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

Jens Christian Claussen
Mathematics EAS
Aston University
Aston Triangle,
Birmingham B4 7ET, UK
j.claussen@aston.ac.uk

Marc Timme
Chair for Network Dynamics
cfaed & Institute of Theoretical Physics,
TU Dresden, 01062 Dresden
marc.timme@tu-dresden.de

Jan Nagler
Frankfurt School of Finance & Management
Adickesallee 32–34,
60322 Frankfurt am Main
j.nagler@fs.de

Overview of Invited Talks and Sessions

(Lecture halls GÖR 226 and HSZ 01-03; Poster P2/4OG)

Young Scientist Award for Socio- and Econophysics (YSA) - Award Session and Prize Talks

SOE 5.1	Mon	15:00–15:45	HSZ 01	**After more than two decades: The bounded confidence model reconsidered** — •Rainer Hegselmann
SOE 5.2	Mon	16:00–16:30	HSZ 01	**Multilayer modeling and analysis of complex socio-economic systems** — •Manlio de Domenico
SOE 5.3	Mon	16:30–17:00	HSZ 01	**Quantifying Science and Art** — •Roberta Sinatra

Invited Tutorial talks

SOE 1.1	Sun	16:00–16:50	HSZ 03	**Stochastic models for particles in turbulence** — •Bernhard Mehlig
SOE 1.2	Sun	16:50–17:40	HSZ 03	**From Percolation and Explosive Percolation to a unifying principle** — •Jan Nagler
SOE 1.3	Sun	17:40–18:30	HSZ 03	**Spreading dynamics on networks: from social interactions to epidemics and pandemics** — •Fakhteh Ghanbarnejad

Invited and Topical Talks

SOE 7.1	Tue	9:30–10:00	GÖR 226	**One model to rule them all** — •Jens Timmer
SOE 7.3	Tue	10:15–10:45	GÖR 226	**Gaming the system - Analyzing Uber price data reveals anomalous supply shortages** — •Malte Schröder, David Storch, Philip Marszal, Marc Timme
SOE 7.6	Tue	11:15–11:45	GÖR 226	**Data driven modelling of spatio-temporal chaos in extended dynamical systems** — •Ulrich Parlitz, Sebastian Herzog, Florentin Wörgötter, Roland S. Zimmermann, Jonas Isensee, George Datseris
SOE 7.8	Tue	12:00–12:30	GÖR 226	**Limits to predictability of complex systems dynamics** — Jonathan Brisch, •Holger Kantz
SOE 8.1	Wed	12:15–12:45	HSZ 02	**A physics of governance networks: critical transitions in contagion dynamics on multilayer adaptive networks with application to the sustainable use of renewable resources** — •Jonathan F. Donges, Fabian Geier, Wolfram Barfuss, Marc Wiedermann
SOE 9.1	Wed	15:00–15:30	GÖR 226	**Cross frequency coupling in next generation inhibitory neural mass models** — •Simona Olmi, Andrea Ceni, David Angulo Garcia, Alessandro Torcini
SOE 9.2	Wed	15:30–16:00	GÖR 226	**Brain functional connectivity asymmetry** — •Jaroslav Hlinka
SOE 9.3	Wed	16:00–16:30	GÖR 226	**Partial Synchronization Patterns in the Brain** — •Eckehard Schöll

Invited talks of the joint symposium SYNC

See SYNC for the full program of the symposium.

SYNC 1.1	Mon	9:30–10:00	HSZ 01	**Photonic Reservoir Computing and its Application to Optical Communication** — •Ingo Fischer, Apostolos Argyris
SYNC 1.2	Mon	10:00–10:30	HSZ 01	**Metal-oxide resistance switching memory devices as artificial synapses for brain-inspired computing** — •Sabina Spiga
SYNC 1.3	Mon	10:30–11:00	HSZ 01	**Towards brain-inspired photonic computing** — •Wolfram Pernice
SYNC 1.4	Mon	11:15–11:45	HSZ 01	**Photonic Recurrent Ising Sampler** — •Charles Roques-Carmes, Yichen Shen, Cristian Zanoci, Mihika Prabhu, Fadi Atieh, Li Jing, Tena Dubček, Chenkai Mao, Miles Johnson, Vladimir Čeperić, John Joannopoulos, Dirk Englund, Marin Soljačić
SYNC 1.5	Mon	11:45–12:15	HSZ 01	**Beyond von Neumann systems: Computational memory for efficient AI** — •Irem Boybat

Invited talks of the joint symposium SYSD

See SYSD for the full program of the symposium.

SYSD 1.1	Mon	9:30– 9:55	HSZ 02	**Disentangling transport in topological insulator thin films down to the nanoscale** — •Felix Lüpke
SYSD 1.2	Mon	9:55–10:20	HSZ 02	**Spintronics with Terahertz Radiation: Probing and driving spins at highest frequencies** — •Tom Sebastian Seifert, Tobias Kampfrath
SYSD 1.3	Mon	10:20–10:45	HSZ 02	**Non-radiative voltage losses in organic solar cells** — •Johannes Benduhn
SYSD 1.4	Mon	10:45–11:10	HSZ 02	**Multivalent ions for tuning the phase behaviour of protein solutions** — •Olga Matsarskaia
SYSD 1.5	Mon	11:10–11:35	HSZ 02	**Network Dynamics under Constraints** — •Malte Schröder
SYSD 1.6	Mon	11:35–12:00	HSZ 02	**Exciton spectroscopy of van der Waals heterostructures** — •Philipp Nagler

Invited talks of the joint symposium SYCE

See SYCE for the full program of the symposium.

SYCE 1.1	Wed	9:30–10:00	HSZ 02	**Towards a carbon-free energy system: Expectations from R&D in renewable energy technologies** — •Bernd Rech, Rutger Schlatmann
SYCE 1.2	Wed	10:00–10:30	HSZ 02	**Decarbonizing the Heating Sector - Challenges and Solutions** — •Florian Weiser
SYCE 1.3	Wed	10:30–11:00	HSZ 02	**The challenge of anthropogenic climate change - Earth system analysis can guide climate mitigation policy** — •Matthias Hofmann
SYCE 1.4	Wed	11:15–11:45	HSZ 02	**A carbon-free Energy System in 2050: Modelling the Energy Transition** — •Christoph Kost, Philip Sterchele, Hans-Martin Henning
SYCE 1.5	Wed	11:45–12:15	HSZ 02	**The transition of the electricity system to 100% renewable energy: agent-based modeling of investment decisions under climate policies** — •Kristian Lindgren

Invited talks of the joint symposium SYES

See SYES for the full program of the symposium.

SYES 1.1	Thu	9:30–10:00	HSZ 02	**Understanding the physical variables driving mechanosensing** — •Pere Roca-Cusachs
SYES 1.2	Thu	10:00–10:30	HSZ 02	**Mechanics of life: Cellular forces and mechanics far from thermodynamic equilibrium** — •Timo Betz
SYES 1.3	Thu	10:30–11:00	HSZ 02	**A hydrodynamic approach to collective cell migration in epithelial tissues** — •Jaume Casademunt
SYES 1.4	Thu	11:15–11:45	HSZ 02	**The spindle is a composite of two permeating polar gels** — David Oriola, Benjamin Dalton, Franziska Decker, Frank Julicher, •Jan Brugues
SYES 1.5	Thu	11:45–12:15	HSZ 02	**Adding magnetic properties to epitaxial graphene** — •Rodolfo Miranda
SYES 2.1	Thu	15:00–15:30	HSZ 01	**Interactions in assemblies of surface-mounted magnetic molecules** — •Wolfgang Kuch

SYES 2.2	Thu	15:30–16:00	HSZ 01	**Towards phononic circuits based o optomechanics** — •Clivia M. Sotomayor-Torres
SYES 2.3	Thu	16:00–16:30	HSZ 01	**Optical properties of 2D materials and heterostructures** — •Janina Maultzsch
SYES 2.4	Thu	16:45–17:15	HSZ 01	**Bringing nanophotonics to the atomic scale** — •Javier Aizpurua
SYES 2.5	Thu	17:15–17:45	HSZ 01	**Infrared signatures of the coupling between vibrational and plasmonic excitations** — •Annemarie Pucci

Sessions

SOE 1.1–1.3	Sun	16:00–18:30	HSZ 03	**Tutorials: Stochastic Processes and Applications to Biology and Socio-Economic Systems (joint session SOE/DY/TUT)**
SOE 2.1–2.7	Mon	9:30–11:15	GÖR 226	**Energy Systems (joint SOE/DY/AKE)**
SOE 3.1–3.3	Mon	11:15–12:00	GÖR 226	**Financial Markets, Risk Management and Stochastic Processes**
SOE 4.1–4.4	Mon	11:30–12:30	ZEU 147	**Physics of Power Grids (joint session DY/SOE)**
SOE 5.1–5.3	Mon	15:00–17:00	HSZ 01	**Young Scientist Award for Socio- and Econophysics**
SOE 6.1–6.19	Mon	17:00–20:00	P2/4OG	**Poster**
SOE 7.1–7.11	Tue	9:30–13:15	GÖR 226	**Data analytics for dynamical systems I (Focus Session joint with DY and BP) (joint session SOE/DY/CPP/BP)**
SOE 8.1–8.2	Wed	12:15–13:00	HSZ 02	**Climate Impact and Human-Economy-Nature Interactions (accompanying the symposium SYCE)**
SOE 9.1–9.5	Wed	15:00–17:15	GÖR 226	**Partial Synchronization Patterns in Neuronal Networks I (Focus Session joint with DY / SOE / BP) (joint session SOE/DY)**
SOE 10.1–10.8	Wed	15:00–17:30	ZEU 118	**Data Analytics, Extreme Events, Nonlinear Stochastic Systems, and Networks (joint session DY/SOE)**
SOE 11.1–11.4	Wed	17:30–18:30	GÖR 226	**Networks - From Topology to Dynamics I (joint SOE/DY/BP)**
SOE 12	Wed	18:30–19:30	GÖR 226	**Annual Member's Assembly**
SOE 13.1–13.7	Thu	9:30–11:30	GÖR 226	**Focus Session: Opinion Formation**
SOE 14.1–14.4	Thu	11:30–12:30	GÖR 226	**Social Systems, Opinion and Group Formation**
SOE 15.1–15.3	Thu	12:30–13:15	GÖR 226	**Traffic, Urban and Regional Systems I**
SOE 16.1–16.4	Thu	15:00–16:00	GÖR 226	**Evolutionary Game Theory and Networks (joint SOE/DY/BP)**
SOE 17.1–17.5	Thu	16:00–17:30	GÖR 226	**Traffic, Urban and Regional Systems I**
SOE 18.1–18.4	Thu	17:30–18:30	GÖR 226	**Networks - From Topology to Dynamics II (joint SOE/DY/BP)**
SOE 19.1–19.2	Fri	9:30–10:00	GÖR 226	**Data analytics for dynamical systems II (Focus Session joint with DY and BP) (joint session SOE/CPP/DY)**
SOE 20.1–20.6	Fri	10:00–12:00	GÖR 226	**Partial Synchronization Patterns in Neuronal Networks II (Focus Session joint with DY / SOE / BP) (joint session SOE/DY)**

Annual General Meeting of the Physics of Socio-economic Systems Division

Wednesday 18:30–19:30 GÖR 226

1. Report of the Chairpersons
2. Announcements and Discussion of future Activities
3. Elections
4. Miscellaneous

SOE 1: Tutorials: Stochastic Processes and Applications to Biology and Socio-Economic Systems (joint session SOE/DY/TUT)

Stochastic Processes are an essential ingredient of models in biology, physics and chemistry, as well as in socio-economic systems where agents are often modeled by a simple set of rules. The tutorials first lay foundations, then introduce advanced concepts and finally demonstrate their application in turbulence, critical phenomena in socio-technical networks, and the dynamics of epidemic spreading. (Session organised by Jens Christian Claussen.)

Time: Sunday 16:00–18:30 Location: HSZ 03

Tutorial SOE 1.1 Sun 16:00 HSZ 03

Stochastic models for particles in turbulence — •Bernhard Mehlig — Department of Physics, University of Gothenburg, Sweden

The subject of this tutorial is the dynamics of heavy particles in turbulence, such as water droplets in the turbulent air of a cumulus cloud, dust grains in the turbulent gas around a growing star, or motile microorganisms in the turbulent ocean. The analysis of such highly nonlinear and multi-scale problems poses formidable challenges, because any description of the dynamics must refer to the turbulent fluctuations that the particles experience as they move through the fluid. Experiments resolving the particle dynamics have only recently become possible, and direct numerical simulations of such systems are still immensely difficult.

In this tutorial I explain how to understand the fundamental mechanisms determining the dynamics of particles in turbulence in terms of statistical models that account for the symmetries and statistics of the turbulent flow. Using simple examples I illustrate how to solve such models with diffusion approximations, highlighting an analogy with Kramers' escape problem. I discuss the limitations of the approach, and summarise recent progress. I conclude by discussing open questions, arguing that the approach outlined provides a unique opportunity to make significant progress regarding this challenging and important problem.

