupling phases it is expected to find various stable solutions for the whole network that can be described by anti-phase or in-phase dynamics of the different nodes. If a large number of lasers are coupled the occurrence of multi-stability as well as possible transient dynamics should open the possibility to use the network for information processing.

Control of single quantum excitations in cavities

Julia Kabuß, Franz Schulze, Alexander Carmele, and Andreas Knorr

Institut für Theoretische Physik, Technische Universität Berlin

Quantum emitters, such as semiconductor quantum dots or other nanostuctures, coupled to photonic or acoustic cavities exhibit non-linear and non-Markovian interactions. For such devices, it is highly desirable to control single and few excitations, such as single photons or coherent phonon wave packets. In the quantum limit, studied here, not only mean values of observables, such as the average phonon number obey a non-linear dynamics. Their statistics is of most importance, since fluctuations can be as large as the mean value. Our goal is to establish methods to control the quantum statistics of cavity photons and phonons in the limit where fluctuations dominate the dynamics. We focus on two examples:

First, we discuss single photon control in a quantum dot-cavity system, coupled to an external mirror to provide delayed feedback. Here, we study a regime, where classical factorization and Markovian feedback schemes break down. We discuss, that the external mirror, providing a structured external mode continuum enforces self-feedback temporal delay effects leading to modified single-photon Rabi-oscillations [1]. In contrast, in the limit of many photons, we apply classical factorization about mean values of observables for the description of time-delayed self-feedback of a quantum dot microcavity laser. Such lasers can work in a regime between the classical regime (Lang- Kobayashi model [2]) and quantum limit and are ideal candidates to study the transition between both regimes. The laser characteristics is studied on the level of light field intensities and light field statistics, where siginificant differences between a quantized and a classical approach arise.

Second, we discuss a novel scheme of a quantum dot-phonon laser, based on the coupling of an optically pumped quantum dot to an acoustic cavity mode [3]. Making use of external pumping at the anti-Stokes resonance, single phonons, chaotic phonons and coherent phonon laser action can be obtained as a function of the external control field. We compare a fully quantum approach with a reduced classical model valid for the coherent phonon laser regime. subsystem approach in the semiclassical regime, predicts coherent phonon laser action on the basis of the statistical properties of the phonon cavity field as well as the threshold behavior of the system.

[1] A. Carmele, J. Kabuß, F. Schulze, S. Reitzenstein, and A. "Single Photon Delayed Feedback: A Way to Stabilize Intrinsic Quantum Cavity Electrodynamics", Phys. Rev. Lett. 110, 013601 (2013).

[2] C. Otto, K. Lüdge and E. Schöll: "Modeling Quantum Dot Lasers with Optical Feedback: Sensitivity of Bifurcation Scenarios" phys. stat. sol. (b) 247, 829-845 (2010).

[3] J. Kabuß, A. Carmele, T. Brandes, and A. Knorr, "Optically Driven Quantum Dots as Source of Coherent Cavity Phonons: A Proposal for a Phonon Laser Scheme", Phys. Rev. Lett. 109, 054301 (2012).

Feedback Control: quantum transport, thermodynamics, and phase transitions

Tobias Brandes

Institut für Theoretische Physik, Technische Universität Berlin

I will review some of our efforts to formulate and understand quantum feedback control for electronic transport, focussing on implementing feedback schemes in (quantum) master equations, their thermodynamical interpretation ('Maxwell demon'), and their relation to state-of-the-art experiments in nanostructures. In a second part, I will outline some ideas (possibly relevant to the second phase of our SFB) related to phase transitions in ground and excited states of quantum systems, and possibilities to combine quantum criticality with feedback control schemes.

Optimal control of particle separation in inertial microfluidics

Christopher Prohm, Holger Stark

Institut für Theoretische Physik, Technische Universität Berlin

At intermediate Reynolds numbers, particles in a microfluidic channel assemble at fixed distances from the channel axis and bounding walls, an effect first discovered by Segré and Silberberg [1]. This behavior is very different from particle movement at low Reynolds numbers, where due to kinematic reversibility rigid particles do not cross streamlines. The Segré-Silberberg effect can be described in terms of an effective lift force acting on the particles.

