DY 12: Nonlinear Dynamics, Synchronization and Chaos I

Time: Tuesday 9:30–12:45 Location: H48

DY 12.1 Tue 9:30 H48

Monte Carlo Sampling in Open Dynamical Systems — •Jorge C. Leitão[1], Eduardo G. Altmann[1], and João Viana Lopes[2] — [1]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [2]CEsA - Centre for Wind Energy and Atmospheric Flows, Faculdade de Engenharia da Universidade do Porto, 4200-465 Porto, Portugal

In this presentation I will show how Monte Carlo methods can be used to efficiently perform averages on chaotic open dynamical systems. I will introduce a new algorithm, based on the well known Wang-Landau algorithm, to compute both the escape time distribution and the maximum Lyapunov exponent of the system in polynomial time, much faster than the exponential scaling of the standard uniform sampling. From the algorithmic point of view, this problem corresponds to sample a landscape with fractaly-distributed minima (singularities).

DY 12.2 Tue 9:45 H48

Chaotic systems with absorption — •Eduardo G. Altmann[1], Jefferson S. E. Portela[2], and Tamas Tel[3] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Fraunhofer Institute for Industrial Mathematics ITWM, Kaiserslautern, Germany — [3]nstitute for Theoretical Physics - HAS Research Group, Eotvos University, Budapest, Hungary

In this talk we will introduce a dynamical-systems operator formalism to describe absorption. In opposite to scattering or open systems, in which trajectories escape, in systems with absorption (e.g., in acoustics and optics) it is the intensity associated to the trajectory (ray) which decays in time. Applying our formalism to fully chaotic systems we obtain new expressions for the escape rate and an increased multifractality of the invariant sets when compared to the spectrum of dimensions obtained without taking absorption and return times into account. Results are illustrated by analytical calculations in simple maps and simulations in the cardioid billiard.

DY 12.3 Tue 10:00 H48

Estimating forces by observing a noise-driven mechanical system — •Andreas Ruttor, Philipp Batz, and Manfred Opper — Technische Universität Berlin

Predicting the dynamics of a mechanical system is easy as long as its properties, e.g. moments of inertia and friction coefficients, are exactly known. But for real devices, e.g. robots, this is usually not the case. Applying a noisy control force leads in combination with friction to a stationary stochastic dynamics. We show that one can estimate the forces in the system as a function of its state by observing these movements. While it is possible to measure accelerations directly, this approach requires very dense and evenly spaced observations. In contrast, our method estimates the probability distribution in phase space, which works with larger time intervals between data points, too. It is even possible to choose the position of the observations randomly. Prior knowledge about the system can be included in a parametric model of the potential energy. But we also have a non-parametric approach based on Gaussian process regression, which works without that information.

DY 12.4 Tue 10:15 H48

Noise-induced oscillations in network motifs of non-linear oscillators with delay — •Andrea Vüllings[1], Valentin Flunkert[2,1], and Eckehard Schöll[1] — [1]Technische Universität Berlin, Germany — [2]IFISC, Palma de Mallorca, Spain

We investigate noise-induced oscillations of network motifs composed of non-linear oscillators (super- or subcritical Hopf-normal forms), which are paradigmatic for neural networks and coupled semiconductor lasers. Fluctuations are modeled by Gaussian white noise, and finite signal propagation velocities are accounted for by a time-delayed coupling. Using a self-consistent mean-field approach, we study stochastic synchronization and compare our results with numerical simulations. We find that the delay can enhance or destroy the collective oscillations in a network motif depending upon the delay time. For the supercritical case with nonzero amplitude-phase coupling (corresponds to the linewidth enhancement factor in semiconductor-laser physics) a noise-induced frequency shift of the oscillations is observed. In the case of noisy subcritical Hopf-normal forms we observe coherence resonance. We study numerically the effect of the time delay on the optimal noise strength in the coupled system.

