Physics of Socio-economic Systems Division
Fachverband Physik sozio-ökonomischer Systeme (SOE)

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Overview of Invited Talks and Sessions

(Lecture hall H11; Poster P2)

Plenary Talk Ricard Sole

PLV IX Thu 14:00–14:45 H1 **Evolutionary transitions: universality, complexity and predictability** — •Ricard Sole

Lunch Talk Nicolas Wöhrl

PSV II Tue 13:15–13:45 H2 **Wissenschaftkommunikation - für wen eigentlich?** — •Nicolas Wöhrl, Peter Kohl, Axel Lorke

Invited Talks

SOE 2.1 Mon 9:30–10:15 H11 **Two-armed bandits versus Carnapian truth seekers and epistemic free riders with bounded confidence** — •Rainer Hegselmann

SOE 8.1 Tue 9:30–10:15 H11 **Musicians' Synchronization and the Enigma of Swing** — •Theo Geisel

SOE 11.1 Wed 9:30–10:15 H11 **The Corona Data Donation Project - When Citizens Collaborate to Fight a Pandemic** — •Dirk Brockmann

Invited Tutorial Talks

SOE 1.1 Sun 16:00–16:50 H4 **Diffusion approximations for particles in turbulence** — •Bernhard Mehlig

SOE 1.2 Sun 16:50–17:40 H4 **Probabilities in physics, paradoxes and populations** — •Tobias Galla

SOE 1.3 Sun 17:40–18:30 H4 **Risk Revealed: Cautionary Tales, Understanding and Communication** — •Paul Embrechts

Invited Talks of the joint Symposium SKM Dissertation Prize 2022 (SYSD)

See SYSD for the full program of the symposium.

SYSD 1.1 Mon 10:15–10:45 H2 **Charge localisation in halide perovskites from bulk to nano for efficient optoelectronic applications** — •Sascha Feldmann

SYSD 1.2 Mon 10:45–11:15 H2 **Nonequilibrium Transport and Dynamics in Conventional and Topological Superconducting Junctions** — •Raffael L. Klees

SYSD 1.3 Mon 11:15–11:45 H2 **Probing magnetostatic and magnetotransport properties of the antiferromagnetic iron oxide hematite** — •Andrew Ross

SYSD 1.4 Mon 11:45–12:15 H2 **Quantum dot optomechanics with surface acoustic waves** — •Matthias Weiss

Invited Talks of the joint Symposium United Kingdom as Guest of Honor (SYUK)

See SYUK for the full program of the symposium.

SYUK 1.1 Wed 9:30–10:00 H2 **Structure and Dynamics of Interfacial Water** — •Angelos Michaelides

SYUK 1.2	Wed	10:00–10:30	H2	**A molecular view of the water interface** — •Mischa Bonn
SYUK 1.3	Wed	10:30–11:00	H2	**Motile cilia waves: creating and responding to flow** — •Pietro Cicuta
SYUK 1.4	Wed	11:00–11:30	H2	**Cilia and flagella: Building blocks of life and a physicist's playground** — •Oliver Bäumchen
SYUK 1.5	Wed	11:45–12:15	H2	**Computational modelling of the physics of rare earth - transition metal permanent magnets from $SmCo_5$ to $Nd_2Fe_{14}B$** — •Julie Staunton
SYUK 2.1	Wed	15:00–15:30	H2	**Hysteresis Design of Magnetic Materials for Efficient Energy Conversion** — •Oliver Gutfleisch
SYUK 2.2	Wed	15:30–16:00	H2	**Non-equilibrium dynamics of many-body quantum systems versus quantum technologies** — •Irene D'Amico
SYUK 2.3	Wed	16:00–16:30	H2	**Quantum computing with trapped ions** — •Ferdinand Schmidt-Kaler
SYUK 2.4	Wed	16:45–17:15	H2	**Breaking the millikelvin barrier in cooling nanoelectronic devices** — •Richard Haley
SYUK 2.5	Wed	17:15–17:45	H2	**Superconducting Quantum Interference Devices for applications at mK temperatures** — •Sebastian Kempf

Invited Talks of the joint Symposium Collective Social Dynamics from Animals to Humans (SYSO)

See SYSO for the full program of the symposium.

SYSO 1.1	Thu	9:30–10:00	H1	**Capturing group interactions: The next frontier of modeling social and biological systems** — •Frank Schweitzer
SYSO 1.2	Thu	10:00–10:30	H1	**Modelling Individual Mobility Behavior** — •Laura Maria Alessandretti
SYSO 1.3	Thu	10:30–11:00	H1	**Validating argument-based opinion dynamics with survey experiments** — •Sven Banisch
SYSO 1.4	Thu	11:15–11:45	H1	**Self-organization, Criticality and Collective Information Processing in Animal Groups** — •Pawel Romanczuk
SYSO 1.5	Thu	11:45–12:15	H1	**Collective dynamics and physiological interactions in bird colonies** — •Hanja Brandl

Sessions

SOE 1.1–1.3	Sun	16:00–18:30	H4	**Tutorial: Stochastic Processes from Financial Risk to Genetics (joint session SOE/TUT/BP/DY)**
SOE 2.1–2.1	Mon	9:30–10:15	H11	**Invited Talk Rainer Hegselmann: Opinion Formation**
SOE 3.1–3.5	Mon	10:15–11:45	H11	**Economic Models**
SOE 4.1–4.2	Mon	12:00–12:30	H11	**Financial Risk**
SOE 5.1–5.4	Mon	12:30–13:30	H11	**Social Systems, Opinion and Group Dynamics**
SOE 6.1–6.10	Mon	15:00–17:45	H18	**Data Analytics for Complex Systems (joint session DY/SOE)**
SOE 7.1–7.2	Mon	17:45–18:15	H18	**Big Data and Artificial Intelligence (joint session SOE/DY)**
SOE 8.1–8.1	Tue	9:30–10:15	H11	**Invited Talk Theo Geisel: Human Synchronization in Music Performance**
SOE 9.1–9.3	Tue	10:15–11:15	H11	**Physics of Contagion Processes**
SOE 10.1–10.6	Tue	11:15–12:45	H19	**Nonlinear Dynamics 1: Synchronization and Chaos (joint session DY/SOE)**
SOE 11.1–11.1	Wed	9:30–10:15	H11	**Invited Talk Dirk Brockmann: Big Data in Epidemic Dynamics (joint session SOE/DY)**
SOE 12.1–12.6	Wed	10:15–12:45	H11	**Networks: From Topology to Dynamics (joint session SOE/BP/DY)**
SOE 13.1–13.2	Wed	12:45–13:15	H11	**Energy Networks (joint session SOE/DY)**
SOE 14.1–14.5	Wed	15:00–16:45	H11	**Computational Social Science**
SOE 15.1–15.3	Wed	17:00–18:15	H11	**Traffic Dynamics, Urban and Regional Systems**
SOE 16	Wed	18:15–19:30	H11	**Members' Assembly**
SOE 17.1–17.6	Thu	15:00–18:00	P2	**Poster**
SOE 18.1–18.1	Fri	9:30–10:00	H19	**Invited Talk Kathy Lüdge (joint session DY/SOE)**
SOE 19.1–19.5	Fri	10:00–11:15	H19	**Machine Learning in Dynamics and Statistical Physics (joint session DY/SOE)**
SOE 20.1–20.5	Fri	11:30–12:45	H19	**Nonlinear Dynamics 2: Stochastic and Complex Systems, Networks (joint session DY/SOE)**

Members' Assembly of the Physics of Socio-economic Systems Division

Wednesday 18:15–19:30 H11

Agenda:

- Report on Activities
- Announcements
- Elections
- Miscellaneous

SOE 1: Tutorial: Stochastic Processes from Financial Risk to Genetics (joint session SOE/TUT/BP/DY)

Macroscopic and microscopic models from Economy to Biology must account for stochasticity on various levels. While classical physics strives for deterministic descriptions through differential equations from fundamental level to thermodynamics, many physics-based models on higher level explicitely include stochasticity from various sources. Discrete and continuous stochastic processes then become the mathematical foundation of these models. This tutorial highlights classical as well as current methods and approaches of probabilistic models and stochastic processes in physics, biology as well as socio-economic systems, thereby bridging the risk to extinction in genetics with its economic counterpart. (Session organized by Jens Christian Claussen.)

Time: Sunday 16:00–18:30 Location: H4

Tutorial SOE 1.1 Sun 16:00 H4

Diffusion approximations for particles in turbulence — •Bernhard Mehlig — University of Gothenburg, Gothenburg, Sweden

The subject of this tutorial is the dynamics of particles in turbulence, such as micron-sized water droplets in the turbulent air of a cumulus cloud. The particles respond in intricate ways to the turbulent fluctuations. Non-interacting particles may cluster together to form spatial patterns – even though the turbulent fluid is incompressible [1]. In this tutorial I explain how to understand spatial clustering using diffusion approximations, highlighting an analogy with Kramers' escape problem [2]. I introduce/review the necessary elements of diffusion theory. My goal is to give a pedagogical introduction to diffusion approximations in non-equilibrium statistical physics, using particles in turbulence as an example.

[1] K. Gustavsson and B. Mehlig, Statistical models for spatial patterns of heavy particles in turbulence, Adv. Phys. 65 (2016) 57 (read Sections 1, 3.1, and 6.1).

[2] H. A. Kramers, Brownian motion in a field of force and the diffusion model of chemical reactions, Physica 7 (1940) 284 (read up to eq. (17)).

Tutorial SOE 1.2 Sun 16:50 H4

Probabilities in physics, paradoxes and populations — •Tobias Galla — Instituto de Física Interdisciplinary Sistemas Complejos, IFISC (CSIC-UIB), Campus Universitat Illes Balears, E-07122 Palma de Mallorca, Spain

It is notoriously hard for humans to develop a good intuition for probabilities and stochastic processes. Our brains are not able to do this naturally, and there are numerous mistakes which are easy to make. These mistakes are in fact made regularly in the press (sometimes perhaps deliberately). More worrisome, decision makers such as judges, doctors or politicians are also prone to mishandling probabilities. In this tutorial I will outline a few of these traps, and how to avoid them. I will also discuss the nature of probabilistic models of physical processes – is there genuine randomness in the world around us? I will then present a number of instances in which physics approaches combined with stochastic modelling can make a difference. As one example, I will outline experimental and theoretical results which highlight the importance of stochastic processes in population dynamics. Other examples will include stochastic processes in genetics, the evolution of cancer and in game theory.

Tutorial SOE 1.3 Sun 17:40 H4

Risk Revealed: Cautionary Tales, Understanding and Communication — •Paul Embrechts — Department of Mathematics, ETH Zürich

The title of the tutorial refers to a forthcoming book, to be published by Cambridge University Press, co-authored with Valérie Chavez-Demoulin (Lausanne) and Marius Hofert (Waterloo). Extreme Value Theory (EVT) offers a mathematical tool for the modeling of so-called What-If events, or stress scenarios. I will present several examples of risk-based decision-making and show how EVT can be used as part of the solution. The current pandemic has clearly shown that the communication of scientific evidence has a difficult stand in the ubiquitous environment of social media. I will discuss some examples of this struggle.

