DY 14: Complex Systems

Time: Monday 16:15–17:45 Location: H47

DY 14.1 Mon 16:15 H47

An integrative quantifier of multistability in complex systems based on ecological resilience — •Chiranjit Mitra[1,2], Jürgen Kurths[1,2,3,4], and Reik V. Donner[1] — [1]Potsdam Institute for Climate Impact Research, Transdisciplinary Concepts & Methods - Research Domain 4, Potsdam, 14412, Germany — [2]Humboldt University of Berlin, Department of Physics, Berlin, 12489, Germany — [3]University of Aberdeen, Institute for Complex Systems and Mathematical Biology, Aberdeen, AB24 3UE, United Kingdom — [4]Nizhny Novgorod State University, Department of Control Theory, Nizhny Novgorod, 606950, Russia

The abundance of multistable dynamical systems calls for an appropriate quantification of the respective stability of the (stable) states of such systems. Motivated by the concept of ecological resilience, we propose a novel and pragmatic measure called 'integral stability' which integrates different aspects commonly addressed separately by existing local and global stability concepts. We demonstrate the potential of integral stability by using exemplary multistable dynamical systems such as the damped driven pendulum, a model of Amazonian rainforest as a known climate tipping element and the Daisyworld model. A crucial feature of integral stability lies in its potential of arresting a gradual loss of the stability of a system when approaching a tipping point, thus providing a potential early-warning signal sufficiently prior to a qualitative change of the system's dynamics.

Reference: Mitra, C. et al. An integrative quantifier of multistability in complex systems based on ecological resilience. Sci. Rep. 5 (2015).

DY 14.2 Mon 16:30 H47

Fractional interpolation methods for two phase flow in porous media — •Pradeep Kumar, Rouven Steinle, Bakkyraj Thangarashu, and Rudolf Hilfer — Institute for Computational Physics, University Stuttgart, Germany

Two phase flow in porous media is described macroscopically using the generalized Darcy theory with hysteresis. Recently, numerical solutions for various hysteresis models were found to exhibit non-monotone profiles [1] and [2]. In this talk, we will focus on analytical solutions of this model by using the theory of semigroups and fractional interpolation methods [3]. In this framework uniqueness, global existence and maximal regularity of the solutions are also discussed.

[1] Hilfer, R. and Steinle, R., Eur. Phys. J. ST, **223**, 2323 (2014)
[2] Steinle, R. and Hilfer, R., Transp. Porous Media, (in print) 2016
[3]. Yagi, A., *Abstract parabolic evolution equations and their applications*, Springer-Verlag, Berlin (2010)

DY 14.3 Mon 16:45 H47

Scale dependent complexity measure for time series — •Eckehard Olbrich[1] and Georg Martius[2] — [1]Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany — [2]IST Austria, Klosterneuburg, Austria

The predictive information - also known as effective measure complexity or excess entropy - is a natural complexity measure for temporal sequences. It measures the amount of information that the past contains about the future which is equal to the non-extensive part of the entropy of the sequence. In order to apply it to dynamical systems with continuous states one has to partition the state space first. But, then the result will depend on the partition and will be different even for different generating partitions. Here we will study the excess entropy using scale dependent entropies. We show that the excess entropy becomes infinite in the limit of infinite resolution for deterministic systems. The attractor dimension controls, how the excess entropy diverges with increasing resolution while the resolution independent offset provides a complexity measure on its own — if appropriately rescaled — that is related to the correlations. Moreover, we show that the excess entropy remains finite for noisy systems, and discuss how it is determined by the noise levels and the entropy rate on the large scales. We demonstrate the usefulness of the scale dependent excess entropy using it for quantifying the effects of autonomously learned behavior of simulated robots using task independent objective functions.