Devices utilizing inertial lift forces for the separation of bacteria and red blood cells have recently been demonstrated [2]. The separation is most efficient for large size differences since the inertial lift force scales with the third power of the particle radius. Here, we show that one can use optimal control theory to determine external control forces generated, for example, by optical tweezers to steer particles and to separate them when they are similar in size.

We study the system by mesoscopic simulations of the fluid using multi-particle collision dynamics (MPCD) [3]. We determine lift forces and single-particle probability distributions in steady state and analyze their dependence on particle radius and Reynolds number. We show that the Boltzmann distribution for the potential connected to the lift force reproduces the observed distribution functions.

We use the lift force determined by MPCD to set up a Smoluchowski equation which describes the particle motion in lateral channel direction. We then employ the formalism of optimal control [4] to determine profiles of the external force, which help to steer particles and thereby maximize particle separation. We verify that the calculated force profiles are indeed able to separate particles of similar size by performing independent simulations of the corresponding Langevin equations.

[1] G. Segré and A. Silberberg, *Nature*, **189**, 209 (1961).

[2] A. J. Mach and D. Di Carlo, *Biotechnol. Bioeng.*, **107**, 302 (2010).

[3] C. Prohm, M. Gierlak, and H. Stark *EPJE*, **35**, 80 (2012).

[4] F. Tröltzsch, Optimal Control of Partial Differential Equations, American Mathematical Society, first edition (2010).

Generic model of pattern formation in nonlinear systems with two spatial scales

David Schüler, Sergio Alonso⋆ and Markus Bär

Physikalisch-Technische Bundesanstalt, Berlin
⋆ Presenting author

Pattern formation is typically obtained in nonlinear systems from an unstable homogeneous-state. The resulting process happens with characteristic spatial and temporal scales. However, two instabilities with different spatialscales can appear simultaneously in multiscale systems. Such type of behaviors can be observed in extended chemical systems and in proteinand phospholipid dynamics in biological membranes.

Here, we couple two simplesystems, each of them giving rise to pattern formation. The dynamics of the whole system differs substantially from the original uncoupleddynamics, and a codimension-two point between wave and Turing instabilities is observed. The coexistence of the different patternsand the corresponding dominance is studied with the amplitude equations obtained from the coupled system. Finally, delay feedbackis employed to control the dominant instability.

Prediction of complex dynamics – who cares about chaos?

Holger Kantz

Max Planck Institute for the Physics of Complex Systems, Dresden

Abstract: Complex systems in Nature are most often so complex that we are unable to set up a deterministic model which describes them perfectly. In such cases, any conclusions drawn from the investigation of a model system must be carefully validated by comparison to nature in order to be a relevant statement about the natural system. A relevant consequence of such model errors is that stochastic elements in the model can represent our uncertainty about the details of the dynamics. In this talk, we illustrate the issue of stochastic nonlinear models and their interpretation, mainly by refering to weather predictions.

Sparse optimal control of the Schlögl and FitzHugh-Nagumo system

Eduardo Casas [1], Christopher Ryll [2,⋆], Fredi Tröltzsch [2]

[1] Depto. Matematica Aplicada y Ciencias de la Computacion E.T.S.I. Industriales y de Telecomunicacion, Universidad de Cantabria, Spain
[2] Institut für Mathematik, Technische Universität Berlin
⋆ Presenting author

We investigate optimal control problems for two reaction-diffusion problems, namely the so-called Schlögl or Nagumo model and the FitzHugh-Nagumo equations. Under appropriate initial conditions, the uncontrolled solutions of these systems behave like a traveling wave or a spiral wave. It is a natural task to control such wave type solutions in an optimal way. Often, it is desired to apply controls only in small parts of the spatial domain, since it is not always realistic to apply distributed controls in the whole spatial domain. This is a typical situation, where the theory of sparse optimal control can be applied. Therefore, the objective functional is extended by the weighted L^1-norm of the control. The topic of sparse controls itself has recently been studied actively for elliptic partial differential equations and the needed techniques for dealing with the not-differentiable part of the objective functional can be easily applied to our case, namely semilinear parabolic equations or systems.

Since they are of non-monotone type, the theory of existence, uniqueness and regularity of associated solutions is more delicate than for equations of monotone type. We prove existence and uniqueness of a solution of the FitzHugh-Nagumo equations that works in Lipschitz domains of spatial dimension one, two or three. By an L^∞- approach, we show the second-order Fr'echet-differentiability of the control-to-state mapping. Based on this foundation, we derive first order necessary optimality conditions for sparse optimal controls.