DY 12.5 Tue 10:30 H48

Phase retrapping in a φ Josephson junction — the butterfly effect — •Edward Goldobin[1], Dieter Koelle[1], Reinhold Kleiner[1], and Roman G. Mints[2] — [1]Universität Tübingen, 72076 Tübingen, Germany — [2]Tel Aviv University, Tel Aviv 69978, Israel

We consider retrapping of the phase in a point-like φ Josephson junction[1,2] upon switching from a finite voltage state back to a zero-voltage state, i.e. retrapping of a particle moving viscously in a tilted periodic double-well potential when the tilt is adiabatically reduced. We find the dependence of the retrapping current (tilt) γ_R on the damping parameter α and analyze in which well of the double-well potential the phase is trapped for given α. In the limit of low damping α (low temperature) the system exhibits a butterfly effect — extreme sensitivity of the destination well on the damping α and even on temperature $T \propto \ln(\alpha)$, which leads to an impossibility to forecast the destination well where the phase will be retrapped.

[1] E. Goldobin et al., Phys. Rev. Lett. **107**, 227001 (2011).
[2] H. Sickinger et al., Phys. Rev. Lett. **109**, 107002 (2012).

DY 12.6 Tue 10:45 H48

The relevance of Arnold tongues for systems with time-varying delay — •Andreas Otto, David Müller, and Günter Radons — Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany

Is it possible to convert a dynamical system with variable time delay into a system with constant delay? In this talk nonlinear time scale transformations of time delay systems are investigated, which are connected with a topological conjugation of the retarded arguments of the delay differential equations.

A necessary and sufficient condition for the existence and a method for the transformation of systems with time-varying delay to systems with constant delay are presented. For instance, in case of a time-varying delay similar to a circle map the existence of a transformation to constant delay depends on whether the parameters of the variable delay are located in an Arnold tongue or not.

The results can be helpful for the numerical solution and the characterization of the dynamical behavior of non-autonomous delay differential equations.

15 min. break.

DY 12.7 Tue 11:15 H48

Spontaneous formation of chimera states under strong global coupling: theory — •Lennart Schmidt[1,2], Konrad Schönleber[1], Katharina Krischer[1], and Vladimir García-Morales[1,2] — [1]Physik Department, Nonequilibrium Chemical Physics, Technische Universität München, Garching, Germany — [2]Institute for Advanced Study - Technische Universität München, Garching, Germany

Chimera states are spatiotemporal patterns in coupled oscillatory media, where synchronized and incoherent domains coexist. A nonlocal coupling is believed to be indispensable for the formation of such states. By means of a modified complex Ginzburg-Landau equation (MCGLE) we demonstrate, however, that chimera states arise spontaneously through a bifurcation from cluster states when just a strong global coupling is present. This prediction was validated experimentally with the oscillatory electrooxidation of silicon in fluoride containing electrolytes, for which the MCGLE was originally derived. The results confirm that the proposed new route to chimeras is robust. Furthermore, as a global coupling is much more frequently encountered than a nonlocal coupling, the occurrence of chimeras is considerably more likely than previously anticipated.

DY 12.8 Tue 11:30 H48

Spontaneous formation of chimera states and other cluster patterns under strong global coupling: experiment — •Konrad Schönleber, Andreas Heinrich, Carla Zensen, Lennart Schmidt, Vladimir Garcia-Morales, and Katharina Krischer — Technische Universität München, Garching, Deutschland

We investigate the spatial thickness distribution of oxide layers formed at illuminated n-type silicon samples during the anodic electrodissolution in fluoride containing electrolytes by means of spatially resolved ellipsometric imaging. Spontaneous pattern formation in the oxide thickness can be observed for intermediate illumination strengths while the total current and spatially averaged oxide thickness oscillate simply periodic. The patterns are typically cluster patterns where the electrode splits into several domains showing different oscillatory behavior for example subharmonic clusters or chimera states. These patterns are well captured by a modified Ginzburg-Landau equation with nonlinear global coupling. In addition, a novel type of spatial organization involving periodically growing and collapsing oscillating domains with peculiar front dynamics are discussed.