Tutorial SOE 1.2 Sun 16:50 HSZ 03

From Percolation and Explosive Percolation to a unifying principle — •Jan Nagler — Frankfurt School of F&M, Frankfurt, Germany

The emergence of large-scale connectivity crucially underlies the structure, proper functioning, and failure of many complex socio-technical networks. For many decades, percolation was studied predominately as a second-order phase transition where at the critical threshold, the order parameter increases in a rapid but continuous way. In 2009, an explosive, i.e. extremely rapid, transition was found for a network growth process where links compete for addition. This observation of "explosive percolation" started an enormous surge of analyzing explosive phenomena and their consequences. Many models are now shown to yield discontinuous explosive percolation transitions, and some models exhibit a hybrid transition with a combination of second- and first- order features. Important mechanisms that achieve the required delay for explosive transitions include history dependence, non-self-averaging, and strong correlations. In this tutorial we will start to review standard percolation and end with "explosive phenomena" in networked systems. Examples include social systems, globalization, and the emergence of molecular life [D'Souza, Gomez-Gardenes, Nagler, Arenas, Explosive phenomena in complex networks, Advances in Physics 68(3):123, 2019]. We will close with some recent publication that provides a unifying framework for continuous, discontinuous and even hybrid phase transitions [Fan, Meng, Liu, Saberi, Kurths, Nagler, Universal gap scaling in percolation, Nature Physics, in press].

Tutorial SOE 1.3 Sun 17:40 HSZ 03

Spreading dynamics on networks: from social interactions to epidemics and pandemics — •Fakhteh Ghanbarnejad — Sharif University of Technology, Tehran, Iran

Spreading of gossips, news, infectious diseases, computer viruses, new products, etc. are some examples of epidemic dynamics. In this tutorial, firstly we review the basic models for modelling such phenomena including deterministic and stochastic approaches. Also we address how social contacts and the underlying topology of interactions can affect the dynamics. Finally we discuss when and how a spreading dynamics may end to a widespread endemic or pandemic and if and how social interactions play a role.

SOE 2: Energy Systems (joint SOE/DY/AKE)

Time: Monday 9:30–11:15 Location: GÖR 226

SOE 2.1 Mon 9:30 GÖR 226

Data-driven analysis of power grid fluctuations — •Benjamin Schäfer and Christian Beck — School of Mathematical Sciences, Queen Mary University of London, London E1 4NS, United Kingdom

The Paris conference 2015 set a path to limit climate change to "well below 2°C". To reach this goal greenhouse gas emissions have to be reduced and renewable generators, electrical mobility or smart grids are integrated into the existing power system.

The introduction of these new technologies raises several questions about control, stability and operation and therefore requires a solid understanding of existing and future systems and new conceptional approaches.

Here, we use data-driven approaches to work towards a quantitative understanding of the power grid with a particular focus on fluctuations, as they are for example introduced by the changing demand or volatile energy generation of renewable generators. We analyse time series from wind power plants, households and various power grids grids to understand differences in grid operation and design.

We highlight significant deviations from Gaussianity in several quantities and report on the progress of the Marie-Curie project DAMOSET, which focuses on building up an open data base of power grid frequency measurements.

SOE 2.2 Mon 9:45 GÖR 226

Linear response theory of power grids with correlated multi-node fluctuations — •mehrnaz anvari, anton plietzsch, and frank hellmann — Potsdam Institute for Climate Impact Research

Modern societies highly depend on electricity supply via power grids. Without electricity, people do not have access to food, transportation, medical treatment and so on. Moreover, in an extended outage the security of a community can be in danger. Therefore, stability of the power grid has highest priority. For that, the balance between the energy consumption and energy production should be provided. Recently the ongoing energy transition towards renewable generation fundamentally changes the conditions for the operation of the power system. The variable renewable energies, i.e. wind and solar are known as the sources of fluctuations, which can affect the stability of the power grid frequency. In previous works, linear response theory has been shown to be a powerful tool to study the impact of power fluctuations on frequency stability in complex power grid networks. However, so far this response theory has only be developed for single node fluctuations, while real power grids are subjected to fluctuations at multiple nodes. Employing the same theoretical technique, we therefore investigate the influence of the multi-node fluctuations in the power grid, when there exists spatial correlation between the fluctuating nodes.

SOE 2.3 Mon 10:00 GÖR 226

Modeling the dynamics of future power grids — •Raphael Kogler — Potsdam Institute for Climate Impact Research, Germany

An important aspect of tackling the problems posed by climate change

is the transition from fossil-based and nuclear energy toward a greater share of renewable energy sources. For our power grids this means a gradual replacement of the conventional synchronous machines by converter-interfaced generation units.

While the dynamical behavior of synchronous machines is commonly modeled by the swing equation (the Kuramoto model with inertia), the dynamics of converter-interfaced units will be given by the specific control scheme applied to the converters. There are various proposals for such control schemes but no clear consensus as of yet.

However, as different as they appear, there are certain shared aspects when viewed in the context of complex amplitude oscillators. I discuss how the Stuart-Landau oscillator can serve as a paradigmatic model of such an oscillator and provide a basis for understanding the dynamics of future power grids.

SOE 2.4 Mon 10:15 GÖR 226

Facing heterogeneity - towards a unified description of power grid dynamics — •Frank Hellmann — Potsdam Institut für Klimafolgenforschung, Potsdam, Germany

Future power grids will feature a large variety of dynamical actors. In this talk I review a number of relevant dynamical nodes, their similarities and differences, and sketch how a unified perspective on these dynamical systems could look.

SOE 2.5 Mon 10:30 GÖR 226

An analysis of cost allocation methods for energy systems based on power flows — Fabian Hofmann[1], Markus Schlott[1], Matthias Hanauske[1], •Alexander Kies[1], Alexander Zerrahn[2], and Horst Stöcker[1] — [1]Frankfurt Institute for Advanced Studies, Frankfurt, Germany — [2]DIW Berlin, Berlin, Germany

The continuing expansion of renewable generation in Europe and the World has had profound impact on power system operation.

A first step on the way towards fair cost allocation schemes in electricity networks is the allocation of power flows. Power flow allocation refers to algorithms, which allocate the flow of electric power in electricity system components such as transmission lines to users of the system such as generators or consumers.

In this talk, different flow allocation methods are compared and evaluated using different criteria such as stability, computational effort and fairness.

SOE 2.6 Mon 10:45 GÖR 226

The role of transmission expansion in a cost-optimal highly-renewable European power system — •Fabian Hofmann — Frankfurt Insitute for Advanced Studies, Frankfurt, Germany

The transition towards a highly renewable European power system which is both cost-efficient and resilient requires detailed planning of infrastructure needs as well as a comprehensive trade-off between different technologies. Especially against the backdrop of high wind power potentials around the North Sea, the role of expanding the transmission system becomes increasingly important. The highly-refined open-source model PyPSA-EUR is used to showcase how different levels of transmission expansion impact the optimal setup of the European power system. It is shown that within the range of the first 25% total transmission expansion, the optimization opens up bottlenecks which suppress the exploitation of sites with good renewable resources. This leads to a strong decrease of curtailment, total system cost and peak line loading. By using flow tracing methods, it is further broke down how the transmission expansion changes the interplay of storage and generation technologies and enables to shift the optimal setup towards a more centralized and less storage based system.

SOE 2.7 Mon 11:00 GÖR 226

Explosive amortization times of photovoltaic systems? — •Raoul Schmidt, Malte Schröder, and Marc Timme — Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), TU Dresden

To combat climate change, renewable energy systems such as photovoltaics (PV) are becoming increasingly important. The amortization time of a PV unit relates the energy (and CO_2) expended for production, transport and installation of a unit to its electric power generation (and thus potential savings in CO_2 emissions). Here, we consider the CO_2 budgeting dynamics of many PV units continuously added by new installations [von der Heydt, DPG Spring Meeting Berlin (2018)] and find that the resulting systemic amortization time necessarily is (much) larger than that of a single unit. We demonstrate analytically, that at constant installation rate, it already is twice the amortization time of a single unit, whereas at an exponentially increasing rate, it may be arbitrarily much larger, with resulting relevant time scales in between 10 and more than 30 years - beyond the life time of a PV unit. Intriguingly, evaluating installation data of the past two decades indicates an exponential installation rate that may cause such explosive increase of CO_2 budget amortization times on the global scale.

SOE 3: Financial Markets, Risk Management and Stochastic Processes

Time: Monday 11:15–12:00 Location: GÖR 226

SOE 3.1 Mon 11:15 GÖR 226

Grasping asymmetric information in price impacts — •Shanshan Wang[1], Sebastian Neusüss[2], and Thomas Guhr[1] — [1]Fakultät für Physik, Universität Duisburg–Essen, Lotharstraße 1, 47048 Duisburg, Germany — [2]Deutsche Börse AG, Frankfurt, Germany

The price impact for a single trade is estimated by the immediate response on an event time scale, *i.e.*, the immediate change of midpoint prices before and after a trade. We work out the price impacts across a correlated financial market. We then quantify the asymmetries of the distributions and of the market structures of cross-impacts, and find that the impacts across the market are asymmetric and non-random. Using spectral statistics and Shannon entropy, we visualize the asymmetric information in price impacts. Also, we introduce an entropy of impacts to estimate the randomness between stocks. We show that the useful information is encoded in the impacts corresponding to small entropy. The stocks with large number of trades are more likely to impact others, while the less traded stocks have higher probability to be impacted by others.

SOE 3.2 Mon 11:30 GÖR 226

Revealing evolution of the correlation structure in financial markets — •Anton J. Heckens, Sebastian M. Krause, and Thomas Guhr — Universität Duisburg-Essen, Lotharstr. 1, 47048 Duisburg

Complex systems are characterized by a variety of interactions and often produce a strong correlated behavior of their system components. Financial markets are particularly well suited as examples of such complex systems due to their abundance of data for the analysis of correlated phenomena. The correlated price development of various stocks massively increases the financial risk of even broadly diversified financial operators. Financial markets are showing a strong non-stationarity, which must be taken into account in the analysis of correlations. Münnix et al. [1] use correlation matrices over short time horizons, in order to analyze their dynamics with respect to their non-stationarity. Using a cluster procedure, it became apparent that there are longer quasi-stationary periods that are corresponding to so-called market states. Crises break up these structures due to their strong collective behaviour and therefore cause non-stationary periods. Here we present new developments to improve the clustering method concerning the quasi-stationarity of the market states.

[1] M.C. Münnix, T. Shimada, R. Schäfer, F. Leyvraz, T.H. Seligman, T. Guhr and H.E. Stanley, Identifying States of a Financial Market, Scientific Reports 2 (2012) 644.

SOE 3.3 Mon 11:45 GÖR 226

The north pole problem – Explaining asymmetry in repeated random rotations — Malte Schröder and •Marc Timme — Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), TU Dresden

Imagine rotating a globe uniformly at random by applying an isotropic rotation R, resulting equally likely in any orientation of the globe. By definition, a given point like the north pole is mapped to any other point on the sphere with equal probability. Repeating the same random rotation twice (applying R^2), the north pole ends up on the

northern hemisphere with 71% probability. This *north-pole-problem* was originally observed numerically [Marzetta et al., IEEE Trans. Inform. Theory 48 (2002)] and subsequently mathematically analyzed using measure theory [Eaton and Muirhead, Stat. Probab. Lett. 79 (2009)]. Here we provide an intuitive, geometric explanation for this phenomenon [Schröder and Timme, Phys. Rev. Res. 1 (2019)] by decomposing the isotropic rotation into two sequential elementary rotations and explicitly following the action of the rotation. The same geometric argument generalizes to higher dimensions $d > 3$ and also explains why the asymmetry is absent in $d = 2$ dimensions, is strongest in $d = 3$ dimensions and disappears again as $d \to \infty$.

SOE 4: Physics of Power Grids (joint session DY/SOE)

Time: Monday 11:30–12:30 Location: ZEU 147

SOE 4.1 Mon 11:30 ZEU 147

Dynamic Vulnerability of Oscillatory Networks and Power Grids — •Xiaozhu Zhang[1], Cheng Ma[2], and Marc Timme[1] — [1]Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), Cluster of Excellence Physics of Life, Technical University of Dresden, 01062 Dresden, Germany — [2]School of Physics, Nankai University, Tianjin 300071, China

Driven by dynamic fluctuations, oscillatory networks such as AC power grids exhibit highly heterogeneous, nontrivial resonant patterns that jointly depend on the driving frequency, the interaction topology of the network and the nodes driven [1,2]. However, it remains an open problem to identify which nodes are most susceptible and may make entire systems vulnerable to dynamic driving signals. Here we propose a Dynamic Vulnerability Index (DVI) [3] for identifying those nodes that exhibit largest amplitude responses to dynamic driving signals with given power spectra, and thus are most vulnerable. The DVI is easy to compute and enables robust high-quality predictions. It shows potential for a wide range of applications across dynamically driven networks, e.g. for identifying the vulnerable nodes in AC power grids driven by power fluctuations from renewable energy sources and customers' behaviour.

[1] X. Zhang et al., Science Advances 5:eaav1027 (2019).
[2] S. Tamrakar et al., Scientific Reports 8:6459 (2018).
[3] X. Zhang et al., arXiv:1908.00957 (2019).