Further, we study various numerical exapmles in spatial dimension one and two. We control traveling wave fronts as solutions to the Schlögl-equation. In the case of the FitzHugh-Nagumo-system, spiral waves occur. Controlling such patterns is geometrically impressive but numerically fairly demanding. To our best knowledge, sparse optimal controls for such equations were not yet discussed in literature. However, there is a rich literature on feedback control problems in the community of Physics.

Friday, 30.08.

Nonlinear Dynamics in Optical Networks: Patterns and Synchronization

Rajarshi Roy

Institute for Physical Science and Technology, University of Maryland

Experiments and results on patterns of synchrony in networks of coupled optical elements will be reported. We will describe optoelectronic devices and systems that we use in our lab and how these can be used to explore aspects of synchrony that involve symmetries. Measures of synchronization and the dynamics of coupled systems they can reveal will be illustrated with experimental results and numerical simulations that emphasize the importance of symmetry of the networks.

Homogenization of degenerated reaction-diffusion equations

Sina Reichelt and Alexander Mielke

Weierstrass Institut für angewandte Analysis und Stochastik, Berlin

Many reaction-diffusion processes arising in civil engineering, biology, or chemistry take place in porous media, for instance concrete carbonation or the spread-out of substances in biological tissues. A porous medium can be modeled as a perforated domain, where the particles or holes are periodically distributed in the domain with the period length $\varepsilon > 0$.

Here the characteristic length scale of the microstructure, which is proportional to ε, e.g. the particles or holes, is much smaller compared to the overall size of the domain. Systems with such differences in the involved length scales are very difficult to handle numerically, because the step size of the algorithm has to be of order ε in order to resolve the qualitative behavior of the system. Therefore it is the aim to derive effective equations, independent of ε, which are ideally simpler and qualitatively describe the properties of the original system. In the classical case, the coefficients in the effective equation are homogeneous and in this sense, the passage $\varepsilon \to 0$ is called homogenization.

In my talk I deal with a class of parabolic PDE, depending on ε, that allow for degenerated diffusion coefficients and nonlinear reaction terms. Using the method of two-scale convergence, I derive effective equations, which are defined on a two-scale space. The two-scale space consists of the macroscopic domain and the microscopic unit cell attached to each point of the macroscopic domain.

Reaction-diffusion systems with hysteresis

Pavel Gurevich (joint work with Dmitrii Rachinskii and Sergey Tikhomirov)

Institut für Mathematik, Freie Universität Berlin

We give an overview of a number of models where hysteresis plays a role of a feedback control in a reaction-diffusion system and gives rise to spatio-temporal patterns. In particular, hysteresis on the boundary of a spatial domain may lead to time-periodic solutions, while hysteresis inside the domain may lead to spatial concentric-rings or sign-changing patterns. From the mathematical point of view, the challenge is that we have to deal with discontinuous and non-variational objects, where not only a long-term dynamics but even the well-posedness is a nontrivial issue.

We will also discuss spatially discretized reaction-diffusion systems (dynamical systems on lattices or, more generally, on graphs) and see how hysteresis may lead to a certain self-organization. This will indicate a way to quantitatively describe the dynamics of a corresponding continuous model.

Questions to be addressed in the next funding period include delay control of periodic solutions, traveling-wave solutions in "hysteretic" slow-fast systems, and discrete-vs-continuous issues.

Spatio-temporal dynamics of scalar delay differential equations

Serhiy Yanchuk[1], Leonhard Lücken[1], Matthias Wolfrum[2], und Alexander Mielke[12]

[1] Institut für Mathematik, Humboldt-Universität zu Berlin
[2] Weierstrass Institut für angewandte Analysis und Stochastik, Berlin

We consider scalar delay differential equations (DDEs) with long delay:

$$\frac{dx}{dt}(t) = g(x(t), x(t-\tau)),\ \tau = \frac{1}{\varepsilon} \gg 1. \tag{1}$$

In some cases, there is a correspondence of solutions of (1) and solutions of spatially extended systems which are derived by formal arguments. This perspective to DDEs with long delay was firstly described and investigated by Kashchenko [1] and Arecchi et al. [2].