DY 12.9 Tue 11:45 H48

Geometric signature of complex synchronisation scenarios — Jan H. Feldhoff[1,2], •Reik V. Donner[1], Jonathan F. Donges[1,2], Norbert Marwan[1], and Jürgen Kurths[1,2] — [1]Potsdam Institute for Climate Impact Research, Germany — [2]Department of Physics, Humboldt University, Berlin, Germany

Synchronisation between coupled oscillatory systems is a common phenomenon in many natural as well as technical systems. Varying the strength of coupling often leads to qualitative changes in the complex dynamics of the mutually coupled systems including different types of synchronisation such as phase, lag, generalised, or even complete synchronisation. Here, we study the geometric signatures of coupling along with the onset of generalised synchronisation between two coupled chaotic oscillators by mapping the systems' individual as well as joint recurrences in phase space to a complex network. For a paradigmatic continuous-time model system, the transitivity properties of the resulting joint recurrence networks display distinct variations associated with changes in the structural similarity between different parts of the considered trajectories. They therefore provide a useful indicator for the emergence of generalised synchronisation.

DY 12.10 Tue 12:00 H48

Testing time series reversibility using complex network methods — Jonathan F. Donges[1,2], •Reik V. Donner[1], and Jürgen Kurths[1,2] — [1]Potsdam Institute for Climate Impact Research, Germany — [2]Department of Physics, Humboldt University, Berlin, Germany

The absence of time-reversal symmetry is a fundamental property of many nonlinear time series. Here, we propose a set of novel statistical tests for time series reversibility based on standard and horizontal visibility graphs. Specifically, we statistically compare the distributions of time-directed variants of the common graph-theoretical measures degree and local clustering coefficient. Unlike other tests for reversibility, our approach does not require constructing surrogate data and can be applied to relatively short time series. We demonstrate its performance for realisations of paradigmatic model systems with known time-reversal properties as well as picking up signatures of nonlinearity in some well-studied real-world neuro-physiological time series.

DY 12.11 Tue 12:15 H48

Statistics, Predictability and Dynamics of Critical Transitions — •Xiaozhu Zhang[1], Christian Kühn[2], and Sarah Hallerberg[1] — [1]Network Dynamics Group, Max Planck Institute for Dynamics and Self-Organization, 37077 Göttingen, Germany — [2]Vienna University of Technology, Institute for Analysis and Scientific Computing, 1040 Vienna, Austria

Critical transitions in multistable systems have been discussed as models for a variety of phenomena ranging from the extinctions of species to socio-economic changes and climate transitions between ice-ages and warm-ages. From Bifurcation theory we can expect a critical transition to be announced by a decreased recovery from external perturbations. The consequences of this critical slowing down have been observed as an increase in variance and correlation before to the transition happens. However, it is not clear, whether these changes in observation variables are statistically relevant such that they could be used as predictors for critical transitions. In this contribution we investigate the predictability of critical transitions in the Van der Pol Oscillator under the influence of external noise. We focus especially on the statical analysis of the success of predictions and the overall predictability of the system.

DY 12.12 Tue 12:30 H48

A comparison of different measures of predictability — •Stefan Siegert and Holger Kantz — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We consider the event that the temperature anomaly in a certain location exceeds a fixed threshold. For this event probabilistic forecasts are issued one day into the future based on a) an auto-regressive model and b) a global circulation model (GCM) of atmospheric dynamics. The quality of these forecasts is then evaluated by comparison to the actual realizations of the exceedance events. It was observed previously that, under certain circumstances, the autoregressive forecast can outperform the GCM forecast. This was shown by analyzing the predictions using different measures of predictive skill, namely the Brier Skill Score (BSS) and the Area Under the Curve (AUC).

In this contribution, differences between these two predictability measures are illustrated, using the example of temperature anomalies. It is shown that the ranking of the two models depends crucially on the predictability measure used; one model can be better than the other in terms of BSS, but worse in terms of AUC, and vice versa. Causes and consequences of these differences are elaborated and discussed.