SOE 4.2 Mon 11:45 ZEU 147

Message Passing for State Estimation of Power Grids — •Tim Ritmeester and Hildegard Meyer-Ortmanns — Jacobs University, Bremen

The method of message passing is known from statistical physics and computer science. Here we use it to estimate the state of power grids in terms of the generator production and power flow, based on redundant error-prone measurements. We illustrate the method on the IEEE300-grid, and show that it outperforms standard least-squares approaches if the influence from distant nodes matters. We perform our analysis in this regime and show under what circumstances missing data can reliably be retrieved and how placement of modern measurement devices such as PMUs (Phasor Measurement Units) affects the accuracy of the estimate.

SOE 4.3 Mon 12:00 ZEU 147

Large-deviation properties of the basin stability of power grids — •Yannick Feld and Alexander K. Hartmann — Institute of Physics, University of Oldenburg, Germany

Due to climate change the usage of fossil power sources has to be reduced. This results in more and more fluctuating power sources, which makes maintaining a stable energy grid more challenging and the properties of extremely stable (or unstable) power grid typologies are of interest. We use a dynamic model of power grids, specifically the Kuramoto-like model [1].

An advanced, however, nonlinear way to characterize the stability of power grids against (possibly large) fluctuations is the *basin stability*. Thus, we study numerically [2] the probability distribution of the basin stability for two random graph ensembles, namely an *Erdős-Rényi* and a *small-world* ensemble. Using *large deviation techniques* [3], we were able to measure [4] the probability distribution ranging over eight decades in probability, which is considerably larger than possible using standard sampling. Additionally we investigated the correlations of the basin stability with other measurable quantities like *backup capacity* [3] and number of leafs (dead ends).

[1] G. Filatrella, A.H. Nielsen, and N.F. Pedersen, Eur. Phys. J. B **61** 485-491 (2008)
[2] A.K. Hartmann, *Big Practical Guide to Computer Simulations* (World Scientific, 2015).
[3] T. Dewenter and A.K. Hartmann, New J. Phys. **17**, 015005 (2015)
[4] Y. Feld and A.K. Hartmann, Chaos **29**, 113103 (2019).

SOE 4.4 Mon 12:15 ZEU 147

Enhancing power grid synchronization and stability through time delayed feedback control — Halgurd Taher[1], •Simona Olmi[1], and Eckehard Schöll[2] — [1]Inria Sophia Antipolis Mediterranee Research Centre, 2004 Route des Lucioles, 06902 Valbonne, France — [2]Institut fuer Theoretische Physik, Technische Universitaet Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

We study the synchronization and stability of power grids within the Kuramoto phase oscillator model with inertia with a bimodal natural frequency distribution representing the generators and the loads. We identify critical nodes through solitary frequency deviations and Lyapunov vectors corresponding to unstable Lyapunov exponents. To cure dangerous deviations from synchronization we propose time-delayed feedback control, which is an efficient control concept in nonlinear dynamic systems. Different control strategies are tested and compared with respect to the minimum number of controlled nodes required to achieve synchronization and Lyapunov stability. As a proof of principle, this fast-acting control method is demonstrated for different networks (the German and the Italian power transmission grid), operating points, configurations, and models.

SOE 5: Young Scientist Award for Socio- and Econophysics

Time: Monday 15:00–17:00 Location: HSZ 01

Invited Talk SOE 5.1 Mon 15:00 HSZ 01

After more than two decades: The bounded confidence model reconsidered — •Rainer Hegselmann — Frankfurt School of Finance and Management, Frankfurt, Germany

By usual academic standards, the bounded confidence model (BC model) is quite successful. It is often cited; to overlook all its extensions is hardly possible. I find that surprising. But the success is probably due to two factors. First, the definition of the model is extremely simple. The dynamics is basically driven by just one parameter. Second, it is often easy to modify the model such that it covers whatever one thinks is missing.

The talk will demonstrate that the definitional simplicity of the basic BC-model is deceptive. There are lots of counter-intuitive effects that usual simulation approaches (including my own) have overlooked for a long time. The effects, for the most part surprising non-monotonicities, are not completely understood until now.

I will then focus on a certain class of extensions. They introduce an external signal that is heard by some or all of the agents that exchange in an BC-process. The talk demonstrates the explanatory advantages of a methodological approach that substitutes random start distributions by their deterministic idealisations.

Presentation of the YSA Award to the Awardee

Prize Talk SOE 5.2 Mon 16:00 HSZ 01

Multilayer modeling and analysis of complex socio-economic systems — •Manlio de Domenico — ICT Foundazione Bruno Kessler — Laureate of the Young Scientist Award 2020

Complex systems are characterized by constituents – from neurons in the brain to individuals in a social network – which exhibit special structural organization and nonlinear dynamics. As a consequence, a complex system can not be understood by studying its units separately because their interactions lead to unexpected emerging phenomena, from collective behavior to phase transitions.

Recently, we have discovered that a new level of complexity characterizes a variety of natural and artificial systems, where units interact, simultaneously, in distinct ways. For instance, this is the case of multimodal transportation systems (e.g., metro, bus and train networks) or of social networks, whose interactions might be of different type (e.g. trust, trade, virtual, etc.).

The unprecedented newfound wealth of socio-economic data allows to categorize system's interdependency by defining distinct "layers", each one encoding a different network representation of the system. The result is a multilayer network model.

In this talk we will discuss the most salient features of multilayer systems, with special attention to socio-ecological and socio-technical ones.

Prize Talk SOE 5.3 Mon 16:30 HSZ 01

Quantifying Science and Art — •Roberta Sinatra — IT University of Copenhagen — ISI Foundation Torino — Laureate of the Young Scientist Award 2020

Performance, representing the objectively measurable achievements in a certain domain of activity, like the publication record of a scientist or the winning record of an athlete, captures the actions of an individual entity. In contrast, success, captured by impact or visibility, is a collective phenomenon, representing a community's reaction and acceptance of an individual entity's performance. We are often driven by the belief that the detection of extraordinary performance is sufficient to predict exceptional success. However, the link between these two measures, while often taken for granted, is actually far from being understood. Nevertheless, differently from performance, success is quantifiable and predictable: given its collective nature, its signatures can be uncovered from the many pieces of data around us using the tools of statistical physics, complex systems, network science, and data science. In this talk, I will focus on success in science and art as a way to test our ability to model and predict the collective phenomenon of success. I will discuss the role of luck in achieving success, and will address the relation between performance and success in a variety of settings, highlighting the challenges of gauging performance through success.

The session will be followed by an informal get-together with beer and pretzels alongside the poster session on the 4th floor of HSZ.

SOE 6: Poster

Time: Monday 17:00–20:00 Location: P2/4OG

SOE 6.1 Mon 17:00 P2/4OG

Voter model with recurrent mobility calibrated to Swedish data — •Attila Szilva[1] and Jérôme Michaud[2] — [1]Department of Physics and Astronomy, University of Uppsala, 752 37 Uppsala, Sweden — [2]Department of Sociology, University of Uppsala, 751 20 Uppsala, Sweden

In PHYSICAL REVIEW E 97, 062313 (2018), we have discussed the possible generalizations of the social influence with recurrent mobility (SIRM) model [Phys. Rev. Lett. 112, 158701 (2014)] by extended it for multiparty systems that are mathematically well-posed in case of extreme vote shares, too, by handling the noise term in a different way. The model is ready to apply for Swedish data, and preliminary results based on functional network analysis will be presented for the case of Sweden by analysing the spatial clustering of voting behaviour from 1985 to 2018.

SOE 6.2 Mon 17:00 P2/4OG

Policy and Innovation Spreading on the Global City Network — •Niklas Kitzmann[1], Xuemei Bai[2], Steven Lade[3], Ricarda Winkelmann[1], and Jonathan Donges[1] — [1]Potsdam Institute for Climate Impact Research, Germany — [2]Fenner School of Environment & Society, Australian National University, Canberra, Australia — [3]Stockholm Resilience Centre, Stockholm University, Sweden

Only a fast and global transformation towards decarbonization and sustainability can keep the Earth in a civilization-friendly state. Cities play an important role in this transformation: they are responsible for a dis-proportionally large part of greenhouse gas emissions, and simultaneously are one of the main drivers of sustainable policy innovation and adoption. Learning from each other to reduce, prepare for and react to the coming environmental changes, they can be conceptualized as nodes in a globe-spanning network. Such a network may be approximated by global air traffic, political and trade relations, and other city-to-city connections.

Here, we model the spreading of several municipal sustainability policies and innovations as contagion processes on such inter-city networks. For this purpose, several networks, comprised of different types of city interconnections, are extracted from empirical data. The spread of several urban technology and policy innovations, such as Bus Rapid Transit Systems and carbon neutrality targets, are then investigated to discover which network correlates best with the contagion process. Different hypotheses for the type of the contagion process are also tested, potentially yielding insights on social tipping dynamics.

SOE 6.3 Mon 17:00 P2/4OG

Simplicity as Ultimate Sophistication? — •Stephen I. Ternyik — POB.201 D-82043 Munich

There can be no doubt that the physical reality on our spaceship earth is extremely complex, with many complicated layers of interaction, concerning the empirical nature of human experiences.In the recent development of scientific methodology, computation has reached the research status level of experimental laboratory presicion and exactness, with artificial cognition (AI) and cognitive artifacts replacing real world applications (e.g. exponential medicine, in silico technologies).

In the economic sciences, we can observe the same methodical paradigm progress to beat complexity with even more complexity and to create virtual economic systems, which are extremely detached from everyday human economic action.The recommendations of Leonardo da Vinci and Albert Einstein, to formulate possible solutions to an existing problem in its most simplest degree, suggests that there are simple problem-solving techniques for complex tasks in science and life.

It is, therefore, very reasonable to assume that simplicity remains the ultimate sophistication, even in our tech-know-logical age of computational exponentiality, i.e. reducing and computing economic complexity into single working elements and to identify its dynamic interplay (matching tool and task intelligently). To paraphrase Ronald Coase, the data should not be tortured, until they confess to everything.

SOE 6.4 Mon 17:00 P2/4OG

Numerical study of phase transition and replica symmetry of bipartite z-matching — •Till Kahlke[1], Martin Fränzle[2], and Alexander K. Hartmann[1] — [1]Institut of Physics, University of Oldenburg, Germany — [2]Institut of Computer Science, University of Oldenburg, Germany

We study numerically [1] the many-to-one bipartite *z-matching*, a generalisation of the matching problem. It can be used, e.g., to model a wireless communication network of users and servers, where z denotes the maximum number of users a server can treat at one time. Within a bipartite graph representation, there are links from each user to all servers which are feasible, e.g., close enough. The maximum matching capacity of this graph is the largest total number of users all servers can serve. After mapping to standard maximum matching, we use a numerically *exact algorithm* (Edmonds blossom shrinking) to solve the z-matching problem. First, we compare it with previous analytic results [2]. Next, we look at the saturation probability as order parameter and *observe phase transitions* when varying the average number of neighbors. We describe these transitions by their critical points and

an universal critical exponent. We also verify using a perturbation technique [3] that *replica symmetry* holds for this model.

[1] A.K. Hartmann, *Big Practical Guide to Computer Simulations* (World Scientific, 2015).
[2] E. Kreačić and G. Bianconi, Europhys. Lett. **126**, 28001 (2019).
[3] H. Schawe, J. Kumar Jha, and A.K. Hartmann, Phys. Rev. E **100**, 032135 (2019).

SOE 6.5 Mon 17:00 P2/4OG

Coupling strategies in spreading of SIS dynamics — •Felix Köster[1] and Fakhteh Ghanbarnejad[2,3] — [1]Institut für Theoretische Physik, TU Berlin, Hardenbergstraße 36, 10623 Berlin — [2]Department of Physics, Sharif University of Technology (SUT), Tehran, Iran — [3]Quantitative Life Sciences (QLS), The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy

Infectious diseases are of the most fatal threats in human history. Some recent studies have investigated the way interacting diseases become epidemic. In this work we consider two pathogenes each having two different strategies: cooperation or defection. By analysing the fundamental properties of the interacting contagious processes a well-mixed population, i.e. homogenous mean field approximation, new discontinous phase transitions are discovered. For a deeper understanding the parameters are altered and the change in the steady state solutions described. Using stochastic simluations we find multistabilites and show the relationships between the defective and cooperative pathogens.This work aims to improve our understanding of the natural dynamics of species populations in an evolutionary ecological framework.

SOE 6.6 Mon 17:00 P2/4OG

Demand responsive bimodal ride pooling systems: effects of network geometry — •Puneet Sharma[1,2], Stephan Herminghaus[1,2], and Knut Heidemann[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Institute for Dynamics of Complex Systems, University of Göttingen, Germany

Demand responsive ride pooling with minibuses is useful as a cheap door-to-door public transport, but leads to undue competition with line services, which provide much better pooling (average number of passengers per vehicle). A combination of both modes may provide an ideal solution, but is challenging to organize. We discuss various aspects of geometry of the involved networks affecting the efficiency of such systems. The geometry of the street network is found to strongly affect the poolability of routing requests to minibuses. The geometry and mesh size of the line service network is relevant for efficient combination with the minibus system. We find that for setting up an effective public transportation system, both aspects need to be optimized simultaneously.