I will introduce the asymptotic continuous spectrum (PCS) of (1) and explain how an amplitude equation describes the dynamics of (1) close to a destabilization which is induced by the PCS. For the case of cubic nonlinearities, I will present an error estimate for the deviation of the original solution from its formal approximation [3]. This is a first step to put the spatio-temporal representation of DDEs on solid grounds.

[1] S. A. Kashchenko. "Normalization Techniques as Applied to the Investigation of Dynamics of Difference-Differential Equations with a Small Parameter Multiplying the Derivative." Differ. Uravn 25 (1989): 1448-1451.

[2] F. T. Arecchi , G. Giacomelli, A. Lapucci, and R. Meucci. "Two-dimensional representation of a delayed dynamical system." Physical Review A 45, no. 7 (1992): R4225-R4228.

[3] S. Yanchuk, L. Lücken, M. Wolfrum, and A. Mielke. "Spectrum and amplitude equations for scalar delay-differential equations with large delay" in preparation

Differential-algebraic equations with time-delay: solvability analysis and control

Phi Ha

Institut für Mathematik, Technische Universität Berlin

During the last 20 years, much research has been focused on differential-algebraic equations (DAEs). These systems appear in a wide variety of scientific and engineering applications, including circuit analysis, computer-aided design and real-time simulation of mechanical (multibody) system, power systems, chemical process simulation. On the other hand, much work has also been done in the field of delay differential equations (DDEs). Delay differential equations arise from, for example, real time simulation, where time delays can be introduced by the computer time needed to process the input data. Delays also arise in circuit simulation and power systems, due to, for example, interconnects for computer chips and transmission lines, and in chemical process simulation when modeling pipe flows.

Even though the theory of the analytical and numerical solution of delay differential equations (DDEs) as well as differential-algebraic equations (DAEs) is well understood, the intersection of them, the delay differential-algebraic equations (DDAEs), is still an open object, even for the relatively simple case of linear systems with constant coefficients.

In this talk, we first address the solvability analysis of linear delay differential-algebraic equations by proposing an algorithm that explicitly reads off underlying delay differential equations, and also all hidden constraints. In the remaining part of the talk, we discuss the problem of controlling DAEs by time-delayed feedback, followed by several illustrated examples.

A closer look at Liquid Crystal Displays

Robert Lasarzik and Etienne Emmrich

Institut für Mathematik, Technische Universität Berlin

In every part of our life, we nowadays get in touch with liquid crystal displays. Our computers, watches, and phones contain this mysterious fluid, which is at a physical state between liquid and solid matter. To be able to keep pace with the rapid development of displays of electrical devices in recent years, a thorough theoretical understanding of the materials used in these devices is required.

In this talk, we present results concerning liquid crystals of nematic type. We first consider the essential physical properties of such fluids and discuss the mathematical models available. We then study the governing nonlinear partial differential equations from a more math- ematical point of view and discuss corresponding functional analytic techniques as well as difficulties arising. Recent theoretical results are presented.

In particular, we show existence of generalized solutions for the Ericksen-Leslie model under certain general assumptions on the free energy potential using a discrete approximation scheme. Finally, we discuss the adaption of the proof to non-nematic liquid crystal phases and other open problems.

Manipulating transport phenomena of colloidal particles at surfaces

Tarlan A. Vezirov, Robert Gernert, Sarah A. M. Loos and Sabine H. L. Klapp

Institut für Theoretische Physik, Technische Universität Berlin

Colloidal particles under the combined influence of an external driving force and restricted geometry exhibit a wealth of non-linear phenomena, which are relevant in diverse fields such as directed particle transport, sorting mechanisms and friction phenomena at the nanoscale. Here we discuss recent examples and present first developments to manipulate such driven colloidal systems by feedback control strategies. We focus on the following situations:

First, we consider a crystalline bilayer of charged colloids squeezed between two planar surfaces. Switching on an external shear flow we find, by using particle-based Brownian Dynamic simulations, a sequence of states characterised by pinning, shear-induced melting and reentrant ordering into a moving hexagonal state with synchronised oscillations of the particles [1]. By adding an additional feedback equation of motion we are able to stabilise specific properties such as the degree of hexagonal ordering or the shear stress. This opens the route for a deliberate control of friction properties.