G. Martius and E. Olbrich, Quantifying Emergent Behavior of Autonomous Robots, Entropy 17(10), 2015, 7266-7297.

DY 14.4 Mon 17:00 H47

Anisotropic Gaussian random fields characterized by Minkowski tensors — •Michael A. Klatt[1,2], Max Hörmann[2], and Klaus Mecke[2] — [1]KIT, Institut für Stochastik, Englerstraße 2, 76131 Karlsruhe — [2]FAU, Institut für Theoretische Physik, Staudtstraße 7, 91058 Erlangen

Anisotropic Gaussian random fields are important models of anisotropic disordered structures that appear in very different physical and biological systems. Often physical insight is best achieved by a rigorous structure characterization, for which comprehensive shape descriptors are needed. We here show how the Minkowski tensors as sensitive and robust measures of anisotropy, which extend the notion of volume and surface area to scalar and tensorial morphometric measures [1], comprehensively characterize the shape of level sets of Gaussian random fields.

We give explicit expressions for the mean values and compare them to simulation results. We also provide explicit integral expressions for the second moments of the Minkowski functionals. Which additional information is contained in higher rank Minkowski tensors? We find that tensors of higher rank indeed contain additional anisotropy information as compared to the tensor of rank two. Surprisingly, we can show that the latter is nevertheless sufficient to estimate the model parameters which are necessary to determine all Minkowski tensors of arbitrary rank. Using this relation a null hypothesis test for non-Gaussianities in anisotropic random fields can be defined.

[1] G. E. Schröder-Turk et al., Adv. Mater. 23:2535, 2011.

DY 14.5 Mon 17:15 H47

Propagation, growth and decay of saturation overshoot — •Rouven Steinle and Rudolf Hilfer — Institute for Computational Physics, University of Stuttgart, Germany

A sequence of drainage and imbibition shocks within the traditional theory of two-phase immiscible displacement can give rise to shallow non-monotone saturation profiles [1]. This phenomenon depends sensitively on model parameters and initial conditions. The systematical investigation of saturation overshoot on initial conditions allows to determine regions in the parameter space for the observation of saturation overshoot and to explore limitations of the underlying idealized hysteresis model. Numerical solutions of the nonlinear partial differential equations of motion reveal a strong dependence of the overshoot phenomenon on the boundary and initial conditions [2]. Overshoot solutions with experimentally detectable height are shown to exist numerically. Extensive parameter studies reveal different classes of initial conditions for which the width of the overshoot region, can decrease, increase or remain constant.

[1] Hilfer, R. and Steinle, R., Eur.Phys.J.ST, **223**, 2323 (2014)
[2] Steinle, R. and Hilfer, R., Transp. Porous Media, (in print) (2016)

DY 14.6 Mon 17:30 H47

A novel experimental technique for analyzing spreading droplets — •Roghayeh Shiri[1], Ali Najafi[1], and Mehdi Habibi[2] — [1]University of Zanjan, Zanjan, Iran — [2]Institute for advanced studies in basic sciences, Zanjan, Iran

Recently, a simple and accurate phase measurement method, called the sampling moiré method was developed for thickness distribution measurement of transparent plates from a single image. A single image taken from a Ronchi grating that encoded the optical characteristics of transparent sample is the main experimental element of the sampling moiré method. This method can obtain small displacements up to 1/500 of the grating pitch by analyzing the phase distribution of the moiré fringe of each single grating image before and after deformation.

Therefore, Sampling moiré method can provide an accurate technique to investigate the dynamical properties of a spreading droplet of a transparent fluid over a rigid substrate where the air-liquid interface evolves in time. Studying the dynamics of such a multi-phase flow interface is interesting either from fundamental or technical point of view.

We have performed the spreading experiment with silicone oils with different viscosities and compared them with a universal scaling relation that quantifies the early time dynamics in non-gravitational regime as:$h(t) \sim t^{-0.2}$. In our experiments, all droplets with different viscosities show a linear dynamics with slope -0.2 in the logarithmic scale that are in good agreement with the theoretical results.