SOE 6.7 Mon 17:00 P2/4OG

Analysis and control of multilayer, multi-timescale power grids — Lia Strenge[1], •Paul Schultz[2], Jörg Raisch[1], and Frank Hellmann[2] — [1]Potsdam Institute for Climate Impact Research (PIK), 14473 Potsdam, Germany — [2]Control Systems Group, Technische Universität Berlin, Germany

Power systems are subject to fundamental changes due to the increasing infeed of decentral renewable energy sources and storage. The decentral nature of the new actors in the system requires new concepts for structuring the grid, and achieving a wide range of control tasks ranging from seconds to days. Here we introduce a multilayer dynamical network model covering all control time scales. Crucially we combine a decentral, self-organised low-level control and a smart grid layer of devices that can aggregate information from remote sources. The stability-critical task of frequency control is performed by the former, the economic objective of demand matching dispatch by the latter. Having both aspects present in the same model allows us to study the interaction between the layers. Remarkably we find that adding communication in the form of aggregation does not improve the performance in the cases considered. Instead the self-organised state of the system already contains the information required to learn the demand structure in the entire grid. The model introduced here is highly flexible, and can accommodate a wide range of scenarios relevant to future power grids. We expect that it will be especially useful in the context of low-energy microgrids with distributed generation.

SOE 6.8 Mon 17:00 P2/4OG

Demand Responsive Ride Pooling: Theory, Simulation, Experiment — •Felix Jung and Stephan Herminghaus — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Undeniably one of the most pressing challenges of our time is the question how human mobility can be made sustainable. A possible way to reduce environmental impact is to increase the average ratio of the number of persons being transported to the number of vehicles utilized for the task. This has the potential to not only reduce the impact during operation (i.e. burning of fossil fuels) but also during manufacturing of the vehicles. On a public transport scale this type of operation is termed *ride pooling*: Persons expressing a desire to travel in similar spatial directions get assigned to a common vehicle, reducing the parallel travel of multiple vehicles.

To predict the key parameters of demand responsive ride pooling systems and to estimate their market potential a corresponding mean field theory has been developed [1], which is investigated here further in the context of experimental data and computer simulations [2].

[1] Herminghaus, Transportation Research Part A **119** (2019)
[2] Sorge et al., Proceedings of the 2015 Winter Simulation Conference

SOE 6.9 Mon 17:00 P2/4OG

Evaluation of Demand Responsive Ride Pooling on Real Life Taxi Data — •Michael Sternbach[1,2], Felix Jung[1,2], Puneet Sharma[1,2], Stephan Herminghaus[1,2], and Knut Heidemann[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Institute for Dynamics of Complex Systems, University of Göttingen, Germany

Climate change caused by human greenhouse gas (GHG) emissions is one of the vital challenges of humankind. Passenger cars contribute significantly to human GHG emissions. To reduce this effect, more eco-friendly transport modes are needed. Demand responsive ride pooling (DRRP) offers door-to-door service — similar to taxi or personal car — while pooling customers with similar routes on the same vehicle, thereby reducing emissions and the number of cars needed. In this study, we measure the performance of a DRRP system on real life taxi request data and evaluate under which conditions — e. g. request rate, number of vehicles, allowed detour or waiting time — DRRP can operate more efficiently than taxi service at a reasonable service quality. We compare our results to a mean field description of DRRP [1] to analyze the effect of road network structure and spatial request distribution. Our results provide significant insight on the prerequisites for ecological and economic feasibility of DRRP.

[1] Herminghaus, S. (2019). Mean field theory of demand responsive ride pooling systems. Transportation Research Part A: Policy and Practice, 119, 15-28.

SOE 6.10 Mon 17:00 P2/4OG

Comparing spatial distributions of population and stores/facilities based on multifractal analysis — •Mariko Ito and Takaaki Ohnishi — The University of Tokyo, Tokyo, Japan

By multifractal analysis, we can characterize the structural feature of an object in which the density is spatially heterogeneous. The multifractal spectrum obtained from the analysis shows the relationship between the local fractal dimension (singularity strength) and the fractal dimension of all points that have the singularity strength around each of those. We applied multifractal analysis to the investigation on how the population and stores/facilities distribute spatially in the metropolitan area in Japan. As the data of the population and stores/facilities, we used Japanese 100-meter estimated mesh data from national censuses and corporate telephone directory database telepoint with coordinates, respectively.

We derived the multifractal spectrums for the spatial distribution of the population and 39 categories of stores/facilities. We compared the spectrums of the population and the categories, by using the indicators relating to the shape of each spectrum, such as the width of the singularity strength of the spectrum. In this presentation, we will show what kind of stores/facilities possess similar multifractal spectrum to that of the population. We will discuss which categories of stores/facilities are close to the population in the point of view of the spatial distribution.

SOE 6.11 Mon 17:00 P2/4OG

Transition from Hierarchical to Distributed Verification Protocols: Consensus Formation in Transforming Network Topologies — Kateryna Isirova[1,2], Oleksandr Potii[2], and •Jens Christian Claussen[1] — [1]Department of Mathematics, Aston University, Birmingham B4 7ET, U.K. — [2]V. N. Karazin Kharkiv National University, Ukraine

Computer verification protocols are distributed processes on networks and have the goal of reaching an overall consensus state where all nodes become verified through a protocol interaction. An important goal is to ensure the security of such interactions, especially in advent of quantum computing technologies. It might be that in the post-quantum world, the avatar of verification architectures will be manifested through distributed protocols. Here we augment the discussion by explicitely drawing the analogy between distributed protocol consensus formation and consensus formation in social networks in various topologies. Hierarchical networks, in both domains, exhibit slowest timescale of consensus formation. We conclude this supports universal argument towards establishment of distributed protocol mechanisms, wherever the scaleability with network size is of relevance.

SOE 6.12 Mon 17:00 P2/4OG

A model of public opinion with time-dependent media bias, audience attention and social influence. — •Michael Schnabel and Daniel Diermeier — Harris School of Public Policy, University of Chicago, USA

We consider a simple model of binary opinions. Individuals form their opinion based on individual preferences, time dependent media bias and the overall opinions in the population. In addition, we also incorporate a mechanism that is responsive to the salience of the media signal and can be used to account for variations in public attention. We explore how attention affects the opinion dynamics in the population as well as the equilibrium properties in a hypothetical static environment.

SOE 6.13 Mon 17:00 P2/4OG

Masking Motifs in Networks of Coupled Oscillators — •Jonas Wassmer[1,2], Franz Kaiser[1,2], and Dirk Witthaut[1,2] — [1]Forschungszentrum Jülich, Institute for Energy and Climate Research - Systems Analysis and Technology Evaluation (IEK-STE) — [2]University of Cologne, Institute for Theoretical Physics

Electric power grids, vascular networks in leaves and neuronal networks in the human brain are examples of complex networks which are subject to fluctuations. Local changes in the underlying dynamics may affect the whole network and, in the worst case, cause a total collapse of the system through a cascading failure. However, certain network motifs exist, which effectively decouple different network modules and thus reduce failure spreading drastically, or even inhibit it completely. In this contribution we review the function of network isolator motifs for linear flow networks and investigate their operation for non-linear network dynamical systems, such as Kuramoto networks. We demonstrate how these network motifs can hide the source of a perturbation and discuss how they may be applied to improve the robustness of different types of networks.

SOE 6.14 Mon 17:00 P2/4OG

Machine Learning Applications in Energy Research — •Omar El Sayed, Alexander Kies, and Horst Stoecker — Frankfurt Institute for Advanced Studies, Frankfurt, Germany

In recent years, machine learning has received considerable attention in different fields of research. Machine learning provides efficient tools for different applications with respect to energy research. Different applications of machine learning in the field of energy research include:

- forecasting of relevant quantities for power systems such as demand, renewable generation, electricity prices - grid optimisation, monitoring and control - smart future market mechanism based on novel paradigms - accurate energy system modelling, for instance via weather data analysis and generation.

In this work, we show and discuss exemplary applications.

SOE 6.15 Mon 17:00 P2/4OG

Optimal transport flow networks with a linear congestion model — •Matthias Dahlmanns[1,2], Franz Kaiser[1,2], and Dirk Witthaut[1,2] — [1]Forschungszentrum Jülich, Institute for Energy and Climate Research (IEK-STE), 52428 Jülich, Germany — [2]Institute for Theoretical Physics, University of Cologne, 50937 Köln, Germany

In our daily life, we rely on the proper functioning of various types of supply networks, such as power grids, water supply networks or transportation networks. But what determines the optimal structure of such networks, i.e. how should they be designed? And what happens to them in case of link failures or damages?

A variety of analytical results are available for optimal structures and the response to damages for shortest path flow networks on the one hand and potential flow networks, such as electrical power grids, on the other hand.

In a transportation network, however, travelers try to minimise their travel time, but congestion effects occur on highly frequented links due to limited capacity.

In this contribution, we introduce an approach to study the congestion by a travel time that depends linearly on the local flow which leads to a combination of the two well studied flow types. We then focus on the impact of link failures in this interpolating model and analyse the transition between both flow types in detail. Our results can be applied to understand the influence of congestion on the design of optimal traffic flow networks.

SOE 6.16 Mon 17:00 P2/4OG

Die Benutzung der Mathematischen Begriffstheorie von E. Wojschwillo für Analyse der Parteisystemen — •Alexey Iakovlev[1] und Ekaterina Pchelko-Tolstova[2] — [1]TU Dresden, Dresden, Deutschland, RUDN University, Moscow, Russia — [2]RUDN University, Moscow, Russia

Im 21. Jahrhundert gibt es kaum politische Systemen ohne Parteien. Diese Parteien unterscheiden sich voneinander nach den ideologischen Grundlagen ihrer Tätigkeit. Die Ideologie ist meistens als die Grundlage der Klassifizierung der Parteien benutzt. Wenn sie zugeordnet sind, so bilden sie das politische Spektrum. Die Ideologie besteht aus vielen Teilen: Wirtschaftspolitik, Sozialpolitik, Kulturpolitik usw. In der globalisierten Welt bilden mehrere Parteien aus untershiedlichen Ländern die Bündnissen. Sie verbinden sich miteinander nach der Ideologie. Die Politikwissenschaftler und politische Berater prognostizieren die Politik der Länder nach den Wahlergebnissen. Das Problem ist aber, dass oft die Parteien, die als ähnliche bezeichnet wurden, oft ganz unterschiedlich in unterschiedlichen Ländern sind.

Der sowjetische Mathematiker,Logiker und Philosoph Jewgeni Kazimirowitsch Wojschwillo entwickelte seit der 1960-er Jahren die mathematisierte Lehre über den Begriff,die Beziehungen zwischen den Mengen und ihre Klassifizierung zuordnet. Die Benutzung der Mengendiagrammen bei der Arbeit mit den Begriffen und der Definitionen zeigt, welche Parteien zu welchen passen und welche tatsächlich ganz unterschiedlich sind. Das verbessert die Qualität der Prognosen der Dynamik der politischen Systemen.

SOE 6.17 Mon 17:00 P2/4OG

African Swine Fever - potential topic of awareness in social movements — •Andrzej Jarynowski and Vitaly Belik — Institute for Veterinary Epidemiology and Biostatistics, FU Berlin

African Swine Fever (ASF) is a viral infection in domestic pigs and wild boars causing more than one billion EUR yearly losses in Eastern Europe. To illustrate the impact, only in Poland, after introduction in 2014, due to restrictions ca. 90% of farms stopped pig production or were banned. The intensive control measures against ASF in European Union significantly transforms biosecurity, trade, sanitary, environmental etc. regulations and ethics, thus causing protests of various groups of interest as (1) farmers (who are not ready to apply biosecurity measures), (2) animal right defenders (who do not agree with governmental policy of wild boars depopulation) and (3) hunters with public administration (who have to control wild boars population). We analyze ASF topic awareness in the Internet in Poland and Germany. In particular, we reviewed possibility of using Twitter and Facebook data on ecological, animal rights activism, farmers association as well hunters and veterinarians organisations. We showed by using retweeting and following networks from Polish twitter, that meaningfull clusters of agents can be detected. The possible appearance of political consultancy or foreign intelligence in social media, which could polarize society, were observed because Twitter accounts, already classified as potentially suspicious were also propagating anti-government content which fueled animal right movement.

SOE 6.18 Mon 17:00 P2/4OG

Impact of temporal correlations on high risk outbreaks — •Sina Sajjadi, Mohammad Reza Ejtehadi, and Fakhteh Ghanbarnejad — Sharif University of Technology, Tehran, Iran

In this work, we first propose a quantitative approach to detect high risk outbreaks of independent and coinfective SIR dynamics on three empirical networks: a school, a conference and a hospital contact network. This measurement is based on the k-mean clustering method and identify proper samples for calculating the mean outbreak size and the outbreak probability. Then we study systematically impact of different temporal correlations on high risk outbreaks by different

shuffling. We observe that in the coinfection process, randomization of the sequence of the events makes the outbreak, i.e. the mean outbreak size of high risk cases, more pervasive. On the other hand these correlations don't have a consistent effect on the independent infection dynamics, and can either decrease or increase this mean. Our results suggest that some sort of randomizing contacts in organization level of schools, events or hospitals might help to suppress the spreading dynamics while the risk of an outbreak is high.