Second, we discuss the transport of colloids through a one-dimensional periodic, static potential. In such systems, feedback control strategies can induce a current reversal as well as time-dependent oscillatory density profiles [2, 3]. Here we present analytical treatment of the diffusion properties of single colloids at short and intermediate time scales [4], as well as attempts to feedback-control the density distribution of interacting colloids in the framework of Dynamical Density Functional Theory.

The third system involves again a one-dimensional potential which is however, spatially asymmetric and time-dependent (rocking ratchet). Based on a Fokker-Planck equation we introduce time-delayed feedback control with the mean particle position as control target. We analyze the resulting dynamics and the net current as opposed to that observed with open-loop control [5].

[1] T. A. Vezirov and S. H. L. Klapp, Phys. Rev. E, submitted (2013).
[2] K. Lichtner and S. H. L. Klapp, EPL 92, 40007 (2010).
[3] K. Lichtner, A. Pototsky, and S. H. L. Klapp, Phys. Rev. E 86, 051405 (2012).
[4] C. Emary, R. Gernert, and S. H. L. Klapp, Phys. Rev. E 86, 061135 (2012).
[5] S. A. M. Loos, R. Gernert, and S. H. L. Klapp, in preparation.

Nonlocal Control of Chemical Front Propagation in the Schlögl Model

Julien Siebert, Rhoslyn Coles, and Eckehard Schöll

TU Berlin, Institute of Theoretical Physics, Collaborative Research Center SFB 910

We investigate the dynamics of a paradigmatic model of a bistable reaction-diffusion system (known as the Schlögl model) under the effect of a non-local or time-delayed distributed noninvasive control. The system without control is known to exhibit a traveling front joining the two stable steady states, which is stable and travels in space at a constant velocity. Noninvasive control means that we do not change the spatially uniform steady states of the system. However, we may change their stability and for some critical control parameters we may obtain new spatial structures (Turing instability, travelling waves). In this talk, we will present some recent results on the effect of nonlocal spatial control for different spatial integral kernels, and distributed-delay feedback control with various temporal kernels, and show that, depending upon the control parameters, the front may be accelerated, slowed down, or suppressed, or new spatio-temporal patterns may be generated.

Titles of contributed posters

	Authors	Title
A1	J. Lehnert, A. Selivanov, A. Fradkov, E. Schöll	Controlling cluster synchronization by adaptive network topology
A3	S. Yanchuk, M. Kantner	Periodic patterns in a 2D-lattice of delay-coupled neurons
A3	L. Lücken, J. P. Pade, K. Knauer, S. Yanchuk	Reduction of interaction delays in networks of coupled dynamical systems
A3	L. Lücken, S. Yanchuk	Two-cluster bifurcations in systems of globally pulse-coupled oscillators
A4	I. Schneider, B. Fiedler	Stabilization of symmetrically coupled oscillators with time-delayed feedback control.
A7	V. Bastidas, T. Brandes	AC-driven quantum phase transitions
A7	K. Mosshammer, T. Brandes	Quantum feedback in transport quantum dots coupled with a local magnetic moment
A7	G. Engelhardt, T. Brandes	The Lipkin-Meshkov-Glick model
A7	G. Schaller, T. Brandes	Hardwiring a Maxwell demon
A7	W. Kopylov, T. Brandes	Time-delayed feedback control of the Dicke-Hepp-Lieb superradiant quantum phase transition
A8	E. Emmrich, H.-C. Kreusler und Robin Beier	Nonlinear evolution equations with nonlocality in time
A8	M. Merkle	Delay differential equations - without delay?!
B1	F. Schulze, B. Lingnau, A. Carmele, E. Schöll, K. Lüdge, A. Knorr	Quantum Optical Time-Delayed Feedback: Bunching above the Laser Threshold
B1	N. Naumann, J. Kabuß, A. Knorr	Theory of a driven two level system inside a Fabry-Perot cavity with one movable mirror
B1	S. M. Hein, J. Kabuß, A. Carmele, A. Knorr	Dynamics of a biexciton cascade influenced by time-delayed feedback
B2	R. Gernert, C. Emary, S. H. L. Klapp.	One dimensional transport of interacting colloids in periodic potentials
B2	S. Loos, R. Gernert, S. H. L. Klapp	Ratchet effect induced by time delayed feedback control in 1D
B4	N. Zöller, C. Prohm, H. Stark	Control of Inertial Microfluidics
B6	P. Paulau	Stabilization of a scroll ring by a cylindrical Neumann boundary
B8	F. Kneer, K. Obermayer	Analyzing critical propagation effects in a generic neuronal model with external forcing
B8	M. Augustin, J. Ladenbauer, K. Obermayer	Reduced dynamics of interacting noisy adaptive neurons