SOE 2: Invited Talk Rainer Hegselmann: Opinion Formation

Time: Monday 9:30–10:15 Location: H11

Invited Talk SOE 2.1 Mon 9:30 H11

Two-armed bandits versus Carnapian truth seekers and epistemic free riders with bounded confidence — •Rainer Hegselmann — Frankfurt School of Finance & Management, Adickesallee 32-34, 60322 Frankfurt

In its original version, the so-called bounded confidence model only knows the exchange of opinions among individuals. The individuals may have formed their opinions beforehand through systematic experience (observation, experimentation), but no signal from the external world enters the modeled social exchange process. Later, Ulrich Krause and I extended the model to include a signal from the external world acting on the social exchange process. However, we put all details of this influence process into a black box.

In my talk I will present how this black box can be opened: The social exchange process of the bounded confidence model is linked to an explicitly modeled experimentation and evaluation of experimentally obtained data. The starting point is a community that has a choice between n strategies (n = 2), each leading to success with a constant but unknown probability. Such problems are known as n-armed-bandit-problems. It is further assumed that the community consists only partly of truth-seekers who 'conscientiously', following certain rules from Carnap's inductive logic, evaluate their experiences. Another part of the community consists of epistemic free riders, who do no statistics at all, but opportunistically follow their close-by neighbors. The talk will show that such a setting allows to answer questions about the efficiency of different epistemic policies.

SOE 3: Economic Models

Time: Monday 10:15–11:45 Location: H11

SOE 3.1 Mon 10:15 H11

Generic catastrophic poverty when selfish investors exploit a degradable common resource — •Claudius Gros — Institute for Theoretical Physics, Goethe University Frankfurt a.M.

The productivity of a common pool of resources may degrade when overly exploited by a number of selfish investors, a situation known as the tragedy of the commons. We examine the case that degradation is functionally dependent on total investments. The payoffs, which are independently optimized by each agent, are given by the balance between the return from investing in the common resource and the investment costs, which are a function of the agent-specific per-unit costs. The payoffs of most agents are shown rigorously not to scale as 1/N, the result for cooperating agents, but as 1/(N*N), where N is the number of agents. This scaling in the stationary state is denoted catastrophic poverty. A finite number of oligarchs may be present in addition, with the payoffs of the oligarchs remaining finite even in the large-N limit. The results hold under very general conditions for a wide class of models.

SOE 3.2 Mon 10:45 H11

Games in rigged economies — •Luis F Seoane — Systems Biology Department, Spanish National Center for Biotechnology (CNB-CSIC), C/ Darwin 3, Madrid, Spain.

Modern economies evolved from simpler material exchanges into very convoluted systems. Today, a multitude of aspects can be regulated, tampered with, or left to chance; these are economic degrees of freedom (DOF) which shape the flow of wealth. Economic actors can exploit them, at a cost, and bend that flow in their favor. If intervention becomes widespread, microeconomic strategies can collide or resonate, building into macroeconomic effects. How viable is a *rigged* economy? How do growing economic complexity and wealth affect it? We capture essential elements of rigged economies with a simple model. Nash equilibria in tractable cases show how increased intervention turns economic DOF from minority into majority games through a dynamical phase. This is reproduced by agent-based simulations of our model, which allow us to explore scenarios out of reach for payoff matrices. Increasing economic complexity appears as a mechanism to defuse cartels or consensus situations. But excessive complexity enters abruptly into a regime of large fluctuations (resulting from non-competitive intervention efforts coupled across DOF) that threaten the system's viability. Thus high economic complexity can result in negative spillover from non-competitive actions. Simulations suggest that wealth must grow faster than linearly with complexity to avoid this large fluctuations regime. Our model provides testable conclusions and phenomenological charts to guide policing of rigged economies.

SOE 3.3 Mon 11:00 H11

Risk Preferences in Time Lotteries — Yonatan Berman[1] and •Mark Kirstein[2] — [1]King's College London — [2]Max Planck Institute for Mathematics in the Sciences, Leipzig

An important but understudied question in economics is how people choose when facing uncertainty in the timing of events. Here we study preferences over time lotteries, in which the payment amount is certain but the payment time is uncertain. Expected discounted utility theory (EDUT) predicts decision makers to be risk-seeking over time lotteries. We explore a normative model of growth-optimality, in which decision makers maximise the long-term growth rate of their wealth as suggested by the framework of ergodicity economics. Revisiting experimental evidence on time lotteries, we find that growth-optimality accords better with the evidence than EDUT. We outline future experiments to scrutinise further the plausibility of growth-optimality.

SOE 3.4 Mon 11:15 H11

Macroscopic approximation for an agent based socio-economic model — •Sören Nagel[1], Eckehard Schöll[1,2], and Jobst Heitzig[1] — [1]Potsdam Institute for Climate Impact Research — [2]Institut für Theoretische Physik, TU Berlin

We investigate an agent-based model for economic growth that contains an underlying social network in order to incorporate bounded rationality. To further extend the results presented in [1] we combine a moment closure approach for the economy and a stochastic differential equation approximation for the social choice. With this approach we can reproduce some characteristics of the original model like economic inequality, and we are able to link the business cycle oscillations to noise-induced excitation oscillations and coherence resonance.

[1] Yuki M Asano, Jakob J Kolb, Jobst Heitzig, and J Doyne Farmer. Emergent inequality and business cycles in a simple behavioral macroeconomic model. PNAS 118, e2025721118 (2021).

SOE 3.5 Mon 11:30 H11

Socioeconomic modeling of a fossil-fuel and renewable-energy based two-sector economy — •Philippe Lehmann[1], Eckehard Schöll[1,2], and Jobst Heitzig[1] — [1]Potsdam Institute for Climate Impact Research — [2]Institut für Theoretische Physik, TU Berlin

We study a stylized economic model to capture the influence of social dynamics on investment decisions in a fossil-fuel and renewable energy based two-sector production economy. For this purpose the socioeconomic model in [1] is extended to two sectors. Although this model is based on simple assumptions, it shows extensive complex dynamics which we illustrate graphically to reveal the underlying mechanism. This empirical approach allows us to draw several analogies to patterns of our real economy that challenge current econometric models.

[1] Yuki M Asano, Jakob J Kolb, Jobst Heitzig, and J Doyne Farmer. Emergent inequality and business cycles in a simple behavioral macroeconomic model. PNAS 118, e2025721118 (2021).

SOE 4: Financial Risk

Time: Monday 12:00–12:30 Location: H11

SOE 4.1 Mon 12:00 H11

From many-body physics to financial markets: sparse modeling for inverse problems — •Daniel Guterding — Fachbereich Mathematik, Naturwissenschaften und Datenverarbeitung, Technische Hochschule Mittelhessen, Wilhelm-Leuschner-Straße 13, 61169 Friedberg, Germany

The accurate valuation of plain-vanilla derivatives is one of the fundamental tasks of mathematical finance. In particular, arbitrage-free interpolations of market-quoted option prices or implied volatilities are needed for the pricing of most options. For this purpose, various standard interpolation techniques have been modified to accommodate the no-arbitrage conditions required by quantitative finance.

Despite this problem being so important for option pricing, the available approaches are quite involved and largely not stable against the noisy inputs that are often encountered in practical applications. Making use of recent progress on inverse problems in many-body physics [1], our method [2] is based on the relation between the terminal density of the underlying asset and plain-vanilla option prices.

We construct a few-parameter model for this relation using the singular value decomposition, which obviates the need to explicitly choose expansion or regression basis functions, such as they are encountered in many other methods. Furthermore, we show that our method by construction delivers arbitrage-free models even for inputs containing noise or severe arbitrage.

[1] Otsuki et al., J. Phys. Soc. Japan 89, 012001 (2020)
[2] Guterding, arXiv:2205.10865

SOE 4.2 Mon 12:15 H11

An ABM Marketmodel Study: Dynamics, Stochastics and Rule based Decisions — •Magda Schiegl — University of Applied Sciences Landshut, Am Lurzenhof 1, D-84036 Landshut

Riskmanagement is a main topic in insurance business with a variety of traditional methods. In recent years more and more methods of the field of complex systems as complex networks or ABMs play an im-

portant role. One of the first in the insurance mathematical literature published ABMs is by Ingram et al. [1]. The paper describes a model of a competitive (insurance and not only insurance) market that shows cyclical behavior.
We reformulate the above cited model in a form that makes it accessible for analytical as well as numerical treatment and discussion. We find three, interacting components of the model: the dynamics, the stochastics and the rule based decisions. The agents, insurance companies, play a rule based strategic game, competing with each other. The actions of the agents depend on both, the statistics of the single agent and the statistics of the market as a whole. We analyze the dynamics of the model being responsible for a parameter dependent, periodic behavior and investigate its stochastic and rule-based components. We implemented the model as a Monte Carlo simulation and examine the interactions of the model's different components.
.[1] Ingram, D., Tayler, P., Thompson, M. (2012) Invited Discussion Paper: Surprise, Surprise From Neoclassical Economics To E-Life. ASTIN Bulletin 42(2): 389-411

SOE 5: Social Systems, Opinion and Group Dynamics

Time: Monday 12:30–13:30 Location: H11

SOE 5.1 Mon 12:30 H11

Bounded rational agents playing a public goods game — •Prakhar Godara, Tilman Diego Aleman, and Stephan Herminghaus — Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Goettingen, Germany

An agent-based model for human behavior in the well-known public goods game (PGG) is developed making use of bounded rationality, but without invoking mechanisms of learning. The underlying Markov decision process is driven by a path integral formulation of reward maximization. The parameters of the model can be related to human preferences accessible to measurement. Fitting simulated game trajectories to available experimental data, we demonstrate that our agents are capable of modeling human behavior in PGG quite well, including aspects of cooperation emerging from the game. We find that only two fitting parameters are relevant to account for the variations in playing behavior observed in 16 cities from all over the world. We thereby find that learning is not a necessary ingredient to account for empirical data.

SOE 5.2 Mon 12:45 H11

Social nucleation: Group formation as a phase transition — Frank Schweitzer and •Georges Andres — ETH Zürich, Chair of Systems Design, Switzerland

The spontaneous formation and subsequent growth, dissolution, merger, and competition of social groups bear similarities to physical phase transitions in metastable finite systems. In this talk, I will examine three different scenarios, percolation, spinodal decomposition, and nucleation, to describe the formation of social groups of varying size and density. In an agent-based model, I will present a feedback between the opinions of agents and their ability to establish links. Groups can restrict further link formation, but agents can also leave if costs exceed the group benefits. I will show how to identify the critical parameters for costs and benefits and social influence to obtain either one large group or the stable coexistence of several groups with different opinions. Analytic investigations then allow to derive different critical densities that control the formation and coexistence of groups. This approach sheds light on the much-neglected early stage of network growth and the emergence of large connected components.

SOE 5.3 Mon 13:00 H11

Multiscale Causal Structure in Armed Conflict — •Niraj Kushwaha and Edward Lee — Complexity Science Hub Vienna, Josefstädter Straße 39, 1080 Vienna, Austria

Armed conflict is a major and ongoing problem around the world today. The very features of conflict that makes it important, its multiscale and multidimensional impact, render it difficult to understand quantitatively. Here, we introduce a first principles approach to conflict by clustering sequences of conflict events into causal conflict avalanches. We rely on armed conflict data from the ACLED project, occurring from the years 1996-2021 in Africa. We investigate different spatial and temporal scales with a systematic coarse-graining procedure. For space, we tile the region with semi-regular bins that constitute our level of resolution, and for time we group days into discrete intervals. This formalism bridges the gap between microscopic and macroscopic descriptions of armed conflict. To infer causal relationships between different spatial bins we use a standard nonlinear measure of statistical dependency called transfer entropy. Using transfer entropy, we extract a directed causal network that links adjacent geographic locations. We then leverage this causal structure to join two conflict events if they are adjacent in time and belong to adjacent and causally connected spatial bins. We call the resulting sequences of conflict events, conflict avalanches. Further statistical and dynamical analysis reveal that many conflict avalanche features follow power-law distributions. Our work paves way for future investigation on classes of models which can explain the emergence of scaling in conflict across different scales.