SOE 6.19 Mon 17:00 P2/4OG

Exact solution of generalized cooperative susceptible-infected-removed (SIR) dynamics — •Fatemeh Zarei[1], Saman Moghimi-Araghi[1], and Fakhteh Ghanbarnejad[1,2,3] — [1]Sharif University of Technology, Tehran, Iran — [2]ITP, Technical University of Berlin, Germany — [3]The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy

In this paper (Phys. Rev. E 100, 012307 (2019)), we introduce a general framework for coinfection as cooperative susceptible-infected-removed (SIR) dynamics. We first solve the SIR model analytically for two symmetric cooperative contagions [L. Chen et al., Europhys. Lett. 104, 50001 (2013)] and then generalize and solve the model exactly in the symmetric scenarios for three and more cooperative contagions. We calculate the transition points and order parameters, i.e., the total number of infected hosts. We show that the behavior of the system does not change qualitatively with the inclusion of more diseases. We also show analytically that there is a saddle-node-like bifurcation for two cooperative SIR dynamics and that the transition is hybrid. Moreover, we investigate where the symmetric solution is stable for initial fluctuations. We finally explore sets of parameters which give rise to asymmetric cases, namely, the asymmetric cases of primary and secondary infection rates of one pathogen with respect to another. This setting can lead to fewer infected hosts, a higher epidemic threshold, and also continuous transitions. These results open the road to a better understanding of disease ecology.

SOE 7: Data analytics for dynamical systems I (Focus Session joint with DY and BP) (joint session SOE/DY/CPP/BP)

Data analytics is often focussed on (generalized) regression to create models of the structure of complex systems. Here we focus on data-driven approaches of data analytics for complex systems that take into account their intrinsic nonlinear dynamics. Applications to natural and human-made systems, from cardiac dynamics to human mobility, illustrate recent progress and current methodological challenges. (Session organized by Marc Timme)

Time: Tuesday 9:30–13:15 Location: GÖR 226

Topical Talk SOE 7.1 Tue 9:30 GÖR 226

One model to rule them all — •Jens Timmer — Institute of Physics, University of Freiburg, Germany

A major goal in systems biology is to reveal potential drug targets for cancer therapy. A common property of cancer cells is the alteration of signaling pathways triggering cell-fate decisions resulting in uncontrolled proliferation and tumor growth. However, addressing cancer-specific alterations experimentally by investigating each node in the signaling network one after the other is difficult or even not possible at all. Here, we use quantitative time-resolved data from different cell lines for non-linear modeling under L1 regularization, which is capable of detecting cell-type specific parameters. To adapt the least-squares numerical optimization routine to L1 regularization, subgradient strategies as well as truncation of proposed optimization steps were implemented. Likelihood-ratio tests were used to determine the optimal penalization strength resulting in a sparse solution in terms of a minimal number of cell-type specific parameters that is in agreement with the data. The uniqueness of the solution is investigated using the profile likelihood. Based on the minimal set of cell-type specific parameters experiments were designed for improving identifiability and to validate the model. The approach constitutes a general method to infer an overarching model with a minimum number of individual parameters for the particular models.

SOE 7.2 Tue 10:00 GÖR 226

Volatility and Fractionality in Power-Grid Frequency — •Leonardo Rydin Gorjão[1,2], Anton Yurchenko-Tytarenko[3], and Dirk Witthaut[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]Department of Mathematics, University of Oslo, P.O. Box 1053 Blindern, N-0316 Oslo

Power-grid frequency is a key indicator of stability in power grids. The trajectory of power-grid frequency embodies several processes of different natures: the control systems enforcing stability, the trade markets, production and demand, and the correlations between these. In this article, we study power-grid frequency from Central Europe, the United Kingdom, and Scandinavia under the umbrella of fractional stochastic processes. We introduce an estimator of the Hurst index for fractional Ornstein–Uhlenbeck processes. We show that power-grid frequency exhibits time-dependent volatility, driven by daily human activity and yearly seasonal cycles. Seasonality is consistently observable in smaller power grids, affecting the correlations in the stochastic noise. The United Kingdom displays daily rhythms of varying volatility, where the noise amplitude consistently doubles its intensity, and displays bi- and tri-modal distributions. Both the Scandinavian and United Kingdom power-grids exhibit varying Hurst indices over yearly scales. All the power grids display highly persistent noise, with Hurst indices above $H > 0.5$.

Topical Talk SOE 7.3 Tue 10:15 GÖR 226

Gaming the system - Analyzing Uber price data reveals anomalous supply shortages — •Malte Schröder[1], David Storch[1], Philip Marszal[1], and Marc Timme[1,2] — [1]Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), TU Dresden — [2]Lakeside Labs, Klagenfurt

Dynamic pricing schemes are ubiquitously employed across industries to balance demand and supply. One well-known example is the ride-hailing platform Uber and their *surge pricing* intended to incentivize drivers to offer their service during times of high demand. However, recent reports [WJLA, Uber, Lyft drivers manipulate fares at Reagan National causing artificial price surges (2019)][Möhlmann and Zalmanson, ICIS 2017 Seoul (2017)] indicate that this surge pricing may instead cause demand-supply imbalances by incentivizing drivers to switch off their app to increase their revenue. Analyzing price estimate time series for trips from 137 locations in 59 urban areas across six continents, we identify locations with strong, repeated price surges. Correlations with demand patterns demonstrate that the observed price surges are indeed driven by supply anomalies instead of demand fluctuations. Moreover, we capture the minimal incentives driving the supply dynamics in a simple game-theoretic model, illustrating that such incentives constitute generic consequences of dynamic pricing schemes.

SOE 7.4 Tue 10:45 GÖR 226

Estimation of Langevin equations with correlated noise for signals of complex systems — •Clemens Willers and Oliver Kamps — Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, Germany

Over the last years, the estimation of stochastic evolution equations of complex systems has been applied in many scientific fields ranging from physics to biology and finance. Especially, Langevin models with delta-correlated noise terms, which realize a Markovian dynamic, have been used successfully in this context [1]. However, many real world data sets exhibit correlated noise and a non-Markovian dynamic, for example data sets from turbulence [2].

To tackle this problem, we use Langevin models containing an added

hidden component which realizes a driving correlated noise. We develop two methods for the systematic estimation of the drift- and diffusion functions, parameterized through spline functions. The first method is based on a likelihood function which is constructed by a short-time propagator for the measured values of the visible component. For the second method, we use a comparison of transition probabilities via Jensen-Shannon divergence. Both methods are demonstrated using real world data sets as the turbulent air flow of a free jet [3], stock market prices [4] and wind energy production [5].

[1] Friedrich et al., Phys. Rep. 506, 87 (2011) [2] Friedrich et al., Phys. Rev. Lett. 78, 863 (1997) [3] Renner et al., J. Fluid Mech. 433, 383 (2001) [4] Nawroth et al., Eur. Phys. J. B 50, 147 (2006) [5] Kamps, in Wind Energy-Impact of Turbulence, Springer 2014, p. 67.

SOE 7.5 Tue 11:00 GÖR 226

Hyper-Parameter Optimization for Identification of Dynamical Systems — •Tobias Wand[1], Alina Steinberg[1], Tim Kroll[2], and Oliver Kamps[2] — [1]Institut für Theoretische Physik, Universität Münster, Deutschland — [2]Center for Nonlinear Science, Universität Münster, Deutschland

In recent years, methods to identify dynamical systems from experimental or numerical data have been developed [1,2]. In this context, the construction of sparse models of dynamical systems has been in the focus of interest and has been applied to different problems. These data analysis methods work with hyper-parameters that have to be adjusted to improve the results of the identification procedure. If more than one hyper-parameter has to be fine-tuned, simple methods like grid search are computationally expensive and due to this, sometimes not feasible. In this talk, we will introduce different approaches to optimally select the hyper-parameters for the identification of sparse dynamical systems.

[1] Brunton et al. Proceedings of the National Academy of Sciences, 2016, 113, 3932-3937
[2] Mangan et al. Proceedings of the Royal Society A, 2017, 473, 20170009

Topical Talk SOE 7.6 Tue 11:15 GÖR 226

Data driven modelling of spatio-temporal chaos in extended dynamical systems — •Ulrich Parlitz[1,2], Sebastian Herzog[1,3], Florentin Wörgötter[3], Roland S. Zimmermann[1,2], Jonas Isensee[1,2], and George Datseris[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Institut für Dynamik komplexer Systeme, Georg-August-Universität Göttingen, Germany — [3]Drittes Physikalische Institut, Georg-August-Universität Göttingen, Germany

Many spatially extended nonlinear systems, an example being excitable media, exhibit complex spatio-temporal dynamics. We shall present machine learning methods to predict the temporal evolution of these systems or estimate their full state from limited observations. The applied techniques include Reservoir Computing [1] and a combination of a Convolutional Autoencoder with a Conditional Random Field [2,3], whose perfomance will be compared to Nearest Neighbours Prediction based on dimension reduced local states [4]. Examples for demonstrating and evaluating the methods employed include the Lorenz-96 model, the Kuramoto-Sivashinsky equation, the Barkley model, and the Bueno-Orovio-Cherry-Fenton model, describing cardiac (arrhythmia) dynamics.

[1] R. S. Zimmermann and U. Parlitz, Chaos 28, 043118 (2018)
[2] S. Herzog et al., Front. Appl. Math. Stat. 4, 60 (2018)
[3] S. Herzog et al., Chaos (to appear) (2019)
[4] J. Isensee, G. Datseris, U. Parlitz, J. of Nonlinear Sci. (2019)

SOE 7.7 Tue 11:45 GÖR 226

Predicting Spatio-Temporal Time Series Using Dimension Reduced Local States — •Jonas Isensee[1,2], George Datseris[1,2], and Ulrich Parlitz[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Institut für Dynamik komplexer Systeme, Georg-August Universität Göttingen, Germany

Understanding dynamics in spatially extended systems is central to describing many physical and biological systems that exhibit behaviour such as turbulence and wave propagation. Correctly predicting dynamics is advantageous in experimental settings and data-driven approaches are useful, particularly when no adequate mathematical models are available. We present an approach to iterated time series prediction of spatio-temporal dynamics based on local delay coordinate states and local modeling using nearest neighbour methods [1]. A crucial step in this process is to find predictive yet low-dimensional descriptions of the local dynamics . We discuss how imposing symmetries on the dynamics can be used to increase the predictiveness of our approach. The efficacy of this approach is shown for (noisy) data from a cubic Barkley model, the Bueno-Orovio-Cherry-Fenton model.

[1] J. Isensee, G. Datseris, U. Parlitz, J. of Nonlinear Sci. (2019)

Topical Talk SOE 7.8 Tue 12:00 GÖR 226

Limits to predictability of complex systems dynamics — Jonathan Brisch and •Holger Kantz — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Motivated by the challenges of weather forecasting and the well known fact that atmospheric dynamics takes place on many temporal and spatial scales, we discuss the possibility of scale dependent error growth and its consequences for predictions. In case that the growth rate of small errors depends on the error magnitude as an inverse power law, we can explain why forecasts of macroscopic observables can be successful on time scales which are orders of magnitude longer than the (estimated) Lyapunov time, and at the same time we find a strictly finite prediction horizon even for arbitrary accuracy of the initial condition. We propose a hierarchical model class, which is able to generate such an error growth behaviour, and finally we re-analyze published data of error-growth in a numerical weather forecast system to present evidence that the error growth rate there is indeed consistent with a power law with diverging growth rate for infinitesimal errors. It is plausible that the same mechanism is active in other complex phenomena which live on a variety of spatial and temporal scales.

SOE 7.9 Tue 12:30 GÖR 226

Network inference from event sequences: Disentangling synchrony from serial dependency — •Reik Donner[1,2], Forough Hassanibesheli[2,3], Frederik Wolf[2,3], and Adrian Odenweller[4,5] — [1]Magdeburg-Stendal University of Applied Sciences, Magdeburg — [2]Potsdam Institute for Climate Impact Research — [3]Department of Physics, Humboldt University, Berlin — [4]Center for Earth System Research and Sustainability, University of Hamburg — [5]Max Planck Institute for Meteorology, Hamburg

Inferring coupling among interacting units or quantifying their synchronization based on the timing of discrete events has vast applications in neuroscience, climate, or economics. Here, we focus on two prominent concepts that have been widely used in the past - event synchronization (ES) and event coincidence analysis (ECA). Numerical performance studies for two different types of spreading processes on paradigmatic network architectures reveal that both methods are generally suitable for correctly identifying the unknown links. By further applying both concepts to spatiotemporal climate datasets, we demonstrate that unlike ECA, ES systematically underestimates linkages in the presence of temporal event clustering, which needs to be accounted for in network reconstruction from data. In turn, for spike train data from multi-channel EEG recordings (with relatively narrow inter-event time distributions), the obtained results are practically indistinguishable. Our findings allow deriving practical recommendations for suitable data preprocessing in the context of network inference and synchronization assessment from event data.

SOE 7.10 Tue 12:45 GÖR 226

Reconstruction of nonlinear correlations and dynamical laws — Mirko Rossini, Konstantin Schmitz, and •Jürgen Stockburger — ICQ, Ulm University, Germany

Time series taken from a stationary process may feature dependencies far more subtle than linear correlations. We introduce a method based on non-linear feature extraction which can uncover and quantify such dependencies. Its utility is demonstrated using both synthetic and real-world data.

SOE 7.11 Tue 13:00 GÖR 226

Collective Response of Reservoir Networks — •Arash Akrami, Fabio Schittler Neves, Xiaozhu Zhang, Malte Schröder, and Marc Timme — Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), TU Dresden

Reservoir Computing constitutes a paradigm of bio-inspired machine learning relying on dynamical systems theory, that exploits high dimensionality of a large network of processing units (reservoir). However, as the collective dynamics of artificial neural networks is far from understood, their learning outcome is hardly predictable or transparent.