Sonderforschungsbereich 910 / Collaborative Research Center 910: Control of self-organizing nonlinear systems: Theoretical methods and concepts of application

Project group A: Theoretical methods

A1: Delayed feedback control of coupled nonlinear systems and networks

Technische Universität Berlin, Institut für Theoretische Physik

Prof. Dr. Eckehard Schöll, PhD	Principal investigator
Dr. Anna Zakharova	PostDoc
Thomas Isele	PhD student
Judith Lehnert	PhD student (core funding)
Alice Schwarze	Student assistant

A2: Analysis, numerical solution and control of delay differential-algebraic equations

Technische Universität Berlin, Institut für Mathematik

Prof. Dr. Volker Mehrmann	Principal investigator
Phi Ha	PhD Student
Vinh Tho Ma	Student assistant

A3: Emergence and control of spatio-temporal dynamics in systems with delay

Humboldt Universität zu Berlin, Institut für Mathematik

Dr. Serhiy Yanchuk	Principal investigator
Leonhard Lücken	PhD student
Markus Kantner	Student assistant

A4: Design of self-organizing spatio-temporal patterns

Freie Universität Berlin, Institut für Mathematik

Prof. Dr. Bernold Fiedler	Principal investigator
Dr. Pavel Gurevich	PostDoc
Dr. Sergey Tikhomirov	PostDoc
Isabelle Schneider	PhD Student
Anna Karnauhova	Student assistant

* Not attending

A5: Pattern formation in systems with multiple scales

Weierstraß-Institut für Angewandte Analysis und Stochastik

Prof. Dr. Alexander Mielke	Principal investigator
Dr. Marita Thomas	PostDoc (core funding)
Sina Reichelt	PhD student

A6: Control of self-organization in dynamical networks

Fritz-Haber-Institut der Max-Planck-Gesellschaft

Prof. Dr. Alexander Mikhailov*	Principal investigator
Dr. Holger Flechsig*	PostDoc
Dr. Nikos Kouvaris	PostDoc
Maximilian Eisbach*	Student assistant

A7: Feedback control of quantum transport

Technische Universität Berlin, Institut für Theoretische Physik

Prof. Dr. Tobias Brandes	Principal investigator
Dr. Victor Bastidas	PostDoc
Mathias Hayn	PhD student (core funding)
Wassilij Kopylov	PhD student (core funding)
Klemens Mosshammer	PhD student
Georg Engelhardt	Student assistant

A8: Analysis of discretization methods for nonlinear evolution equations

Technische Universität Berlin, Institut für Mathematik

Prof. Dr. Etienne Emmrich	Principal investigator
Dr. Hans-Christian Kreusler	PostDoc (core funding)
Robin Beier	PhD student
Robert Lasarzik	PhD student
Marcel Merkle	Student assistant

* Not attending

Project group B: Concepts of application

B1: Feedback control of photon statistics and spatio-temporal photon wavepackets

Technische Universität Berlin, Institut für Theoretische Physik

Prof. Dr. Andreas Knorr	Principal investigator
Sven Moritz Hein	PhD student
Julia Kabuß	PhD student (core funding)
Franz Schulze	PhD student
Oliver Esser⋆	Student assistant

B2: Controlling dynamic structures in sheared colloidal films

Technische Universität Berlin, Institut für Theoretische Physik

Prof. Dr. Sabine Klapp	Principal investigator
Robert Gernert	PhD student
Tarlan Vezirov	PhD student
Sascha Gerloff	Student assistant
Sarah Loos⋆	Student assistant

B4: Controlling dynamic structures in complex fluids by fluid flow on the micron scale

Technische Universität Berlin, Institut für Theoretische Physik

Prof. Dr. Holger Stark	Principal investigator
Christopher Prohm	PhD student
Niko Zöller	Student assistant

B5: Modelling and control of multiscale reaction-diffusion patterns and application to biomembranes and chemical reactions

Physikalisch-Technische Bundesanstalt

Prof. Dr. Markus Bär⋆	Principal investigator
Dr. Sergio Alonso	PostDoc
Lauren Willgeroth	Student assistant