SOE 5.4 Mon 13:15 H11

Ordering dynamics and path to consensus in multi-state voter models — Lucía Ramirez, Maxi San Miguel, and •Tobias Galla — Instituto de Física Interdisciplinary Sistemas Complejos, IFISC (CSIC-UIB), Campus Universitat Illes Balears, E-07122 Palma de Mallorca, Spain

We investigate the time evolution of the density of active interfaces and of the entropy of the distribution of agents among opinions in multi-state voter models. Individual realisations undergo a sequence of extinctions until consensus is reached. After each elimination the population remains in a meta-stable state. The density of active interfaces and the entropy in these states varies from realisation to realisation. Making some simple assumptions we are able to analytically calculate the average density of active interfaces and the average entropy in each of these states. We also show that, averaged over realisations, the density of active interfaces decays exponentially, with a time scale set by the size and geometry of the interaction graph, but independent of the initial number of opinion states. The decay of the average entropy is exponential only at long times when there are at most two opinions left in the network. Finally, we show how meta-stable states comprised of only a subset of opinions can be engineered as genuinely stationary states by introducing precisely one zealot in each of the prevailing opinions.

SOE 6: Data Analytics for Complex Systems (joint session DY/SOE)

Time: Monday 15:00–17:45 Location: H18

SOE 6.1 Mon 15:00 H18

Estimating covariant Lyapunov vectors from data — •Nahal Sharafi, Christoph Martin und Sarah Hallerberg — Hamburg University of Applied Sciences, Hamburg, Germany

Covariant Lyapunov vectors characterize the directions along which perturbations in dynamical systems grow. They have also been studied as predictors of critical transitions and extreme events. For many applications, it is necessary to estimate these vectors from data since model equations are unknown for many interesting phenomena. We propose a novel approach for estimating covariant Lyapunov vectors based on data records without knowing the underlying equations of the system. In contrast to previous approaches, our approach can be applied to high-dimensional datasets. We demonstrate that this purely data-driven approach can accurately estimate covariant Lyapunpov vectors from data records generated by low and high-dimensional dynamical systems. Additionally we test for the robustness against noise in a low-dimensional dynamical system.

SOE 6.2 Mon 15:15 H18

Extending the limits of Electrochemical Impedance Spectroscopy with Machine Learning and Digital Twins — •Limei Jin[1,2], Franz P. Bereck[2], Christian H. Bartsch[2], Josef Granwehr[2], Rüdiger-A. Eichel[2], Karsten Reuter[1], and Christoph Scheurer[1] — [1]Fritz-Haber-Institut der MPG, Berlin, Germany — [2]IEK-9, Forschungszentrum Jülich, Jülich, Germany

Electrochemical impedance spectroscopy (EIS) is widely used to characterize electrochemical energy conversion systems. The traditional analysis with equivalent circuit models (ECM) has recently been augmented by a transform based distribution of relaxation times (DRT) analysis which allows one to reduce the ambiguity in the construction of ECMs and thus overfitting. Yet, DRT, just like most traditional analyses, is firmly based in the linear response regime as well as based on frequency sweeps on a logarithmic scale. The latter makes these approaches time-consuming, the first limits their scope severely. To develop novel experimental spectroscopic excitation schemes that address these limitations, a model space of sufficiently realistic systems is required that substitutes for time-consuming measurements in terms of a digital twin. We present a joint experimental and theoretical approach for the construction of such a target space for the case of battery cell performance and ageing behaviour.

SOE 6.3 Mon 15:30 H18

Bayesian approach to anticipate critical transitions in complex systems — •Martin Hessler[1,2] and Oliver Kamps[2] — [1]Westfälische Wilhelms-Universität Münster, 48149 Münster — [2]Center for Nonlinear Science, Westfälische Wilhelms-Universität Münster, 48149 Münster

Complex systems in nature, technology and society can undergo sudden transitions between system states with very different behaviour. In order to avoid undesired consequences of these tipping events, statistical measures as variance, autocorrelation, skewness and kurtosis have been proposed as leading indicators based on time series analysis. Under favourable conditions they can give a hint of an ongoing bifurcation-induced destabilization process. However, they suffer from their loose connection to complex system dynamics, sensitivity to noise and sometimes misleading trends. Therefore, we want to present an alternative approach assuming the dynamical system being described by a Langevin equation. Starting from this stochastic description, we combine MCMC sampling, rolling window methods and Bayesian reasoning to derive the drift slope as an alternative early warning sign. The Bayesian approach enables us to define credibility bands which make it easier to distinguish random fluctuations from real trends that imply a less resilient system. Our investigations suggest that the estimation procedure is rather robust even under strong noise. Besides, the noise level of the system is computed to get insights into the probability of a noise induced transition. We want to present some of the results and discuss possible limitations and tasks of future research.

SOE 6.4 Mon 15:45 H18

Stochastic Interpolation of Sparsely Sampled Time Series by a Superstatistical Random Process and its Synthesis in Fourier and Wavelet Space — •Jeremiah Lübke[1], Jan Friedrich[2], and Rainer Grauer[1] — [1]Institute for Theoretical Physics I, Ruhr-University Bochum, Universitätsstr. 150, 44801 Bochum, Germany — [2]ForWind, Institute of Physics, University of Oldenburg, Küpkersweg 70, 26129 Oldenburg, Germany

A novel method is presented for stochastic interpolation of a sparsely sampled time signal based on a superstatistical random process generated from a Gaussian scale mixture. In comparison to other stochastic interpolation methods such as kriging, this method possesses strong non-Gaussian properties and is thus applicable to a broad range of real-world time series. A precise sampling algorithm is provided in terms of a mixing procedure that consists of generating a field $u(\xi, t)$, where each component $u_\xi(t)$ is synthesized with identical underlying noise but covariance $C_\xi(t, s)$ parameterized by a log-normally distributed parameter ξ. Due to the Gaussianity of each component $u_\xi(t)$, standard sampling algorithms and methods to constrain the process on the sparse measurement points can be exploited. The scale mixture $u(t)$ is then obtained by assigning each point in time t a $\xi(t)$ and therefore a specific value from $u(\xi, t)$, where $\log \xi(t)$ is itself a realization of a Gaussian process with a correlation time large compared to the correlation time of $u(\xi, t)$. Finally, a wavelet-based hierarchical representation of the interpolating paths is introduced, which is shown to provide an adequate method to locally interpolate large datasets.

SOE 6.5 Mon 16:00 H18

Global sensitivity analysis of Monte Carlo models using Cramer-von Mises distance — •Sina Dortaj[1,2] and Sebastian Matera[1,2] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [2]Institute for Mathematics, Freie Universität Berlin, Arnimallee 6, 14195 Berlin, Germany

Typically, the parameters entering a physical simulation model carry some kind of uncertainty, e.g. due to the intrinsic approximations in a higher fidelity theory from which they have been obtained. Global sensitivity analysis (GSA) targets quantifying which parameters uncertainties impact the accuracy of the simulation results, e.g. to identify which parameters need to be determined more accurately.

We present a GSA approach on basis of the Cramers-von Mises distance. Unlike prevalent approaches it combines the following properties: i) it is equally suited for deterministic as well as stochastic model outputs, ii) it is free of gradients, and iii) it can be estimated from any suitable numerical quadrature (NQ) without further numerical tricks. Using Quasi-Monte Carlo for NQ and prototypical first-principles kinetic Monte Carlo models (kMC), we examine the performance of the approach. We find that the approach typically converges in a modest number of NQ points. Furthermore, it is robust against even extreme relative noise. All these properties make the method particularly suited for expensive (kinetic) Monte Carlo models, because we can reduce the number of simulations as well as the target variance of each of these.

15 min. break

SOE 6.6 Mon 16:30 H18

Reproducible and transparent research software pipelines using semantic research data management and common workflow language — •Alexander Schlemmer[1,2,5], Inga Kottlarz[1,3], Baltasar Rüchardt[1,5], Ulrich Parlitz[1,3,5], and Stefan Luther[1,4,5] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen — [2]IndiScale GmbH, Göttingen — [3]Institute for the Dynamics of Complex Systems, Georg-August-Universität Göttingen — [4]Institute of Pharmacology and Toxicology, University Medical Center Göttingen — [5]German Center for Cardiovascular Research (DZHK), Partner Site Göttingen

Sustainable and well-documented scientific software is essential for effectiveness and reproducibility in data-intensive research. In practice, incompletely documented software hinders in many cases replicability, reproducibility and method comparison. In our terminology, documentation includes method and algorithm descriptions as well as human- and machine-readable representations of parameters, initial conditions and data, versions and dependencies and a well-defined software execution environment. We present an approach combining semantic data management with CaosDB and processing pipelines with Common Workflow Language (CWL), showing use cases from dynamical systems research. The CWL-based environment provides a transparent

description of the process and includes metadata that can be searched within CaosDB. Input-/output-data and parameters can be directly linked to algorithms and software snapshots. The employment of containers simplifies reproducibility and interoperability.

SOE 6.7 Mon 16:45 H18

MDSuite: A post-processing engine for particle simulations — •Fabian Zills[1], Samuel Tovey[1], Francisco Torres-Herrador[2], Christoph Lohrmann[1], and Christian Holm[1] — [1]Institute for Computational Physics, University of Stuttgart, Stuttgart, Germany — [2]von Karman Institute for Fluid Dynamics, Rhode-St-Genese, Belgium

Particle-based simulations are experiencing a rapid growth wherein system sizes in the hundreds of thousands or even millions are becoming commonplace. With this growth in system size comes the additional challenge of post-processing the simulation data.

In this talk, we introduce the Python package MDSuite. MDSuite is designed for the post-processing of particle-based simulation in an efficient manner and on modern hardware. Built on top of TensorFlow, MDSuite calculators are fully parallelised, gpu-enabled, and, due to the use of modern data pipe-lining methods, completely memory safe. Furthermore, the use of HDF5 and SQL database structures enables effective tracking of calcualtion parameters as well as a compressed trajectory storage medium. We present MDSuite as a standalone package for the storage, analysis, and comparison of large-scale simulation studies.

SOE 6.8 Mon 17:00 H18

Distinguishing noise from high-dimensional chaos — •Inga Kottlarz[1,2] and Ulrich Parlitz[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Institute for Dynamics of Complex Systems, Georg-August-Universität Göttingen, Göttingen, Germany

The ordinal pattern-based Complexity-Entropy Plane is a popular tool in nonlinear dynamics for distinguishing noise from chaos. While successful attempts to do so have been documented for low-dimensional maps and continuous-time systems, high-dimensional systems have been somewhat neglected so far. To address the question in which way time series from highdimensional chaotic attractors can be characterized by their location in the Complexity-Entropy Plane we analyze data from the high-dimensional continuous-time Lorenz-96 system, the discrete generalized Hénon map and the Mackey-Glass equation as a delay system and discuss the crucial role of the lag and the pattern length or the ordinal pattern, and the length of the available time series.