In Reservoir Computing systems, learning occurs exclusively in a read-out layer, with the intrinsic reservoir dynamics freely evolving.

Here we study reservoirs of processing units with linear activation functions, i.e., linear reservoirs and analytically predict the dynamic responses of all network units as a function of general, distributed and time-dependent input signals. These insights may help identifying nodes especially suitable for receiving input signals, and finding minimal reservoirs capable of performing a given task.

SOE 8: Climate Impact and Human-Economy-Nature Interactions (accompanying the symposium SYCE)

Time: Wednesday 12:15–13:00 Location: HSZ 02

Topical Talk SOE 8.1 Wed 12:15 HSZ 02

A physics of governance networks: critical transitions in contagion dynamics on multilayer adaptive networks with application to the sustainable use of renewable resources — •Jonathan F. Donges[1,2], Fabian Geier[1], Wolfram Barfuss[1,3], and Marc Wiedermann[1,3] — [1]Potsdam Institute for Climate Impact Research, Potsdam, Germany — [2]Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden — [3]Department of Physics, Humboldt University, Berlin, Germany

Adaptive network models are promising tools to analyze complex interactions in coupled human-economy-nature systems in the context of climate change mitigation and sustainability transformations. Here, we focus on a three-layer adaptive network model, where a polycentric governance network interacts with a social network of resource users which in turn interacts with an ecological network of renewable resources. We uncover that sustainability is favored for slow interaction timescales, large homophilic network adaptation rate (as long it is below the fragmentation threshold) and high taxation rates. We also observe a trade-off between an eco-dictatorship and the polycentric governance network of multiple actors. In the latter setup, sustainability is enhanced for low but hindered for high tax rates compared to the eco-dictatorship case. These results highlight mechanisms generating emergent critical transitions in contagion dynamics on multilayer adaptive networks and show how these can be understood and approximated analytically, relevant for understanding complex adaptive systems from various disciplines ranging from physics to epidemiology.

SOE 8.2 Wed 12:45 HSZ 02

Dynamic emergence of domino effects in systems of interacting tipping elements in ecology and climate — •Ann Kristin Klose[1,2], Volker Karle[1,3], Ricarda Winkelmann[1,4], and Jonathan Donges[1,5] — [1]Earth System Analysis, Potsdam Institute for Climate Impact Research, Potsdam, Germany — [2]Carl von Ossietzky University Oldenburg, Oldenburg, Germany — [3]Institute of Science and Technology Austria, Klosterneuburg, Austria — [4]Department of Physics and Astronomy, University of Potsdam, Potsdam, Germany — [5]Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden

In ecology, climate and other fields, systems have been identified that can transition into a qualitatively different state when a critical threshold in a driving process is crossed. An understanding of those tipping elements is of great interest given the increasing influence of humans on the biophysical Earth system. Tipping elements are not independent from each other as there exist complex interactions. Based on earlier work on such coupled nonlinear systems, we systematically assessed the qualitative asymptotic behavior of interacting tipping elements. We developed an understanding of the consequences of interactions on the tipping behavior allowing for domino effects to emerge under certain conditions. The application of these qualitative results to real-world examples of interacting tipping elements shows that domino effects with profound consequences can occur and calls for the development of a unified theory of interacting tipping elements and the quantitative analysis of interacting real-world tipping elements.

SOE 9: Partial Synchronization Patterns in Neuronal Networks I (Focus Session joint with DY / SOE / BP) (joint session SOE/DY)

Understanding the dynamics of the human brain is one of the main scientific challenges today. Synchronization is important for information transmission in the brain and also plays a central role in various neurological diseases, such as Alzheimer's disease and epilepsy, for example. It is therefore crucial to develop and analyze models of brain circuits in which various synchronization patterns appear. In this focus session we show how these patterns emerge in models of neuronal networks, with particular attention to chimera states, solitary states but also with a broader outlook on partial synchronization in general. We aim to bring together scientists from different backgrounds to share ideas, in particular on analogies between partial synchronization in model systems and physiological processes in the brain. (Session organized by Giulia Ruzzene and Iryna Omelchenko)

Time: Wednesday 15:00–17:15 Location: GÖR 226

Invited Talk SOE 9.1 Wed 15:00 GÖR 226

Cross frequency coupling in next generation inhibitory neural mass models — •Simona Olmi[1], Andrea Ceni[2], David Angulo Garcia[3], and Alessandro Torcini[4] — [1]Inria Sophia Antipolis Mediterranee Research Centre, 2004 Route des Lucioles, 06902 Valbonne, France — [2]Department of Computer Science, College of Engineering, Mathematics and Physical Sciences, University of Exeter, UK — [3]Grupo de Modelado Computacional - Dinamica y Complejidad de Sistemas. Instituto de Matematicas Aplicadas, Universidad de Cartagena, Colombia — [4]Laboratoire de Physique Theorique et Modelisation, Universite de Cergy-Pontoise, 95302 Cergy-Pontoise cedex, France

Coupling among neural rhythms is one of the most important mechanisms at the basis of cognitive processes in the brain. In this study we consider a neural mass model, rigorously obtained from the microscopic dynamics of an inhibitory spiking network with exponential synapses, able to autonomously generate collective oscillations. Furthermore, we show that two inhibitory populations in a master-slave configuration with different synaptic time scales can display various collective dynamical regimes: namely, damped oscillations towards a stable focus, periodic and quasi-periodic oscillations, and chaos. Finally, when bidirectionally coupled, the two inhibitory populations can exhibit different types of θ-γ cross-frequency couplings: namely, phase-phase and phase-amplitude cross-frequency couplings.

Topical Talk SOE 9.2 Wed 15:30 GÖR 226

Brain functional connectivity asymmetry — •Jaroslav Hlinka — Institute of Computer Science of the Czech Academy of Sciences, Prague, Czech Republic

The brain is one of the iconic complex systems with a very intricate structure of interconnections and interactions among its many parts. It is also commonly studied via application of graph-theoretical approaches [1], while the representative graph can be defined using the functional connectivity approach: two brain regions are considered connected to an extent given by the strength of their activity syn-

chronization, assessed by the statistical dependence between their activity as sampled over time, typicaly by linear correlation [2]. The human brain is organized into two almost symmetrical hemispheres, with the hemispheres containing further subdivision into key subnetworks/modules. However, there is some level of asymmetry that is known to be functionally relevant; in the current contribution we provide evidence that the left hemisphere functional connectivity, experimentally observed in resting state by functional magnetic resonance imaging, has more modular structure. We further discuss the origin of this asymmetry in structure or dynamics [3], its functional relevance and robustness with respect to methodological choices.

[1] Bullmore, E. et al. Nature Reviews Neuroscience, 2009, 10, 186-198

[2] Hlinka, J. et al. NeuroImage, 2011, 54, 2218-2225

[3] Hlinka, J. & Coombes, S., European Journal of Neuroscience, 2012, 36, 2137-2145

Topical Talk SOE 9.3 Wed 16:00 GÖR 226

Partial Synchronization Patterns in the Brain — •Eckehard Schöll — Institut für Theoretische Physik, Technische Universität Berlin

Partial synchronization patterns play an important role in the functioning of neuronal networks, both in pathological and in healthy states. They include chimera states, which consist of spatially coexisting domains of coherent (synchronized) and incoherent (desynchronized) dynamics. We show that partial synchronization scenarios are governed by a delicate interplay of local dynamics, network topology, and time delay. Our focus is in particular on applications of brain dynamics like unihemispheric sleep [1], epileptic seizure [2], and relay synchronization between distant areas of the brain.

[1] Ramlow, L., Sawicki, J., Zakharova, A., Hlinka, J., Claussen, J. C. and Schöll, E., Partial synchronization in empirical brain networks as a model for unihemispheric sleep, EPL 126, 50007 (2019), highlighted in phys.org https://phys.org/news/2019-07-unihemispheric-humans.html and Europhys. News 50 no.5-6 (2019).

[2] Chouzouris, T., Omelchenko, I., Zakharova, A., Hlinka, J., Jiruska, P. and Schöll, E., Chimera states in brain networks: empirical neural vs. modular fractal connectivity, Chaos 28, 045112 (2018).

SOE 9.4 Wed 16:30 GÖR 226

Coexistence of fast and slow gamma oscillations in one population of inhibitory spiking neurons — Hongjie Bi, Marco Segneri, Matteo di Volo, and •Alessandro Torcini — Laboratoire de Physique Théorique et Modélisation, Université de Cergy-Pontoise, CNRS, UMR 8089, Cergy-Pontoise, France

Oscillations are a hallmark of neural population activity in various brain regions with a spectrum covering a wide range of frequencies. Within this spectrum gamma oscillations have received particular attention due to their ubiquitous nature and to their correlation with higher brain functions. Recently, it has been reported that gamma oscillations in the hippocampus of behaving rodents are segregated in two distinct frequency bands: slow and fast. These two gamma rhythms correspond to different states of the network, but their origin has been not yet clarified. We show that a single inhibitory population can give rise to coexisting slow and fast gamma rhythms corresponding to collective oscillations of a balanced spiking network. The slow and fast gamma rhythms are generated via two different mechanisms: the fast one being driven by the coordinated tonic neural firing and the slow one by endogenous fluctuations due to irregular neural activity. Furthermore, to make a closer contact with the experimental observations, we consider the modulation of the gamma rhythms induced by a slower (theta) rhythm driving the network dynamics. In this context, depending on the strength of the forcing and the noise amplitude, we observe phase-phase coupling with different theta-phases preferences for the two coexisting gamma rhythms.

SOE 9.5 Wed 17:00 GÖR 226

Solitary States in Neural Networks — •Leonhard Schülen and Anna Zakharova — Institut für theoretische Physik, Technische Universität Berlin, Deutschland

Understanding mechanisms of desynchronization plays a significant role in the study of neural networks. Dynamical scenario of transition from pathological neural synchrony to a healthy state can involve partial synchronization patterns, such as chimera states or solitary states. The term "solitary" comes from the Latin "solitarius" and can be understood as "alone", "lonely", or "isolated". In the case of chimera states, a network spontaneously splits into coexisting domains of synchronized and desynchronized behavior, which are localized in space. For solitary states, on the contrary, it is typical that individual "solitary" oscillators split off from the synchronized cluster at random positions in space. Here we discuss the formation of solitary states and, in particular, the conditions under which these patterns occur in one-layer and two-layer networks of oscillatory FitzHugh-Nagumo neurons. Furthermore, we present a technique that allows to engineer solitary states. By delaying links of selected nodes we are able to control their position and displacement with respect to the synchronized cluster.

SOE 10: Data Analytics, Extreme Events, Nonlinear Stochastic Systems, and Networks (joint session DY/SOE)

Time: Wednesday 15:00–17:30 Location: ZEU 118

Invited Talk SOE 10.1 Wed 15:00 ZEU 118

I want it all and I want it now! — •Alexander K. Hartmann — University of Oldenburg, Germany

For every random process, all measurable quantities are described comprehensively through their probability distributions. Ideally, they would be obtained analytically, i.e., completely. Since most physical models are not accessible analytically, one has to perform numerical simulations. Usually this means one does many independent runs, allowing one to measure histograms. Since the number of repetitions is limited, maybe 10 million, correspondingly the distributions can be estimated in a range down to probabilities like 10^{-10}. But what if one wants to obtain the full distribution, in the spirit of obtaining all information? Thus, one desires to get the distribution down to the rare events, without waiting for a huge running time.

Here, we study rare events using a very general black-box method [1]. It is based on sampling vectors of random numbers within an artificial finite-temperature (Boltzmann) ensemble to access rare events and large deviations for almost arbitrary equilibrium and non-equilibrium processes. In this way, we obtain probabilities as small as 10^{-500} and smaller, hence (almost) the full distribution can be obtained in a reasonable amount of time. Examples are presented for applications to random graphs [2], traffic flow models, biological sequence alignment, particle diffusion, or calculation of partition functions [3].

[1] A.K. Hartmann, Phys. Rev. E **89**, 052103 (2014)

[2] A.K. Hartmann and M. Mézard, Phys. Rev. E **97**, 032128 (2018)

[3] A.K. Hartmann, Phys. Rev. Lett. **94**, 050601 (2005)

SOE 10.2 Wed 15:30 ZEU 118

Constructing accurate and data-efficient molecular force-fields with machine learning — •Igor Poltavskyi, Grégory Fonseca, Valentin Vassilev-Galindo, and Alexandre Tkatchenko — University of Luxembourg, Luxembourg

Employing machine learning (ML) force-fields (FF) is becoming a standard tool in modern computational physics and chemistry. Reproducing potential energy surfaces of any complexity, ML models extend our horizons far beyond the reach of *ab initio* calculations. One can already perform nanosecond-long molecular dynamics simulations for molecules containing up to a few tens of atoms on a coupled-cluster level of accuracy, providing invaluable information about subtle details of intra-molecular interactions [1,2]. Next challenges are constructing ML FFs to molecules with 1000s of atoms and describing far-from-equilibrium geometries without losing accuracy and efficiency. To reach these goals, we developed methods for optimizing reference datasets and partitioning the problem of training global FFs into parts. By minimizing the prediction error for subsets of molecular configurations obtained by clustering, we can build ML FFs equally applicable for the entire range of reference data. Dividing the configuration space into sub-domains by physical and chemical properties, training corresponding ML models, and combining them into one global model enables highly-accurate FFs for molecules containing hundreds of atoms.