B6: Optimal control of nonlinear waves in three-dimensional dissipative active media

Technische Universität Berlin, Institut für Theoretische Physik / Institut für Mathematik

Prof. Dr. Harald Engel	Principal investigator
Prof. Dr. Fredi Tröltzsch	Principal investigator
Dr. Steffen Martens	PostDoc
Christopher Ryll	PhD student
Dirk Kulawiak⋆	Student assistant
Marian Moldenhauer	Student assistant

⋆ Not attending

B7: Controlling neural wave dynamics by nonlocal and time-delayed feedback

Technische Universität Berlin, Institut für Theoretische Physik

Prof. Dr. Eckehard Schöll, PhD	Principal investigator
Dr. Julien Siebert	PostDoc
Rhoslyn Coles	Student assistant

B8: Dynamics and control of recurrent cortical networks

Technische Universität Berlin, Institut für Softwaretechnik und Theoretische Informatik

Prof. Dr. Klaus Obermayer	Principal investigator
Moritz Augustin	PhD student (core funding)
Frederike Kneer	PhD student
Josef Ladenbauer	PhD student
Douglas Sterling*	Student assistant

Coordination Office

Technische Universität Berlin, Institut für Theoretische Physik

Prof. Dr. Eckehard Schöll, PhD	Coordinator of the SFB (Sprecher)
Roland Aust	Managing Director
Kai Silvia Pfenning*	Secretary
Paul Geffert	Student assistant

Invited Keynote Speakers

Prof. Peter Ashwin, PhD	University of Exeter, U.K
Prof. Hugues Berry, PhD	Project-Team Beagle, INRIA Rhône-Alpes, Université de Lyon, France
Prof. Dr. Holger Kantz	Max Planck Institute for the Physics of Complex Systems, Dreseden
Prof. Rajarshi Roy, PhD	University of Maryland, USA

Young Researcher Projects and Guests

Dr. Ihar Babushkin	WIAS, Berlin
Dr. Philipp Hövel	TU Berlin, BCCN
PD Dr. Kathy Lüdge	TU Berlin
Dr. Gernot Schaller	TU Berlin
Mark Curran	FU Berlin
Marie Kapeller	HU / TU Berlin
Nicolas Naumann	TU Berlin
Daria Neverova	FU Berlin
Eyal Ron	FU Berlin

* Not attending

Excursion and restaurant information

In addition to the scientific program, guided tours around Wittenberg and its old town are offered on Thursday. Each of the three tours has its own theme and lasts about 60 min. The meeting point is the lobby of Leucorea at 17:30.

1. "Pillory, torture, murder stories - stories about justice and injustice" (EN)

Two Wittenberg local women in historical dress will guide you through the city. They tell your about old laws, humiliating punishments and spectacular crimes. You will wonder at the old ways of finding justice, be it trial by ordeal or the royal courts.

2. "Hexenkraut und Aderlass – Wissenswertes und kurioses aus der Geschichte der Heilkunst" (DE)

Welche Vorstellungen und Kenntnisse hatte man in vergangener Zeit über den menschlichen Körper? Welche Verfahren zum Erkennen und Heilen von Krankheiten gab es? Ob hochgelehrter Medicus oder volksweise Kräuterfrau – erstaunliches Wissen und haarsträubender Aberglaube lagen oft dicht beieinander! Eine unterhaltsame Reise in die Vergangenheit der Medizin mit kleinen Überraschungen.

3. "Nonnenflucht und Kirchenbann - Marie's Tratschgeschichten" (DE)

Begleitet das ehrbar, tugendsame und äußerst geschwätzige Waschweib Marie durch die mittelalterlichen Gassen der hochwohllöblichen Stadt zu Wittenberg. Höret in alter Mundart allerlei Geschichte und Geschichten aus dem Wittenberg des 16. Jahrhunderts und lasset Euch von vergangenen Wirklichkeiten berichten. Auf diesem Rundgang sehen Sie die schönsten Plätze der historischen Altstadt von Wittenberg.