SOE 6.9 Mon 17:15 H18

The impact of the UEFA European Football Championship on the spread of COVID-19 — •Jonas Dehning[1], Sebastian B. Mohr[1], Sebastian Contreras[1], Philipp Dönges[1], Emil Iftekhar[1], Oliver Schulz[2], Philip Bechtle[3], and Viola Priesemann[1,4] — [1]MPI for Dynamics and Self-Organization, 37077 Göttingen — [2]MPI for Physics, 80805 München — [3]Physikalisches Institut, University of Bonn — [4]Institute for the Dynamics of Complex Systems, University of Göttingen

Large-scale international events like the UEFA Euro 2020 football championship offer a unique opportunity to quantify the impact of match-related social gatherings on COVID-19, as the number of matches played by participating countries resembles a randomized trial. Moreover, soccer-related activities have a marked gender-imbalance that we can exploit for inference. In our work, we build a differentiable Bayesian SEIR-like model. Its parameters are inferred with Hamiltonian Monte-Carlo using the PyMC3 package. Our model simulates COVID-19 spread in each country using a discrete renewal process and gender-resolved case numbers. On average, 3.2% (95% CI: [1.3%, 5.2%]) of new cases in the 12 analyzed countries can be associated with the match-related social gatherings throughout our analysis period. Individually, England, the Czech Republic and Scotland showed a significant effect. Besides these insights on the spread of COVID-19 during large-scale events, our approach is an example of how modern Bayesian tools can be leveraged to gain insights on a complex dynamic process.

SOE 6.10 Mon 17:30 H18

Recurrence-based analysis of instantaneous fractal characteristics of geomagnetic variability — •Reik V. Donner[1,2], Tommaso Alberti[3], and Davide Faranda[4] — [1]Hochschule Magdeburg-Stendal, Magdeburg, Germany — [2]Potsdam Institute for Climate Impact Research, Potsdam, Germany — [3]National Institute for Astrophysics, Rome, Italy — [4]LSCE, Université Paris-Saclay, Gif-sur-Yvette, France

We employ two complementary approaches based on the concept of recurrences in phase space to quantify the local (instantaneous) and global fractal dimensions of the temporal variations of a suite of low (SYM-H, ASY-H) and high latitude (AE, AL, AU) geomagnetic indices and discuss similarities and dissimilarities of the obtained patterns for one year of observations during a solar activity maximum. Subsequently, we introduce bivariate extensions of both approaches, and demonstrate their capability of tracing different levels of interdependency between low and high latitude geomagnetic variability during periods of magnetospheric quiescence and along with perturbations associated with geomagnetic storms and magnetospheric substorms, respectively. Our results open new perspectives on the nonlinear dynamics and intermittent mutual entanglement of different parts of the geospace electromagnetic environment, including the equatorial and westward auroral electrojets, in dependence of the overall state of the geospace system affected by temporary variations of the solar wind forcing.

SOE 7: Big Data and Artificial Intelligence (joint session SOE/DY)

Time: Monday 17:45–18:15 Location: H18

SOE 7.1 Mon 17:45 H18

Revealing interactions between HVDC cross-area flows and frequency stability with explainable AI — •Sebastian Pütz[1,2], Benjamin Schäfer[3], Dirk Witthaut[1,2], and Johannes Kruse[1,2] — [1]Forschungszentrum Jülich, Institute for Energy and Climate Research - Systems Analysis and Technology Evaluation (IEK-STE), 52428 Jülich, Germany — [2]Institute for Theoretical Physics, University of Cologne, 50937 Köln, Germany — [3]Karlsruhe Institute of Technology, Institute for Automation and Applied Informatics (IAI), 76344 Eggenstein-Leopoldshafen, Germany

The energy transition introduces more volatile energy sources into the power grids. In this context, power transfer between different synchronous areas through High Voltage Direct Current (HVDC) links becomes increasingly important. Such links can balance volatile generation by enabling long-distance transport or by leveraging their fast control behavior. Here, we investigate the interaction of power imbalances - represented through the power grid frequency - and power flows on HVDC links between synchronous areas in Europe. We use explainable machine learning to identify key dependencies and disentangle the interaction of critical features. Our results show that market-based HVDC flows introduce deterministic frequency deviations, which however can be mitigated through strict ramping limits. Moreover, varying HVDC operation modes strongly affect the interaction with the grid. In particular, we show that load-frequency control via HVDC links can both have control-like or disturbance-like impacts on frequency stability.

SOE 7.2 Mon 18:00 H18

From sample management to workflow integration: Semantic research data management in glaciology. — •Florian Spreckelsen[1], Daniel Hornung[1], and Johannes Freitag[2] — [1]IndiScale Gmbh, Göttingen — [2]Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven

Organizing data from a diversity of sources, from acquisition to publication, can be a tough challenge. We present implementations with the flexible open-source research data management toolkit CaosDB in the glaciology department at the Alfred Wegener Institute (AWI) in Bremerhaven. CaosDB is used in a diversity of fields such as turbulence physics, legal research, animal behavior and glaciology. CaosDB links research data, makes it findable and retrievable, and keeps data

consistent, even if the data model changes.

At AWI, CaosDB keeps track of ice core samples and to whom samples are loaned for analyses. It made possible additional features such as: A revision system to track all changes to the data and the sample state at the time of analysis. Automated gathering of information for the publication in FAIR-DO meta-data repositories, e.g. Pangaea. Tools for storing, displaying and querying geospatial information and graphical summaries of all analyses performed on each ice core. Automatic data extraction and refinement into data records in CaosDB to minimize manual users interaction. A state machine which guarantees certain workflows, simplifies development and can be extended to trigger additional actions upon transitions.

We demonstrate how CaosDB simplifies semantic data in science.

SOE 8: Invited Talk Theo Geisel: Human Synchronization in Music Performance

Time: Tuesday 9:30–10:15 Location: H11

Invited Talk SOE 8.1 Tue 9:30 H11

Musicians' Synchronization and the Enigma of Swing — •Theo Geisel — Max Planck Institute for Dynamics and Self-Organization & Bernstein Center for Computational Neuroscience Göttingen, Germany

It is a widespread opinion that musicians who are interacting together in a performance should perfectly synchronize their timing. This view was challenged for the swing feel, a salient feature of jazz, which has eluded scientific clarification for a century. For much of this period it was considered arcane, arguing that swing can be felt but not explained, until the theory of 'participatory discrepancies' raised the controversial claim that swing is caused by microtiming deviations between different participating musicians [1].

In several projects we have clarified the controversy on the central role of microtiming deviations for the swing feel using time series analysis and experiments with temporally manipulated MIDI-recordings, whose swing feel was measured through ratings of professional jazz musicians. We thereby showed that involuntary random microtiming deviations are irrelevant for swing, whereas a particular systematic microtiming deviation between musicians enhances the swing feel and is a key component of swing in jazz [2]. It consists in slightly delaying downbeats but not offbeats of soloists with respect to a rhythm section. This effect was unknown to professional jazz musicians, who are using it unconsciously but were unable to determine its nature.

[1] C. Keil, Cultural Anthropology 2, 275 (1987).
[2] C. Nelias et al., Commun. Phys., to be publ.

SOE 9: Physics of Contagion Processes

Time: Tuesday 10:15–11:15 Location: H11

SOE 9.1 Tue 10:15 H11

Emergence of synergistic and competitive pathogens in a coevolutionary spreading model — •Philipp Hövel[1], Alessio Cardillo[2], Kai Seegers[3], and Fakhteh Ghanbarnejad[4] — [1]University College Cork, Ireland — [2]Universitat Rovira i Virgili, Tarragona, Spain — [3]Technische Universität Berlin, Germany — [4]Sharif University of Technology, Iran

Cooperation and competition between pathogens can alter the amount of individuals affected by a coinfection giving rise to phenomena like comorbidity and cross-immunity. However, the evolution of the pathogens' behavior has been underexplored. We present a coevolutionary model where the simultaneous spreading is described by a two-pathogen susceptible-infected-recovered model in an either synergistic or competitive manner. At the end of each epidemic season, the pathogens species reproduce according to their fitness following a replicator equation. The fitness depends on the payoff accumulated during the spreading season in a hawk-and-dove game. We demonstrate that the proposed coevolutionary model displays a rich set of features and emergent behavior. For example, the evolution of the pathogens' strategy induces abrupt transitions in the epidemic prevalence. Furthermore, we observe that the long-term dynamics results in a single, surviving pathogen species, and that the cooperative behavior of pathogens can emerge even under unfavorable conditions.

SOE 9.2 Tue 10:45 H11

Assessing the effectiveness of COVID intervention measures in small communities using agent-based simulations — •Jana Lasser — Graz University of Technology, Graz, Austria — Complexity Science Hub Vienna, Vienna, Austria

The necessity of intervention measures like the wearing of masks, preventive testing and vaccinations to prevent the spread of COVID-19 have been vigorously in our societies. At the centre of these discussions is the effectiveness of these measures in suppressing large outbreaks. With our research, we contribute the necessary facts to the discussion by simulating the spread of COVID-19 using agent-based simulations that are calibrated to empirical outbreak data. Here we present three application cases of our simulations: (i) the development of a preventive testing strategy in nursing homes in a situation where no vaccinations are available yet, (ii) the assessment of the effectiveness of different combinations of measures in schools and (iii) an evaluation of the feasibility of preventing large outbreaks while requiring in-presence teaching in universities under the condition of community spreading of the Omicron variant.

SOE 9.3 Tue 11:00 H11

Epidemic processes on self-propelled particles — •Jorge P. Rodriguez[1], Matteo Paoluzzi[2], Demian Levis[2], and Michele Starnini[3] — [1]IMEDEA, CSIC-UIB, Esporles, Spain — [2]Departament de Física de la Matèria Condensada,Universitat de Barcelona, Barcelona, Spain — [3]ISI Foundation, Torino, Italy

Most spreading processes require spatial proximity between agents. The stationary state of spreading dynamics in a population of mobile agents thus depends on the interplay between the time and length scales involved in the epidemic process and their motion in space. We analyze the steady properties resulting from such interplay in a simple model describing epidemic spreading on self-propelled particles. The epidemic dynamics is described by a Susceptible-Infected-Susceptible model, while the movement of each particle is ruled by Run-and-Tumble motion. The interactions are given by the proximity between particles, with the particles' movement modifying the relative distances between themselves. We analyze this problem from a continuum description of the system, and validate those results by numerical simulations of an agent-based model. Focusing our attention on the diffusive long-time regime, we find that the agents' motion changes qualitatively the nature of the epidemic transition characterized by the emergence of a macroscopic fraction of infected agents. Indeed, the transition becomes of the mean-field type for agents diffusing in one, two and three dimensions, while, in the absence of motion, the epidemic outbreak depends on the dimension of the underlying static network determined by the agents' fixed locations.