[1] Sauceda *et al.*, J. Chem. Phys. **150**, 114102 (2019).
[2] Chmiela *et al.*, Nat. Commun., **9**(1), 3887 (2018).

SOE 10.3 Wed 15:45 ZEU 118

Interpretable Embeddings from Molecular Simulations Using Gaussian Mixture Variational Autoencoders — •Yasemin Bozkurt Varolgunes[1,2], Tristan Bereau[1], and Joseph F. Rudzinski[1] — [1]Max Planck Institute for Polymer Research, Mainz, Germany — [2]Koc University, Istanbul, Turkey

Extracting insight from the molecular simulations data requires the identification of a few collective variables (CVs) whose corresponding low-dimensional free-energy landscape (FEL) retains the essential features of the underlying system. Autoencoders are powerful tools for dimensionality reduction, as they naturally force an information bottleneck. While variational autoencoders (VAEs) ensure continuity of the embedding by assuming a Gaussian prior, this is at odds with the multi-basin FELs that typically arise from the identification of meaningful CVs. Here, we incorporate this physical intuition into the prior by employing a Gaussian mixture variational autoencoder (GMVAE), which encourages the separation of metastable states within the embedding. The GMVAE performs dimensionality reduction and clustering within a single unified framework, and is capable of identifying the inherent dimensionality of the input data, in terms of the number of Gaussians required to categorize the data. We illustrate our approach on two toy models and a peptide, demonstrating the anti-clustering effect of the prior relative to standard VAEs. The resulting embeddings stand as appropriate representations for constructing Markov state models, highlighting the transferability of the dimensionality reduction from static equilibrium properties to dynamics.

SOE 10.4 Wed 16:00 ZEU 118

The entropy of the longest increasing subsequences: typical and extreme sequences — Phil Krabbe[1], •Hendrik Schawe[1,2], and Alexander K. Hartmann[1] — [1]Carl von Ossietzky Universität Oldenburg, Germany — [2]Laboratoire de Physique Théorique et Modèlisation, Université de Cergy-Pontoise, France

Consider a game, where you get a sequence of n numbers. Your objective is to circle the maximum amount of numbers such that each circled number is larger than all circled numbers to their left. To circle the maximum amount numbers, one can calculate the *longest increasing subsequence* (LIS). If the sequence of numbers is a random permutation, this problem is remarkably well studied and for the length L, or in our game the number of circles, not only the mean value, but the whole distribution is known [1,2]. In recent time it was shown that this problem is equivalent to certain surface growth and ballistic deposition models, which led to a large interest from physicists.

Note that the LIS is not unique, there are possibly multiple ways to circle L numbers. While this degeneracy M is expected to increase exponentially with the sequence length n [1], we introduce an algorithm to count the number of degenerate LIS and sample uniformly from all LIS of a given sequence. Especially, we obtain the distribution $P(M)$ down into its far tails with probabilities smaller than 10^{-100} using sophisticated Markov chain sampling methods [3].

[1] D. Romik, The Surprising Mathematics of Longest Increasing Subsequences (2015); [2] J. Börjes, H. Schawe, A. K. Hartmann, Phys. Rev. E 99 (4), 042104 (2019); [3] A.K. Hartmann, EPJB 84, 627 (2011)

15 min. break.

SOE 10.5 Wed 16:30 ZEU 118

Large-deviation simulation of height distribution for the KPZ equation: dependence on initial conditions and morphologie of extreme configurations — •Alexander K. Hartmann[1], Pierre Le Doussal[2], Alexandre Krajenbrink[2], Baruch Meerson[3], and Pavel Sasorov[4] — [1]University of Oldenburg, Germany — [2]Ecole Normale Supérieure, Paris, France — [3]Hebrew University of Jerusalem, Israel — [4]Keldysh Institute of Applied Mathematics, Moscow, Russia

The distribution of relative free energies H of directed polymers in disordered media is studied, which is in the KPZ universality class. We study the distribution at large temperatures, corresponding to short times in KPZ. Using a statistical mechanics-based *large-deviation approach*, the distribution can be obtained over a large range of the support, down to a probability density as small as 10^{-1000} [1]. We compare with analytical predictions for different types of initial conditions and for full as well as for half space [2]. A very good agreement is found for $H < 0$ and a strong convergence is visible for $H > 0$. Furthermore, we study the morphology of atypical fluctuations [3], compare with analytical results from the *optimal fluctuation method*, and find again a good agreement.

[1] A.K. Hartmann, P. Le Doussal, S.N. Majumdar, A. Rosso and G. Schehr, Europhys. Lett. 121, 67004 (2018).
[2] A.K. Hartmann, A. Krajenbrink, and P. Le Doussal, preprint arXiv:1909.0384.
[2] A.K. Hartmann, B. Meerson, and P. Sasorov, arXiv: 1907.05677.

SOE 10.6 Wed 16:45 ZEU 118

Machine Learning on temperature fluctuations in health and disease — •Jens Karschau, Sona Michlíková, Daniel Kotik, Sebastian Starke, Steffen Löck, and Damian McLeod — OncoRay, HZDR, TU Dresden, Dresden, Germany

Rendering disease diagnoses from measurements is a highly complex task. Clinicians train for many years in order to identify pathological events from patient data. Exemplarily, medical expert knowledge recognises subtle differences between normal and tumor-looking features. Today, machine learning (ML) allows us to support not only the clinical decision maker during classification; it also has potential to promptly warn self-monitored individuals. We developed an RNN model that learns on time series temperature data of up to 120 days to detect cancer features in mice. It successfully bins particular days into either tumor vs. no-tumor days. Using out-of-sample data from the same or a different cohort, the model successfully classifies with an accuracy and AUC of up to 0.80. The dynamic time warping dissimilarity measure applied to different days indicates that oscillation patterns contain distinctive features that the RNN model learns. We hypothesise that the model learns features based on oscillatory behaviour at the 150 min time scale: the so-called 'ultradian' rhythm. The double benefit from our method is: (a) it uses non-invasive measurements to classify the disease state and (b) it could be deployed for applications in future on-line monitoring of data from wearable devices. Our next efforts are testing human data to deliver actionable insights in disease control and decision support.

SOE 10.7 Wed 17:00 ZEU 118

Using data crawling and flexible semantic data models to enable sustainable research data management — •Alexander Schlemmer[1,2,3], Ulrich Parlitz[1,2,4], and Stefan Luther[1,2,4,5] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]German Center for Cardiovascular Research (DZHK), Partner Site Göttingen, Germany — [3]IndiScale GmbH, Göttingen, Germany — [4]Institute for the Dynamics of Complex Systems, Georg-August-Universität Göttingen, Germany — [5]Institute of Pharmacology and Toxicology, University Medical Center Göttingen, Germany

Despite the significant advances in computation power and information technology of the last decades, scientific data management is still lacking widespread adoption in many scientific communities. The absence of standardized workflows and corresponding tools significantly impedes complete transparency and reproducibility of research results.

We discuss key concepts to remove omnipresent barriers in scientific data management. Specifically, data crawling strategies and flexible semantic data models are highlighted. With examples using our open source software CaosDB (https://doi.org/10.3390/data4020083) we show how these concepts can be practically applied in order to achieve sustainable research data management.

SOE 10.8 Wed 17:15 ZEU 118

Non-Markovian barrier crossing with two-time-scale memory is dominated by the faster memory component — •Julian Kappler, Victor B. Hinrichsen, and Roland R. Netz — Freie Universität Berlin, Fachbereich Physik, Berlin, Germany

We investigate non-Markovian barrier-crossing kinetics of a massive particle in one dimension in the presence of a memory function that is the sum of two exponentials with different memory times. Our Langevin simulations for the special case where both exponentials contribute equally to the total friction show that the barrier-crossing time becomes independent of the longer memory time if at least one of the two memory times is larger than the intrinsic diffusion time. When we associate memory effects with coupled degrees of freedom that are orthogonal to a one-dimensional reaction coordinate, this counterintuitive result shows that the faster orthogonal degrees of freedom dominate barrier-crossing kinetics in the non-Markovian limit and that the slower orthogonal degrees become negligible, quite contrary to the standard time-scale separation assumption. We construct a crossover

formula for the barrier crossing time that is valid for general multi-exponential memory kernels. This formula can be used to estimate barrier-crossing times for general memory functions for high friction, i.e. in the overdamped regime, as well as for low friction, i.e. in the inertial regime.

SOE 11: Networks - From Topology to Dynamics I (joint SOE/DY/BP)

Time: Wednesday 17:30–18:30 Location: GÖR 226

SOE 11.1 Wed 17:30 GÖR 226

Scaling and Fluctuation Scaling in Systems and Networks of Constant Size — •Cornelia Metzig[1] and Caroline Colijn[2] — [1]Queen Mary University of London, UK — [2]Simon Fraser University, Burnaby, Canada

We propose a preferential-attachment-type model for a system of constant size which applies to urn/ball systems and to networks. It generates a power law for the size (or degree) distribution with exponential cutoff depending on parameters. This distribution can be explained by maximization of the Gibbs-Shannon entropy for one iteration of the stochastic process. We use as constraint the information on the growth of individual urns. Alternatively it is possible to calculate the exact probabilities. Another distribution that often occurs together with power laws, a 'tent-shaped' growth rate distribution, comes out naturally from this model. We confirm our theoretical results with numerical simulations and by another method using recursively calculated exact probabilities.

SOE 11.2 Wed 17:45 GÖR 226

Inferring political spaces from retweet networks — •Eckehard Olbrich, Felix Gaisbauer, Armin Pournaki, and Sven Banisch — Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany, Leipzig,

When people analyze retweet networks from Twitter it is quite common to interpret visualizations generated by some force-directed layout algorithm as political spaces in the sense that distances between nodes are interpreted as political distances. We investigate, under which conditions this is a valid interpretation by building a statistical model for retweet networks in political spaces, i.e. where the agents have a position in a metric space and the retweet probability depends on their distance. These models can be considered as extensions of spatial random graph models for social networks, for which inference algorithms of the underlying social spaces are known [1]. We show that force-directed layout algorithms can be related to maximum likelihood estimators of theses models by using gradient decent. Finally, we propose layout algorithms that are specifically adapted to the task of embedding the graph in a political space.

[1] P. D. Hoff, A. E. Raftery, and M. S. Handcock (2002). Latent space approaches to social network analysis. Journal of the american Statistical association, 97(460), 1090-1098.

SOE 11.3 Wed 18:00 GÖR 226

Exact sampling of connected graphs with a given degree sequence — •Szabolcs Horvát and Carl Modes — Center for Systems Biology Dresden

Sampling random graphs with various constraints is an essential tool for network analysis and modelling, with the connectedness of graph being a common additional requirement. Here we present an algorithm to sample simple connected graphs with a given degree sequence. Most current methods fall into two categories, each with its specific limitations: 1. Rejection-based sampling, such as the configuration model, cannot handle dense graphs due to a very high rate of rejections. 2. Methods based on Markov-chain Monte Carlo cannot guarantee the independence of samples due to unknown mixing times. Recently, a new rejection-free class of methods was proposed that can sample with exact probabilities and generates the sampling weight together with each sample. We describe and implement a generalisation of these methods to sample from the set of connected realisations.

SOE 11.4 Wed 18:15 GÖR 226

Revealing network size from the dynamics of a single node? — •Georg Börner[1], Hauke Haehne[2], Jose Casadiego[1], and Marc Timme[1] — [1]Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), TU Dresden — [2]Institute for Physics, Carl von Ossietzky University Oldenburg

Networks are ubiquitous in the natural and human-made world and their dynamics fundamentally underlie the function of a variety of systems, from gene regulation in the cell and the activity of neuronal circuits to the distribution of electric power and the transport of people and goods.

Recent work [1] introduced a method to infer the size of a network, its number of dynamical variables, from measuring times series of a fraction of its units only. Here we demonstrate that size inference is possible even from the observed time series of a single unit. We state mathematical conditions required for such inference in principle and show that, in practice, the success depends strongly on numerical constraints as well as on experimental decisions. We illustrate successful size inference for systems of $N = 18$ variables and point to ways for improving the reliability and power of the reconstruction. We briefly comment on how the success of the approach depends on the quality and quantity of collected data and formulate some general rules of thumb on how to approach the measurement of a given system.

[1] H. Haehne et al., Detecting Hidden Units and Network Size from Perceptible Dynamics Phys. Rev. Lett. 122:158301 (2019).

SOE 12: Annual Member's Assembly

Agenda: 1. Report of the Chairpersons. 2. Announcements and Discussion of future Activities. 3. Elections. 4. Miscellaneous.

Time: Wednesday 18:30–19:30 Location: GÖR 226

Annual Assembly of SOE, all participants are welcome to attend.