Afterwards we will all meet for a dinner with regional food at the local restaurant:

"Haus des Handwerks"
Collegienstraße 53a

General information

Venue

Leucorea
Collegienstraße 62
Lutherstadt Wittenberg

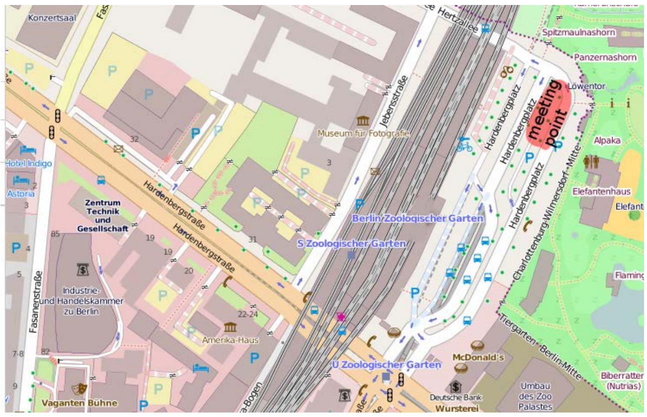
If you stay in Leucorea plase remember to checkout until latest 15:30 on Friday.
If you stay in another hotel, please ask at the reception for the checkout time.

Wireless login

Network: event-net
Password: event-pw1

The city center of Wittenberg

Meeting point for the bus to Wittenberg (Hardenbergplatz, Berlin)



Maps from OpenStreetMap.org

SFB Workshop Wittenberg

Wednesday, 28.8.

08:30 - 10:30	*Bus travel Hardenbergplatz, Berlin - Wittenberg*
11:15 - 11:30	*Settling in, coffee*
Chairperson	Sabine Klapp
11:30 - 11:50	Welcome address
11:50 - 12:40	Hugues Berry (**invited**)
12:40 - 14:00	*Lunch break (Leucorea)*
Chairperson	Roland Aust
14:00 - 14:25	Philipp Hövel (B10)
14:25 - 14:50	Nikos E. Kouvaris (A6)
14:50 - 15:15	Anna Zakharova (A1)
15:15 - 15:35	*Coffee break*
Chairperson	Thomas Isele
15:35 - 16:00	Josef Ladenbauer (B8)
16:00 - 16:25	Bernold Fiedler (A4)
16:25 - 16:40	*Coffee break*
16:40 - 19:00	Poster session
19:00 - 20:00	*Dinner (Leucorea)*

Thursday, 29.8.

8:00 - 9:00	*Breakfast (Leucorea / Hotel respectively)*
Chairperson	Pavel Gurevich
9:00 - 9:50	Peter Ashwin (**invited**)
9:50 - 10:05	*Coffee break*
Chairperson	Franz Schulze
10:05 - 10:30	Kathy Lüdge (B9)
10:30 - 10:55	Julia Kabuß (B1)
11:55 - 11:20	Tobias Brandes (A7)
11:20 - 11:40	*Coffee break*
Chairperson	Anna Zakharova
11:40 - 12:15	Christopher Prohm (B4)
12:15 - 12:40	Sergio Alonso (B5)
12:40 - 14:00	*Lunch break (Leucorea)*
Chairperson	Leonhard Lücken
14:00 - 14:50	Holger Kantz (**invited**)
14:50 - 15:15	Christopher Ryll (B6)
15:15 - 15:30	*Coffee break*
15:30 - 17:20	Meeting of the principial investigators
17:30 - 18:30	Excursion
19:00	*Dinner at the restaurant "Haus des Handwerks"*

Friday, 30.8.

8:00 - 9:00	*Breakfast (Leucorea / Hotel respectively)*
Chairperson	Philipp Hövel
9:00 - 9:50	Rajarshi Roy (**invited**)
9:50 - 10:05	*Coffee break*
Chairperson	Christopher Prohm
10:05 - 10:30	Sina Reichelt (A5)
10:30 - 10:55	Pavel Gurevich (A9)
10:55 - 11:15	*Coffee break*
Chairperson	Sina Reichelt
11:15 - 11:40	Leonhard Lücken (A3)
11:40 - 12:15	Phi Ha (A2)
12:15 - 12:40	Robert Lasarzik (A8)
12:40 - 14:00	*Lunch break*
Chairperson	Eckehard Schöll
14:00 - 14:25	Tarlan A. Vezirov (B2)
14:25 - 14:50	Julien Siebert (B7)
14:50 - 15:00	*Closing remarks*
15:30	*Depature by bus*
17:00	*Arrival in Berlin*