SOE 10: Nonlinear Dynamics 1: Synchronization and Chaos (joint session DY/SOE)

Time: Tuesday 11:15–12:45 Location: H19

SOE 10.1 Tue 11:15 H19

Stable Poisson chimeras in networks of two subpopulations — •Seungjae Lee and Katharina Krischer — Technical University of Munich, Garching, Germany

In this talk, we introduce recent results on dynamical and spectral properties of chimeras in two-population network based on Kuramoto order parameter and Lyapunov stability analysis. In particular, we address two qualitatively different dynamics of incoherent oscillator populations according to the given initial conditions, and which led to the classification of Poisson and non-Poisson chimera states. We numerically calculate the Lyapunov exponents and covariant Lyapunov vectors to determine the spectral properties of the chimera states, and then expound the classification of the Lyapunov exponents. Our stability analysis also confirms that the chimera states of Kuramoto-Sakaguchi phase oscillators in two-population networks are neutrally stable in many directions. Furthermore, we demonstrate that two *perturbations* of the phase model that reflect more realistic situations render Poisson chimeras stable. These models consider a nonlocal intra-population network and Stuart-Landau planar oscillators with amplitude degrees of freedom, respectively. Both these 'perturbations' might be considered a heterogeneity of the phase model and give rise to an asymptotically attracting Poisson chimera in two-population networks.

SOE 10.2 Tue 11:30 H19

On rational reactions - and other ones - of overloaded magnetic gears — •Ingo Rehberg and Stefan Hartung — Universität Bayreuth

Experiments exploring the coupling of two rotating spherical magnets reveal a cogging-free coupling for two specific angles between the input and output rotation axes. The striking difference between these two phase-locked modes of operation is the reversed sense of rotation of the driven magnet. For other angles, the cogging leads to a more complex dynamical behaviour. The experimental results can be understood by a mathematical model based on pure dipole-dipole interaction, with the addition of adequate friction terms [1].

Like all magnetic couplings, the setup contains intrinsic overload protection. The dynamic answer of the gear with cogging to an overload shows a plethora of modes of the driven magnet.

[1] Dynamics of a magnetic gear with two cogging-free operation modes, Stefan Hartung & Ingo Rehberg, Archive of Applied Mechanics 91, 1423-1435 (2021).

SOE 10.3 Tue 11:45 H19

Heteroclinic units acting as pacemakers: Entrained dynamics for cognitive processes — •Bhumika Thakur and Hildegard Meyer-Ortmanns — School of Science, Jacobs University Bremen, Campus Ring 1, 28759 Bremen, Germany

Heteroclinic dynamics is a suitable framework for describing transient and reproducible dynamics such as cognitive processes in the brain. We demonstrate how heteroclinic units can act as pacemakers to entrain larger sets of units from a resting state to hierarchical heteroclinic motion that is able to describe fast oscillations modulated by slow oscillations, features which are observed in brain dynamics. The entrainment range depends on the type of coupling, the spatial location of the pacemaker and the individual bifurcation parameters of the pacemaker and the driven units. Noise as well as a small back-coupling to the pacemaker facilitate synchronization. Units can be synchronously entrained to different temporal patterns, depending on the selected path in the hierarchical heteroclinic network. These locally generated temporal sequences of information items can be transferred over a spatial grid by entrainment to the pacemaker dynamics. Such spatiotemporal patterns are believed to code information in brain dynamics. Depending on the number and location of pacemakers on two-dimensional grids, synchronization can be maintained in the presence of a large number of resting state units and mediated via target waves when the pacemakers are concentrated to a small area of such grids. In view of brain dynamics, our results indicate a possibly ample repertoire for coding information in temporal patterns.

SOE 10.4 Tue 12:00 H19

Suppression of quasiperiodicity in circle maps with quenched disorder — •David Müller-Bender[1], Johann Luca Kastner[1], and Günter Radons[1,2] — [1]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]Institute of Mechatronics, 09126 Chemnitz, Germany

We show that introducing quenched disorder into a circle map leads to the suppression of quasiperiodic behavior in the limit of large system sizes. Specifically, for most parameters the fraction of disorder realizations showing quasiperiodicity decreases with the system size and eventually vanishes in the limit of infinite size, where almost all realizations show mode-locking. Consequently, in this limit, and in strong contrast to standard circle maps, almost the whole parameter space corresponding to invertible dynamics consists of Arnold tongues.

Details can be found in the preprint D. Müller-Bender, J. L. Kastner, and G. Radons, Suppression of quasiperiodicity in circle maps with quenched disorder, arXiv:2204.09392 [nlin.cd] (2022).

SOE 10.5 Tue 12:15 H19

Reservoir Computing and Nonlinear Dynamics — •Ulrich Parlitz — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — Institute for the Dynamics of Complex Systems, Georg-August-Universität Göttingen, Göttingen, Germany

We discuss the interrelation between reservoir computing (RC) and nonlinear dynamics (NLD). On the one hand, the performance of RC can be characterized and improved by concepts from NLD such as generalized synchronization and delay embedding. On the other hand, RC can be used to predict and control dynamical systems, including hybrid architectures that employ physically informed machine learning. Various aspects of this mutual relationship between RC and NLD are illustrated using low-dimensional and spatially extended chaotic dynamical systems.

SOE 10.6 Tue 12:30 H19

Chameleon attractors in deterministic and stochastic Lorenz-63 systems — •Reik V. Donner[1,2], Tommaso Alberti[3], and Davide Faranda[4] — [1]Hochschule Magdeburg-Stendal, Magdeburg, Germany — [2]Potsdam Institute for Climate Impact Research, Potsdam, Germany — [3]National Institute for Astrophysics, Rome, Italy — [4]LSCE, Université Paris-Saclay, Gif-sur-Yvette, France

The dynamical chaacteristics of a trajectory on a chaotic or stochastic attractor undergo marked changes when successively eliminating the low-frequency variability components and focusing on the fast fluctuations only, motivating the new concept of Chameleon attractors. Here, we study the time scale dependent instantaneous and average fractal characteristics of partial sums of dynamical modes identified by means of empirical mode decomposition for the Lorenz-63 system and two stochastic versions thereof with additive and multiplicative noise as obtained by exploiting recurrences in phase space using extreme value theory. While the average fractal dimensions converge to the expected values as more and more low-frequency modes are included, we find an excess dimension larger than 3 for higher frequency modes below the Lyapunov time scale resulting from the stochastic components.

SOE 11: Invited Talk Dirk Brockmann: Big Data in Epidemic Dynamics (joint session SOE/DY)

Time: Wednesday 9:30–10:15 Location: H11

Invited Talk SOE 11.1 Wed 9:30 H11

The Corona Data Donation Project - When Citizens Collaborate to Fight a Pandemic — •Dirk Brockmann — Humboldt University of Berlin, Berlin, Germany

In response to the COVID-19 pandemic we launched the Corona Data Donation Project in April 2020. In this citizen science project participants donate physiological data on heart rate, sleep and physical activity measured by smart watches, fitness trackers and wearable devices on a daily bases. With more than 500,000 donors the project is the largest data donation project worldwide. Initially conceived as a tool for real-time syndromic surveillance of the Covid-19 pandemic and as a monitoring tool, it has evolved into a large scale experimental and exploratory technological framework that continues to reveal a number of fascinating insights concerning Covid-19 related topic such has Long-Covid, the effects of vaccination, sleeping patterns but also insights with broader applications. The project now hosts physiological time-series that span over two years of over 200,000 individuals. I will discuss the promises and discoveries of citizen science and wearable devices from the perspective of digital epidemiology and illustrate what role "physics"-thinking plays in projects like this.

SOE 12: Networks: From Topology to Dynamics (joint session SOE/BP/DY)

Time: Wednesday 10:15–12:45 Location: H11

SOE 12.1 Wed 10:15 H11

Modeling tumor disease and sepsis by networks of adaptively coupled phase oscillators — •Eckehard Schöll[1,2,3], Jakub Sawicki[2], Rico Berner[1,4], and Thomas Löser[5] — [1]Institut für Theoretische Physik, TU Berlin, Germany — [2]Potsdam Institute for Climate Impact Research — [3]Bernstein Center for Computational Neuroscience Berlin — [4]Institut für Physik, HU Berlin — [5]Institut LOESER, Wettiner Straße 6, 04105 Leipzig

In this study, we provide a dynamical systems perspective to the modelling of pathological states induced by tumors or infection. A unified disease model is established using the innate immune system as the reference point. We propose a two-layer network model for carcinogenesis and sepsis based upon the interaction of parenchymal cells (organ tissue) and immune cells via cytokines, and the co-evolutionary dynamics of parenchymal, immune cells, and cytokines [1]. Our aim is to show that the complex cellular cooperation between parenchyma and stroma (immune layer) in the physiological and pathological case can be functionally described by a simple paradigmatic model of phase oscillators. By this, we explain carcinogenesis, tumor progression, and sepsis by destabilization of the healthy state (frequency synchronized), and emergence of a pathological state (multifrequency cluster). The coupled dynamics of parenchymal cells (metabolism) and nonspecific immune cells (reaction of innate immune system) are represented by nodes of a duplex layer. The cytokine interaction is modeled by adaptive coupling weights. [1] Sawicki, J., Berner, R., Löser, T., and Schöll, E., Frontiers Netw. Physiology 1,730385 (2022), arXiv:2106.13325v2.

SOE 12.2 Wed 10:45 H11

Analysis of the Football Transfer Market Network — •Tobias Wand — WWU Münster — CeNoS Münster

Football clubs buy and sell players for millions of Euros and until Covid, their combined transfer values were growing steadily at an impressive rate. Instead of analysing their aggregated transfer activities, one can take a look at the topology of the network of player transfers: complex networks have already been used in various sciences [1] including research on sports [2] and provide a novel approach to investigate the football transfer market network and in particular the impact of Covid on football clubs.

[1] G. Caldarelli and A. Vespignani, "Large Scale Structure and Dynamics of Complex Networks". World Scientific Publishing, 2007.

[2] Arriaza-Ardiles et al. "Applying graphs and complex networks to football metric interpretation". Human Movement Science 57, 2018.

SOE 12.3 Wed 11:00 H11

Variability in mesoscale structure inference using stochastic blockmodels — •Lena Mangold and Camille Roth — CNRS (Paris) / Centre Marc Bloch (Berlin)

Characterising the mesoscale structure of networks, in terms of patterns variously called communities, blocks, or clusters, has represented both a central issue and a key instrument in the study of complex systems. Clearly, distinct methods designed to detect different types of patterns may provide a variety of answers to the mesoscale structure. Yet, even multiple runs of a given method can sometimes yield diverse and conflicting results, posing challenges of model and partition selection. As an alternative to forcing a global consensus from a distribution of partitions (i.e. choosing one among many by maximising some objective), recent work has emphasised the importance of exploring the variability of partitions. Here we examine how a specific type of mesoscale structure (e.g. assortative communities or core-periphery) may be linked with more or less inconsistency in resulting partitions. We focus on Stochastic blockmodels (SBMs), initially proposed in mathematical sociology and increasingly used to infer mesoscale structure with a relatively general definition of similarity between nodes in the same group, and whose stochastic nature lends itself to the exploration of disagreement within populations of partitions. In particular, we generate families of synthetic networks in which we plant different types of mesoscale structures and explore the transitions between consensus and dissensus in the landscape of partitions over multiple SBM runs.

SOE 12.4 Wed 11:15 H11

Extracting signed relations from interaction data — •Georges Andres, Giona Casiraghi, Giacomo Vaccario, and Frank Schweitzer — ETH Zürich, Chair of Systems Design, Switzerland

Social relations influence human interactions and hence, help to explain individual behaviours. Moreover, humans perceive patterns of signed relations, either positive (e.g., friendship) or negative (e.g., enmity), and adapt to them. Data about signed relations are rare, despite their importance for understanding phenomena at the community level. Interaction data is, however, more abundantly available, for example, about proximity or communication events. Interactions and relations change on different time scales; interactions are more volatile and evolve faster than relations. Using this, I will present an ensemble-based approach to infer pair-wise signed relations from interaction data and consequently construct a signed network from them. By studying different datasets on interactions and relations, e.g. between students, I will further evaluate the quality of the inferred networks. Subsequently, I will study the presence of structural balance in the studied communities, describing the cognitive dissonance ensuing from particular triadic constellations of signed relations. Bearing similarities to frustrations in spin systems, structural balance can now be analysed solely from interaction data thanks to the presented method, a task which was previously out of reach.

SOE 12.5 Wed 11:45 H11

Disentangling homophily, community structure and triadic closure in networks — •Tiago Peixoto — Central European University, Vienna, Austria

Network homophily, the tendency of similar nodes to be connected, and transitivity, the tendency of two nodes being connected if they share a common neighbor, are conflated properties in network analysis, since one mechanism can drive the other. Here we present a generative model and corresponding inference procedure that is capable of distinguishing between both mechanisms. Our approach is based on a variation of the stochastic block model (SBM) with the addition of a triadic closure dynamics, and its inference can identify the most plausible mechanism responsible for the existence of every edge in

the network, in addition to the underlying community structure itself, based only on the final observation of the network. We show how the method can evade the detection of spurious communities caused solely by the formation of triangles in the network, and how it can improve the performance of link prediction when compared to the pure version of the SBM without triadic closure.

[1] Tiago P. Peixoto, Disentangling homophily, community structure and triadic closure in networks, Phys. Rev. X 12, 011004 (2022)

SOE 12.6 Wed 12:15 H11

Evolving networks towards complexity: an evolutionary optimization approach — Archan Mukhopadhyay and •Jens Christian Claussen — University of Birmingham, UK

Complexity measures for graphs have been proposed and compared [1,2] widely, but the question how to mathematically define complexity is less clear as for text strings where Lempel-Ziv and Kolmogorov complexity provide clear approaches. In complexity science, the notion of complexity implies distinction from regular structures (lattices) as well as from random structures (here: random graphs). This however has not lead to any constructive definition. Complexity measures therefore typically assess artefacts of complexity (in some cases quite successfully). Here we present a complementary computational approach: we utilize each complexity measure as a fitness function of an evolutionary algorithm, and investigate the properties of the resulting networks. The goal is a better understanding of the existing complexity measures, and to shed some light on (artificial) network evolution: what evolutionary goals lead to complexity?

SOE 13: Energy Networks (joint session SOE/DY)

Time: Wednesday 12:45–13:15 Location: H11

SOE 13.1 Wed 12:45 H11

Revealing drivers and risks for power grid frequency stability with explainable AI — •Benjamin Schäfer[1], Johannes Kruse[2,3], and Dirk Witthaut[2,3] — [1]Institute for Automation and Applied Informatics, Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany — [2]Forschungszentrum Jülich, Institute for Energy and Climate Research-Systems Analysis and Technology Evaluation (IEK-STE), Jülich, Germany — [3]Institute for Theoretical Physics, University of Cologne, Köln, Germany

The transition to a sustainable energy system is challenging for the operation and stability of electric power systems as power generation becomes increasingly uncertain, grid loads increase, and their dynamical properties fundamentally change. At the same time, operational data are available at an unprecedented level of detail, enabling new methods of monitoring and control. To fully harness these data, advanced methods from machine learning must be used.

Here, we present explainable artificial intelligence (XAI) as a tool to quantify, predict, and explain essential aspects of power system operation and stability in three major European synchronous areas. We focus on the power grid frequency, which measures the balance of generation and load and thus provides the central observable for control and balancing. Combining XAI with domain knowledge, we identify the main drivers and stability risks, while our model and open dataset may enable further XAI research on power systems.

SOE 13.2 Wed 13:00 H11

Cascading Failures and Critical Infrastructures in Future Renewable Power Systems — Franz Kaiser[1,2], Johannes Kruse[1,2], •Philipp C. Böttcher[1], Martha Maria Frysztacki[3], Tom Brown[3,4], and Dirk Witthaut[1,2] — [1]IEK-STE Forschungszentrum Jülich, Jülich, Germany — [2]THP Uni Köln, Köln, Germany — [3]KIT-IAI, Karlsruhe, Germany — [4]Institut für Energietechnik TU Berlin, Berlin, Germany

The world's power systems are undergoing a rapid transformation, shifting away from carbon-intensive power generation to renewable power sources. As a result, there is a growing importance of long-distance power transmission, while the intrinsic system inertia provided by thermal power plants decreases. This poses several challenges to the system such as accelerated dynamics and thus a higher control effort for transmission system operators. These developments make power grids more vulnerable to cascading failures, which may result in a splitting of the grid and eventually in a large-scale blackout. While large blackouts are rare but devastating events, several smaller splits were observed in recent years.

In this work, we use the state of the art open energy system model PyPSA to generate future energy systems and assess the risk of cascading failures and systems splits in the European power grid for different carbon reduction targets. We determine the likelihood of dangerous splits and discuss mitigation strategies.

SOE 14: Computational Social Science

Time: Wednesday 15:00–16:45 Location: H11

SOE 14.1 Wed 15:00 H11

Issue bundles: Understanding ideological patterns of polarization in political spaces. — •Eckehard Olbrich[1] and Sven Banisch[2] — [1]Max Planck Institut for Matematics in the Sciences, Leipzig, Germany — [2]Institute of Technology Futures, Karlsruhe Institute of Technology, Germany

Many scholars of politics discuss the rise of the new populism in Western Europe and the US with respect to a new political cleavage related to globalization. In this contribution we empirically address this reconfiguration of the political space by comparing political spaces for Germany built using topic modeling with the spaces based on the content analysis of the Manifesto project and the corresponding categories of political goals. We find that both spaces have a similar structure and that the right-wing populist AfD appears on a new dimension. In order to characterize this new dimension we employ a novel technique to identify clusters of political goals, issue bundles, by maximizing the coherence of inter-issue consistency networks (IICN). These issue bundles allow to analyze the evolution of the correlations between the political positions on different issues over several elections. We find that the new dimension introduced by the AfD can be related to the split off of a new "culturally right" issue bundle from the previously existing center-right bundle.

E. Olbrich, and S. Banisch, The rise of populism and the reconfiguration of the German political space, Frontiers in Big Data 4, 731349 (2021).

SOE 14.2 Wed 15:30 H11

Quantifying the social dimension of citation behavior — •Frank Schweitzer — Chair of Systems Design, ETH Zürich, Switzerland

Collaboration networks of scientists are a prime example of complex social systems. We study co-authorship networks to quantify the impact of social constituents, e.g. of previous co-authors, joint publications, on the success of publications as measured by their number of citations. This requires to solve different problems which are addressed in the talk: (i) to model growing networks with two coupled layers, the network of authors and the network of publications, (ii) to generate and test different hypotheses about the coupling between these two layers, (iii) to estimate parameters and compare models with different complexity. But it is worth the effort: After all, producing academic publications is a social endeavour, and our results shed more light on social feedback mechanisms and successful career paths of authors.

[1] V. Nanumyan, C. Gote, F. Schweitzer: Multilayer network approach to modeling authorship influence on citation dynamics in physics journals, Physical Review E 102, 032303 (2020)

[2] C. Zingg, V. Nanumyan, F. Schweitzer: Citations Driven by Social Connections? A Multi-Layer Representation of Coauthorship Net-

works, Quantitative Science Studies 1, 1493-1509 (2020)

SOE 14.3 Wed 16:00 H11

Idea engines: Innovation & obsolescence in markets, genetic evolution, science — •Edward Lee[1], Christopher Kempes[2], and Geoffrey West[2] — [1]Complexity Science Hub Vienna, Vienna, Austria — [2]Santa Fe Institute, Santa Fe, USA

Innovation and obsolescence describe dynamics of ever-churning and adapting systems from the development of economic markets and scientific progress to biological evolution. The shared aspect is that agents destroy and extend the "idea lattice" in which they live, finding new possibilities and rendering old solutions irrelevant. We focus on this aspect with a simple model to study the central relationship between the rates at which replicating agents discover new ideas and at which old ideas are rendered obsolete. When the rates match, the space of the possible (e.g. ideas, markets, technologies, mutations) is static. A positive or negative difference distinguishes flourishing, ever-expanding idea lattices from Schumpeterian dystopias in which the system collapses. We map the phase space in terms of rates at which agents enter, replicate, and die. With higher dimensions, cooperative agents, or obsolescence-driven innovation, we find that the essential features of the model are preserved. In all cases, we predict a density profile of agents that drops close to new and old frontiers. With data, we reveal that the density signals a follow-the-leader dynamic in firm cost efficiency and biological evolution, whereas scientific progress reflects consensus that waits on old ideas to go obsolete. We show how the fundamental forces of innovation and obsolescence provide a unifying perspective on complex systems.

SOE 14.4 Wed 16:15 H11

Loss of sustainability in scientific work — •Niklas Reisz[1], Vito Domenico Pietro Servedio[1], Vittorio Loreto[1,2,3], William Schueller[2], Márcia Ferreira[1], and Stefan Thurner[1,4,5] — [1]Complexity Science Hub Vienna, Vienna, Austria — [2]Sony Computer Science Lab, Paris, France — [3]Sapienza University, Rome, Italy — [4]Medical University of Vienna, Vienna, Austria — [5]Santa Fe Institute, Santa Fe, USA

For decades the number of scientific publications has been rapidly increasing, effectively out-dating knowledge at a tremendous rate. Only few scientific milestones remain relevant and continuously attract citations. Here we quantify how long scientific work remains being utilized, how long it takes before today's work is forgotten, and how milestone papers differ from those forgotten. To answer these questions, we study the complete temporal citation network of all APS journals. We quantify the probability of attracting citations for individual publications. We capture both aspects, the forgetting and the tendency to cite already popular works, in a microscopic generative model. We find that the probability of citing a specific paper declines with age as a power law with an exponent of a=-1.4. Whenever a paper in its early years can be characterized by a scaling exponent above a critical value, ac, the paper is likely to become "ever-lasting". We validate the model with out-of-sample predictions. The model also allows us to predict that 95% of papers cited in 2050 have yet to be published. Our findings suggest a worrying tendency toward information overload and raises concerns about scientific publishing's long-term sustainability.

SOE 14.5 Wed 16:30 H11

On the empirical distribution functions of examination performance in beginning semesters in mathematics and physics — •Magda Schiegl — University of Applied Sciences Landshut, Am Lurzenhof 1, D-84036 Landshut

With increasing heterogeneity of student groups, the measurement and interpretation of individual study performance becomes more and more important, both in terms of classification in group performance and under developmental aspects. We investigate the empirical distribution of study performance in the 1st and 2nd semesters of industrial engineering over several years. The basis of the study is the exam performance of large groups (approx. 100 students and more per year). We compare the subjects mathematics and physics. Characteristics of the empirical CDFs of the respective cohorts (year groups) are examined. The results are compared,summarised and interpreted.

SOE 15: Traffic Dynamics, Urban and Regional Systems

Time: Wednesday 17:00–18:15 Location: H11

SOE 15.1 Wed 17:00 H11

Gravity Model in Estimating Park Visitation Pre and during COVID-19 Pandemic — Zahra Ghadiri[1], Afra Mashhadi[2], and •Fakhteh Ghanbarnejad[1,3] — [1]Department of Physics, Sharif University of Technology, Tehran, Iran — [2]Computing and Software Systems, University of Washington, Bothell, WA, USA — [3]Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), Technical University of Dresden, 01062 Dresden, Germany

The COVID-19 pandemic and the resulting economic recession have negatively affected many people's social, and psychological health. Parks may have ameliorated the negative effects of the pandemic by creating opportunities for outdoor recreation. At the same time, other public activities were restricted due to the risk of disease transmissions. In our study, we seek to improve our understanding of how the COVID-19 pandemic impacts park visitations by performing a longitudinal study based on the aggregated telecommunication data. To do so, we introduce a novel approach based on the Gravity Model to understand, quantify and model the relationship between distance and the visitation patterns. Particularly, we aim to find out how the park visitation behavior changes post-pandemic and how this change of visitation varies for different socio-economic groups of visitors. Our results show that the park visitation pattern in Washington state (U.S.A) obeys the gravity law. Moreover, we show that, although parameters of the model may vary, the gravity model can still accurately estimate the visitation after applying socio-economic and spatial filters.

SOE 15.2 Wed 17:30 H11

Bimodal transport: Making door-to-door transport sustainable and convenient — •Puneet Sharma[1,2], Helge Heuer[1], Steffen Muehle[1], Stephan Herminghaus[1,2], and Knut Heidemann[1] — [1]Max Planck Institute for Dynamics and Self Organization, Goettingen — [2]Georg-August-Universität Göttingen

Decarbonization of passenger transport is essential for fighting climate emergency. While modern cities offer various modes of transportation, considered separately, none of them is both, sustainable and convenient. A taxi service is convenient, in a sense, due to door-to-door service, but is inefficient since it usually serves one customer only. Demand-responsive ridepooling (DRRP) with minibuses is more efficient, but leads to undue competition with line services (LS), which provide even better pooling but are less convenient due to fixed routes and stops. A combination of both modes, DRRP and LS, may provide an ideal solution but is challenging to organize. Here we introduce a model for such bimodal on-demand transportation based on a square-grid geometry. Our model quantifies under what circumstances bimodal public transportation is feasible, both in terms of convenience and ecological footprint. Moreover, the model yields estimates for how to operate (LS frequency, modal split) a bimodal transportation system optimally. Perhaps surprisingly, we find that operating LS at maximum capacity is not necessarily optimal. We also consider the intricate interplay between LS operations and DRRP performance, i.e., detours, waiting times, and occupancy, via simulations.

SOE 15.3 Wed 17:45 H11

Urban road networks: Geometric characteristics and generative models — •Reik Donner — Hochschule Magdeburg-Stendal, Magdeburg, Germany — Potsdam Institute for Climate Impact Research, Potsdam, Germany

Urban road networks provide the spatial backbone of the development of cities. As planar networks, they possess characteristic size, shape and orientation distributions of their basic constituting elements (road segments and cellular structures). Comparisons with simple benchmark planar graph models show that the latter commonly fail to mimic those characteristic features of the real-world networks, including heavy-tailed object size distributions, specific shapes of node and cell degree distributions, and the predominant orthogonality of street patterns. In order to account for these discrepancies, I introduce a hi-

erarchy of planar network models combining the successive evolution of the network with a perpendicular splitting of road segments controlled by a spatial potential function. The resulting model networks can be used as benchmarks for generating *surrogate cities* for further testing dynamical models of urban traffic.

SOE 16: Members' Assembly

Annual General Assembly of SOE (all participants of SOE sessions are welcome). Agenda: 1. Report on Activities, 2. Announcements, 3. Elections, 4. Miscellaneous.

Time: Wednesday 18:15–19:30 Location: H11

All members of the Physics of Socio-economic Systems Division are invited to participate.

SOE 17: Poster

Time: Thursday 15:00–18:00 Location: P2

SOE 17.1 Thu 15:00 P2

CaosDB – a scientific research data management toolkit — •Florian Spreckelsen[1], Daniel Hornung[1], and Johannes Freitag[2] — [1]IndiScale Gmbh, Göttingen — [2]Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven

Processing interconnected, multi-modal data poses a challenge in many fields, especially when the data model, i.e. the way how data is organized, changes over time or when its structure is poorly documented. The open-source software **CaosDB** is a toolkit for research data management which was originally developed at the Max Planck Institute for Dynamics and Self-Organization (Göttingen) because existing software could not fulfill the needs of the scientists.

We present examples where CaosDB helped make data FAIR (Findable, Accessible, Interoperable, Retrievable) and how it can simplify the workflows for researchers: Automated data collection and integration, export to data repositories, API libraries for third-party programs, integrated revisioning and workflow state machines. If the data model needs to change, existing data can remain as-is and future search queries will return matching results containing "old" and "new" data. We demonstrate how raw and processed data, analysis settings and results, and even labnotebooks and publications can be linked against each other, to improve long-term usability of data and reproducibility of results.

We show how CaosDB can make semantic data AI ready in science.

SOE 17.2 Thu 15:00 P2

contagion dynamics of self-proppeled particles in porous media — Ehsan Irani[1], Abbas Shojakani[2], Mohaddese Sadat Asgari[2], and •Fakhteh Ghanbarnejad[2,3] — [1]Max Delbrück Center for Molecular Medicine in the Helmholtz Association (MDC), The Berlin Institute for Medical Systems Biology (BIMSB), 10115 Berlin, Germany — [2]Department of Physics, Sharif University of Technology, Tehran, Iran — [3]Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), Technical University of Dresden, 01062 Dresden, Germany

We investigate the effect of heterogeneous environment on the spread of disease in systems of active agents. Here we couple susceptible-infected-recovered (S-I-R) contagion dynamics to a system of self-propelled active particles with polar alignment, in the presence of randomly distributed obstacles. The heterogeneity of the environment is controlled by the density of obstacles. The temporal-spatial dynamics of the system is determined by the alignment strength and Peclet number as well as the density of the obstacles. We analyze how the heterogeneity of the environment results in rich set of spatial structures which significantly affect the epidemic dynamics of the disease. We further show that increasing the heterogeneity of the environment could change the outbreaks statistics in a non-monotonic way.

SOE 17.3 Thu 15:00 P2

Modelling discussion dynamics across Reddit communities — •Riccardo Carlucci and João Pinheiro Neto — Max Planck Institute for Dynamics and Self-Organization, Am Faßberg 17, 37077 Göttingen, Germany

Understanding the dynamics of online discussions is an important research challenge, not only in its own right but also in relation to e.g. the study of political polarization. With more than 20 million contributing monthly users, Reddit is one of the largest and most influential social media platforms in the world. Here we analyse the distribution of the number of comments-per-discussion within the largest 500 Reddit communities from an almost fully-sampled dataset, focusing on content created between 2019 and 2021. We find that about 60% of these communities exhibit a distribution which is well-approximated by a power-law with an upper exponential cut-off. However, the width and the exponent of the power-law regime are specific to each particular community. In order to explain this variability we develop a preferential attachment model where the ability of a discussion to attract comments is affected by its age and also by an intrinsic fitness value. After estimating aging and fitness from data, we find that the model is able to reproduce both non-power-law and power-law behaviour. In particular, the width and the exponent of the power-law regime are correlated with the average number of comments and discussion created per day in a community.

SOE 17.4 Thu 15:00 P2

Population dynamics and Nash equilibria in optimizing complexity measures — •Archan Mukhopadhyay and Jens Christian Claussen — University of Birmingham, UK

Do natural networks evolve towards complexity? In a related project (Mukhopadhyay and Claussen, to be submitted) we utilize graph complexity measures as fitness function for an evolutionary algorithm. This effectively leads to an evolutionary dynamics between complexity measures as "species" or "strategies". Here we rephrase each complexity measure value from the numerical simulations (when optimizing towards annother complexity measure as co-evolutionary fitness value of one species within a population where annother species is highly abundant). We analyze the resulting payoff matrix with respect to their Nash equilibria and evolutionarily stable strategies, if interpreted within the context of evolutionary game theory.

SOE 17.5 Thu 15:00 P2

Die Nützlichkeit der mathematischen Begriffstheorie von E.K. Wojschwillo zur Kulturwissenschaft und Gender-Studies — •Marina Zakharchuk — Moskau, Russland

In der mathematischen Logik gibt es eine Begriffstheorie von E.K. Vojschvillo, die heute von D.V. Zaitsev und A.A. Iljin entwickelt wird, die, die Begriffen als Mengen analysiert. Dieses Begriffsverständnis kann mit einem Venn-Diagramm dargestellt werden. Diese Theorie kann man auch in der Kunstforschung benutzen. Wir zeigen, wie das beschriebene Schema konkret zur Klassifizierung von Drag-Künstlern angewendet werden kann. Als Parameter nehmen wir das biologische Geschlecht einer Person und das Geschlecht ihrer Spielfigur. Wir unterteilen jeden der Parameter dichtomisch: biologisch ein Mann, biologisch kein Mann; Spielfigur ist ein Mann, Spielfigur ist kein Mann. Dieses Schema umfasst Bioqueen, Bioking, Drag Queen, Drag King sowie Künstler, die sich keiner dieser Klassen zuordnen. Darüber hinaus kann das Schema erweitert werden, indem eine Unterteilung nach der Modifikation der Grundlage eingeführt wird, wobei die Geschlechtsidentität des Künstlers als Grundlage genommen wird. Zum Beispiel: biologisch männlich -> Spielfigur ist nicht männlich -> Transgender. Diese Klassifikation ist innovativ und fortschrittlich im Bereich der Kulturwissenschaft und Gender-Studies; es ist übersichtlich und macht es einfacher zu definieren, wer welcher Drag-Künstler ist.

SOE 17.6 Thu 15:00 P2

Organisation der soziotechnischen Systeme mit dem industriellen Internet der Dinge (IIOT) — •Dmitrii Abushek — Moscow, Russia

Das Verwenden der Konzepte von Internet der Dinge kann helfen Kosten für Produktion und Entsorgung senken. Zum Beispiel, die Lösungen des Russischen Unternehmens "Strizh" als ein von mehreren. Auf Basis dieser Technologie können wir intelligente Gas-, Wasser- und Stromzähler erstellen. Die Erfassung und Analyse von Ressourcenverbrauchsdaten hilft uns, sie besser zu verwalten und Unfälle und Lecks zu erkennen. Die Grundlage der Plattform "Strizh" modifiziert die LP-WAN Technologie. Dank der Energieeinsparung kann die Heizung der Wohnhäuser billiger werden, besonders in Systemen, in denen grüne Energie verwendet wird. Die Strizh-Plattform besteht aus Sensoren, Daten, und Auswertungsprogrammen unter XNB Protocol mit DB-PSK Modulation. Sie kommunizieren miteinander und helfen Lösungen der unvermeidlichen zu machen. Die Einführung von IIOT bei Volvo ist zudem interessant. Das System von Volvo ermöglicht die Kommunikation zwischen Wagen, Volvo-Ingenieure, und Reparaturwerkstatt. Das ist möglich dank IIOT. Es verbessert die Qualität von Kundenservice. Aufgrund des kommerziellen Erfolges von IIOT kann man sagen dass diese Technologie eine große Zukunft hat.

SOE 18: Invited Talk Kathy Lüdge (joint session DY/SOE)

Time: Friday 9:30–10:00 Location: H19

Invited Talk SOE 18.1 Fri 9:30 H19

Photonic Reservoir Computing: Analytic insights and possibilities for optimization — Lina Jaurigue[1], Felix Köster[2], and •Kathy Lüdge[1] — [1]Institute of Physics, Technische Univ. Ilmenau, Weimarer Str. 25, 98684 Ilmenau — [2]Institute of Theoretical Physics, Technische Univ. Berlin, Hardenbergstr. 36, 10623 Berlin

Reservoir computing has gained a lot of attention because its relatively simple setup that can be easily implemented in hardware, specifically with optical devices. Using one nonlinear node, i.e., a laser with an optical feedback loop and time-multiplexed input, already allows to solve complex time-series prediction tasks after a proper training via linear regression. Nevertheless, the performance depends on properly adjusted timescales and not every physical system is suitable for a given task [1].

We present ways to improve the computing performance of delay-based photonic reservoir computing systems using delay-time tuning, and we discuss to what extent delay-coupled laser-networks with more than one optical element can be beneficial to improve the overall performance. Furthermore, we discuss analytic insights into the information processing capacity of a reservoir computing system and its correlation to the linear system response of the reservoir as well as to the series expansion of a chosen task.

[1] T. Hülser, F. Köster, L. C. Jaurigue, and K. Lüdge, Opt. Mater. Express 12, 1214 (2022).

SOE 19: Machine Learning in Dynamics and Statistical Physics (joint session DY/SOE)

Time: Friday 10:00–11:15 Location: H19

SOE 19.1 Fri 10:00 H19

Reinforcement learning of optimal active particle navigation — •Mahdi Nasiri and Benno Liebchen — Institut für Physik kondensierter Materie, Technische Universität Darmstadt, Hochschulstraße 8, D-64289 Darmstadt, Germany

In sufficiently complex environments, there is no simple way to determine the fastest route of an active particle that can freely steer towards a given target. In fact, while classical path planning algorithms (e.g. A*, Dijkstra) tend to fail to reach the global optimum, analytical approaches are incapable of handling generic complex environments. To overcome this gap in the literature, in the present work, we develop a policy gradient-based deep reinforcement learning method that employs a hybrid continuum-based representation of the environment and allows, for the first time, to determine the asymptotically optimal path in complex environments. Our results provide a key step forward towards a universal path planner for future intelligent active particles and nanorobots with potential applications in microsurgery as well as in drug and gene delivery.

SOE 19.2 Fri 10:15 H19

Deep reinforcement learning for chemotactic active particles — •Edwin Loran, Mahdi Nasiri, and Benno Liebchen — Institute of Condensed Matter Physics, Technische Universität Darmstadt, D-64289 Darmstadt, Germany

Throughout evolution, microorganisms have developed efficient strategies for locating nutrients and avoiding toxins in complex environments. Understanding their adaptive policies can provide new key insights for the development of smart artificial active particles. Here, we use a machine learning approach, namely deep reinforcement learning, to develop smart foraging strategies for chemotactic active particles which consume nutrients for their survival. Our method is able to devise efficient chemotactic navigation strategies guaranteeing "survival" inside unknown and complex landscapes while only having access to local sensory data. Our approach is based on deep Q-learning and uses the particle's observation of its surrounding chemical (nutrient) concentration as the input. The presented method highlights the extent of the capabilities of reinforcement learning approaches in mimicking (and going beyond) the evolutionary strategies learned by microorganisms.

SOE 19.3 Fri 10:30 H19

Machine Learning the 2D percolation transition — •Djénabou Bayo[1,2], Andreas Honecker[2], and Rudolf A. Römer[1] — [1]Departement of Physics, University of Warwick, Coventry, CV47AL, United Kingdom — [2]Laboratoire de Physique Théorique et Modélisation (LPTM) (CNRS UMR8089), CY Cergy Paris Université, 95302 Cergy-Pontoise, France

The percolation model is one of the simplest models in statistical physics displaying a phase transition. A classical lattice is occupied randomly with a given probability at each site (or bond). A phase transition from a non-percolating to a percolating state appears around the so-called percolation threshold. Machine Learning (ML) and Deep Learning (DL) techniques are still relatively new methods when applied to physics. Recent work shows that ML/DL techniques seemingly detect the percolation transition from images of percolation clusters. We employ such supervised learning techniques, i.e., classification and regression for 2D site percolation. We find that the identification of spanning clusters provided by such methods does not fully correlate with their existence. Rather, the identification seems to rely on proxy measures such as the site occupation density. Furthermore, constructing challenging cluster distributions show scope for much misclassification when using even highly trained DL networks. Unsupervised ML strategies, such as variational autoencoders, might be able to reconstruct percolation clusters with acceptable spatial resolution, but in many cases struggle to reproduce the geometry of spanning clusters faithfully. Our work uses Python and the ML/DL libraries of PyTorch.

SOE 19.4 Fri 10:45 H19

Exploring structure-property maps with kernel principal covariates regression — •Guillaume Fraux, Benjamin Helfrecht, Rose Cersonsky, and Michele Ceriotti — Institute of Materials, EPFL, Lausanne, Switzerland

Data analyses based on linear methods constitute the simplest, most robust, and transparent approaches to the automatic processing of large amounts of data for building supervised or unsupervised machine learning models. Principal covariates regression (PCovR) is an underappreciated method that interpolates between principal component analysis and linear regression and can be used conveniently to reveal structure-property relations in terms of simple-to-interpret,

low-dimensional maps. We introduce a kernel version of PCovR (KPCovR), and demonstrate the performance of this approach in revealing and predicting structure-property relations in chemistry and materials science.

For large datasets, interactive exploration of the resulting map is a great tool to extract understanding. To this end, we introduce chemiscope, an open source software able to display and explore maps with hundred of thousands of points together with the corresponding molecular or crystal structure. Chemiscope is usable as an online tool, or locally through jupyter notebooks.

SOE 19.5 Fri 11:00 H19

Investigation of plasticity in off-resonant delay-coupled reservoir computing — •Jonas Naujoks[1], Felix Köster[1], and Kathy Lüdge[2] — [1]Institute for Theoretical Physics, Technische Universität Berlin, 10559 Berlin, Germany — [2]Institute of Physics, Technische Universität Ilmenau, Weimarer Str. 25, 98693 Ilmenau, Germany

We analyse the effect of neuronal plasticity on the performance of a delay-based reservoir computer modelled by a generic oscillator with self-feedback. The memory capacity and task-specific performance are investigated in the case of non-resonant delay-clock-cycle configurations. By modifying the temporal multiplexing of the input, the responsiveness of the virtual nodes is maximised while promoting individual decorrelation. The training is done in an unsupervised manner. The effect on the task-specific performance is investigated, while we additionally demonstrate that the memory capacity can be tuned.

SOE 20: Nonlinear Dynamics 2: Stochastic and Complex Systems, Networks (joint session DY/SOE)

Time: Friday 11:30–12:45 Location: H19

SOE 20.1 Fri 11:30 H19

Thermodynamic uncertainty relations for many-body systems with fast jump rates and large occupancies — •Ohad Shpielberg[1] and Arnab Pal[2] — [1]University of Haifa, Haifa, Israel. — [2]Department of Physics, Indian Institute of Technology, Kanpur, India

The thermodynamic uncertainty relations constitute an important inequality, bounding the entropy production through current fluctuations. The results have been successfully applied, in particular for single body dynamics. Here we present uncertainty relations and other useful inequalities for the many body systems, in the limit of highly occupied systems. The resulting coarse grained theory also accounts for tighter inequalities than the single body case.

SOE 20.2 Fri 11:45 H19

Effects of measures on phase transitions in two cooperative susceptible-infectious-recovered dynamics — Adib Khazaee[1] and •Fakhteh Ghanbarnejad[1,2] — [1]Sharif University of Technology, Tehran, Iran — [2]Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed),Technical University of Dresden, 01062 Dresden, Germany

In recent studies, it has been shown that a cooperative interaction in a co-infection spread can lead to a discontinuous transition at a decreased threshold. Here, we investigate effects of immunization with a rate proportional to the extent of the infection on phase transitions of a cooperative co-infection. We use the mean-field approximation to illustrate how measures that remove a portion of the susceptible compartment, like vaccination, with high enough rates can change discontinuous transitions in two coupled susceptible-infectious-recovered dynamics into continuous ones while increasing the threshold of transitions. First, we introduce vaccination with a fixed rate into a symmetric spread of two diseases and investigate the numerical results. Second, we set the rate of measures proportional to the size of the infectious compartment and scrutinize the dynamics. We solve the equations numerically and analytically and probe the transitions for a wide range of parameters. We also determine transition points from the analytical solutions. Third, we adopt a heterogeneous mean-field approach to include heterogeneity and asymmetry in the dynamics and see if the results corresponding to homogeneous symmetric case stand. (Physical Review E 105 (3), 034311)

SOE 20.3 Fri 12:00 H19

ANDOR and beyond: Dynamically switchable logic gates as modules for flexible information processing in biochemical regulatory networks — •Mohammadreza Bahadorian[1,2] and Carl D. Modes[1,2,3] — [1]Max Planck Institut for Molecular Cell Biology and Genetics (MPI-CBG), 01307 Dresden, Germany — [2]Center for Systems Biology Dresden (CSBD), 01307 Dresden, Germany — [3]Cluster of Excellence Physics of Life, TU Dresden, 01069 Dresden, Germany

Understanding how complex (bio-)chemical regulatory networks may be capable of processing information in flexible, yet robust ways is a key question with implications in biology and dynamical systems theory. Considerable effort has been focused on identification and characterization of structural and dynamical motifs of biological information processing, but a framework for studying flexibility and robustness of the motifs is lacking. We here propose a small set of effective modules capable of performing different logical operations based on the basin of attraction in which the system resides. These dynamically switchable logic gates require fewer components than their traditional analogs where static, separate gates are used for each desired function. We demonstrate the applicability and limits of these circuits by determining a robust range of parameters over which they correctly operate and then characterize their resilience against intrinsic noise of the constituent reactions using the theory of large deviations. Tradeoffs between multi-functionality and robustness against various types of noise are shown.

SOE 20.4 Fri 12:15 H19

Memory formation in adaptive networks — •Komal Bhattacharyya[1], David Zwicker[1], and Karen Alim[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, 37077 Göttingen, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany

Continuous adaptation of networks like our vasculature ensures optimal network performance when challenged with changing loads. Here, we show that adaptation dynamics allow a network to memorize the position of an applied load within its network morphology. We identify that the irreversible dynamics of vanishing network links encode memory. Our analytical theory successfully predicts the role of all system parameters during memory formation, including parameter values which which prvent memory formation. We thus provide an analytically tractable theory of memory formation in disordered systems.

SOE 20.5 Fri 12:30 H19

Inference of fractional nonlinear models from temperature time series and application to predictions — •Johannes A. Kassel and Holger Kantz — MPI for the Physics of Complex Systems, Dresden, Germany

We introduce a method to reconstruct macroscopic models of one-dimensional nonlinear stochastic processes with long-range correlations from sparsely sampled time series by combining fractional calculus and discrete-time Langevin equations. We reconstruct a model for daily mean temperature data recorded at Potsdam (Germany) and use it to predict the first frost date. Including the Arctic Oscillation Index as an external driver into our model, we predict extreme temperatures for several European weather stations, illustrating the potential of long-memory models for predictions in the subseasonal-to-seasonal range.

[1] Johannes A. Kassel and Holger Kantz, Phys. Rev. Research 4, 013206