SOE 13: Focus Session: Opinion Formation

The dynamics of opinion formation is quite an interdisciplinary topic. It has gained increased attention in recent years since the emergence of filter bubbles and opinion polarization have been recognized as major societal problems. Further on, access to social media data has increased the options to study opinion formation data-driven. This focus session will present recent theoretical and empirical research on the dynamic of opinion formation for binary as well as for continuous opinions. (Session organized by Jan Lorenz)

Time: Thursday 9:30–11:30 Location: GÖR 226

SOE 13.1 Thu 9:30 GÖR 226

On Communicative Mechanisms Producing Filter Bubbles — •Jan Lorenz[1], Daniel Geschke[2], and Peter Holtz[3] — [1]Jacobs University Bremen, Germany — [2]Institut für Demokratie und Zivilgesellschaft, Jena, Gemany — [3]Leibniz-Institut für Wissensmedien IWM, Tübingen, Germany

The emergence of filter bubbles and echo chambers is a combined outcome of information filtering processes taking place on the individual, the social, and technological levels. Within this triple-filter-bubble framework, we construct an agent-based model and analyze different information filtering scenarios to answer the question under which circumstances social media and recommender algorithms contribute to fragmentation of modern society into distinct echo chambers. Simulations show that, even without any social or technological filters, echo chambers emerge as a consequence of cognitive mechanisms, such as confirmation bias, under conditions of central information propagation through channels reaching a large part of the population. When social and technological filtering mechanisms are added to the model, polarization of society into even more distinct and less interconnected echo chambers is observed. Directions for future research will be discussed, in particular, the link to social media data as well as a full characterization of systems dynamics.

SOE 13.2 Thu 9:45 GÖR 226

Do filter bubbles contribute to opinion polarization in online social networks? Insights from opinion-dynamics modeling. — •Michael Mäs — University of Groningen, Groningen, The Netherlands

Political events such as the Brexit referendum, the election of Donald Trump, and the success of populists in democratic elections have sparked public and scholarly discussion about the effects of online-communication technology on public debate and collective decision-making. In particular, it has been warned that personalization algorithms installed in online social-networks, and search engines contribute to the formation of so-called 'filter bubbles'. These bubbles isolate users from information that challenges their views and expose them to content that is in line with their opinions. It has been warned that this contributes to opinion polarization, a dynamic where competing political camps develop increasingly opposing political views. Here, I summarize research on the relationship between personalization and polarization. While I echo the warning that personalization can affect societal processes, I demonstrate that we leap to conclusions when we propose that personalization is responsible for increased polarization. Analyzing models of opinion dynamics in networks, I show that we lack crucial empirical insight into the microprocess of social influence and the aggregation of repeated influence to macroprocesses of opinion polarization.

SOE 13.3 Thu 10:00 GÖR 226

User interactions on Twitter: Retweet versus reply networks — •Felix Gaisbauer, Armin Pournaki, Sven Banisch, and Eckehard Olbrich — Max Planck Institute for Mathematics in the Sciences

User interaction on social media platforms, especially on Twitter, has been used extensively to monitor and analyse the spectra of political opinion and often serves as an empirical basis for modelling and investigating opinion dynamics. But previous studies on polarization and user interaction on Twitter have mainly focused on so-called retweet networks. There, separate clusters of users, which share content of each other, might be identified, and users of each cluster can then be assigned a certain political leaning on the topic under investigation.[1] We will show in this contribution that a retweet network alone often lacks crucial information about political discourse: It does not capture direct response patterns between users in general and specifically between users of different opinion groups. The communication (or lack thereof), apart from the simple information transfer by retweeting, is missed. Information about this type of interaction can be gathered with a reply network, constructed from the replies of users between each other. We analyse, among others, tweets about the Saxonian state elections of 2019 in order to substantiate this claim.

[1] Conover et al.: Political Polarization on Twitter. Fifth International AAAI Conference on Weblogs and Social Media (2011)

SOE 13.4 Thu 10:15 GÖR 226

Polarization in Opinion Landscapes — •Martin Gestefeld, Nils Tobias Henschel, Jan Lorenz, and Klaus Boehnke — Jacobs University Bremen, Germany

In recent years, politics and especially opinion formation in society appears to be more polarized than in the years before. Polarization can been proven in specific topics but there is still a lack of evidence for a general trend in society. First, in an exploratory data analysis, the evolution of individual responses has been analyzed on the left-right political self-placements and similar attitude in survey data. Trends in these aspects are captured and compared in the contexts of country and topic using representative survey data from 9 rounds of the European Social Survey. Applying a simple model demonstrates that people who placed their opinions on a 0 to 10 scale can be split up into 5 different groups. In addition to this model various formal measurements can be applied and provide information on the degree of polarization in distributions of attitudes. Concluding, this work extracts polarization and leads to an improved perspective on opinion formations through social surveys.

SOE 13.5 Thu 10:30 GÖR 226

Repulsion drives public opinion into fifty-fifty stalemate — •Sebastian M. Krause[1], Fritz Weyhausen-Brinkmann[2], and Stefan Bornholdt[2] — [1]University of Duisburg-Essen, Lotharstr. 1, 47048 Duisburg — [2]University of Bremen, Otto-Hahn-Allee, 28359 Bremen

The public opinion is often trapped in a fifty-fifty stalemate, especially in controversial debates. This jeopardizes broadly accepted political decisions. Here we demonstrate that fifty-fifty stalemates are favored in case of strong repulsion from opinions [1]. We study a voter model with two opinions and an undecided state in between. In pairwise discussions, undecided agents can be not only convinced, but also repelled from the opinion expressed by another agent, and decided agents may doubt and return to the undecided state. We find that the frequencies of both opinions equalize if an agent is repelled instead of being convinced in at least one out of four interactions, as in controversial debates. This voter model attractor reproduces the phenomenology of repeated Brexit poll data well.

[1] S.M. Krause, F. Weyhausen-Brinkmann, S. Bornholdt, Repulsion in controversial debate drives public opinion into fifty-fifty stalemate, PRE 100 (2019) 042307.

SOE 13.6 Thu 10:45 GÖR 226

Opinion Formation in distributed topologies: the voter model on hierarchical networks — Kateryna Isirova[1,2], Oleksandr Potii[2], and •Jens Christian Claussen[1] — [1]Department of Mathematics, Aston University, Birmingham B4 7ET, U.K. — [2]V. N. Karazin Kharkiv National University, Ukraine

The voter model is a paradigmatic stochastic model that has been widely employed especially for modeling of emergent social phenomena as opinion formation. Consensus formation protocols however also occur in the dynamics of computer networks, where the verification of nodes may become time-critical in large networks, and depend on the network topology. In society, consensus is formed (or not) via messages to neighbours in the network and likewise depends on the network structure. Here, we investigate the average time to consensus in a variety of different hierarchical and other network topologies, namely, small-world networks, various tree structures and hierarchical networks. For hierarchical networks, we consider the straightforward generalization where influencing a node occurs with different probability depending on the direction of hierarchy. Systemeatic Monte-Carlo simulations show that the average time to consensus in hierarchical networks is considerably larger than in regular graphs and small-world networks.

SOE 13.7 Thu 11:00 GÖR 226

Surprising Effects of Inhomogeneity on Opinion Dynamics — •Hendrik Schawe and Laura Hernández — Laboratoire de Physique Théorique et Modèlisation, Université de Cergy-Pontoise, France

We study the Hegselmann-Krause model for bounded confidence opinion dynamics. The premise is that an agent i will assume in each timestep the average opinion of the agents whose opinions differ by at most ε_i from its own opinion x_i. In the original model, the confidence ε_i is equal for all agents, but since a society is usually comprised of diverse individua, we study the case of inhomogeneous ε_i. This case is, up to now, mainly studied for few subpopulations each having a narrow range from which the confidences ε_i are drawn [1, 2]. Instead, we draw the confidences for each agent from parametrized uniform distributions $U(\varepsilon_l, \varepsilon_u)$. Our systematic study of the whole parameter space shows non-monotonous and counterintuitive behavior, e.g., increasing

the trustfulness of the most open minded agents (i.e., increasing ε_u) may lead to a loss of consensus.

[1] Lorenz, J., Complexity, 15: 43-52 (2010), doi:10.1002/cplx.20295
[2] Liang, H., Yang, Y., Wang X., Physica A, 392(9): 2248-2256 (2013), doi: 10.1016/j.physa.2013.01.008

15 min. break

SOE 14: Social Systems, Opinion and Group Formation

Time: Thursday 11:30–12:30 Location: GÖR 226

SOE 14.1 Thu 11:30 GÖR 226

Consensus and diversity in multi-state noisy voter models — •Tobias Galla[1,2] and Francisco Herrerías-Azcué[2] — [1]Instituto de Fisica Interdisciplinar y Sistemas Complejos IFISC (CSIC-UIB), 07122 Palma de Mallorca, Spain — [2]Theoretical Physics, Department of Physics and Astronomy, The University of Manchester, Manchester M13 9PL, UK

We study a variant of the voter model with multiple opinions; individuals can imitate each other and also change their opinion randomly in mutation events. We focus on the case of a population with all-to-all interaction. A noise-driven transition between regimes with multi-modal and unimodal stationary distributions is observed. In the former, the population is mostly in consensus states; in the latter opinions are mixed. We derive an effective death-birth process, describing the dynamics from the perspective of one of the opinions, and use it to analytically compute marginals of the stationary distribution. These calculations are exact for models with homogeneous imitation and mutation rates, and an approximation if rates are heterogeneous. Our approach can be used to characterize the noise-driven transition and to obtain mean switching times between consensus states. We also discuss the influence of zealots on the transition between unimodal and multi-modal stationary distributions.

Reference: Francisco Herrerías-Azcué, Tobias Galla, Phys. Rev. E 100, 022304 (2019)

SOE 14.2 Thu 11:45 GÖR 226

A pair-based approach for modelling epidemics on networks — Rory Humphries, Kieran Mulchrone, and •Philipp Hövel — School of Mathematical Sciences, University College Cork, Ireland

We present a pair-based description to study the spreading of epidemics. For the contagion process, we consider a class of SIS, SIR and SIRS models, which are realized as a temporal network. The shift in perspective from individual-based to pair-based quantities enables exact modelling of Markovian epidemic processes on temporal tree graphs. On arbitrary graphs, the proposed pair-based model provides a substantial increase in accuracy at a low computational and conceptual cost compared to the individual-based model. Using the pair-based model, we derive useful analytical expressions, such as the epidemic threshold for testing the global susceptibility to epidemic outbreaks. This allows to determine the likelihood of paths that a disease may take and to identify areas that will be most affected.

SOE 14.3 Thu 12:00 GÖR 226

A network-based microfoundation of Granovetter's threshold model for social tipping — •Marc Wiedermann[1], E. Keith Smith[2], Jobst Heitzig[1], and Jonathan F. Donges[1,3] — [1]Potsdam Institute for Climate Impact Research, Potsdam, Germany — [2]GESIS – Leibniz Institute for the Social Sciences, Cologne, Germany — [3]Stockholm Resilience Centre, Stockholm, Sweden

Social tipping, where minorities trigger larger populations to engage in collective action, has been suggested as one key aspect in addressing contemporary global challenges, such as climate change and biodiversity loss. Here, we refine Granovetter's widely acknowledged theoretical threshold model of collective behavior as a numerical modelling tool for understanding social tipping processes and resolve issues that so far have hindered such applications. Based on real-world observations and social movement theory, we group the population into certain or potential actors, such that – in contrast to its original formulation – the model predicts non-trivial final shares of acting individuals. Then, we use a network cascade model to explain and analytically derive that previously hypothesized broad threshold distributions emerge if individuals become active via social interaction. Thus, through intuitive parameters and low dimensionality our refined model is adaptable to explain the likelihood of engaging in collective behavior where social tipping like processes emerge as saddle-node bifurcations and hysteresis.

SOE 14.4 Thu 12:15 GÖR 226

Social features in ICT data — •Gábor Tamás[1], Yohsuke Murase[2], Hang-Hyun Jo[3,4,5], János Kertész[5,6], Kimmo Kaski[5], and János Török[1,7] — [1]Dept. of Theoretical Physics, BME, Budapest H-1111, Hungary — [2]R-CCS, Kobe, Hyogo 650-0047, Japan — [3]APCTP, Pohang 37673, Republic of Korea — [4]Dept. of Physics, POSTECH, Pohang 37673, Republic of Korea — [5]Dept. of Computer Science, Aalto University, Espoo FI-00076, Finland — [6]DNDS, CEU, Budapest H-1051, Hungary — [7]MTA-BME Morphodynamics Research Group, Budapest H-1111, Hungary

In human societies homophily, the tendency of similar individuals getting associated and bonded with each other is known to be a prime tie formation factor between a pair of individuals. This is manifested in the egocentric networks of humans, which are characterized by different communities related to our activities. The social features of the acquaintances in these groups are similar to some extent.

To quantify the above effect, we have measured the average group overlap with the ego on two different social network sites (iWiW and Pokec). We found that the feature overlap counterintuitively increases with the egocentric group size.

We use a model [1] that describes social tie formation based on focal and cyclic closure, and we show that the above effect is related to the social effort needed to keep up a big community.

[1] Murase, Y., Jo, H. H., Török, J., Kertész, J., & Kaski, K. (2019). Structural transition in social networks: The role of homophily. Scientific reports, 9(1), 4310.

SOE 15: Traffic, Urban and Regional Systems I

Time: Thursday 12:30–13:15 Location: GÖR 226

SOE 15.1 Thu 12:30 GÖR 226

Optimal bikeability of urban street networks — •Christoph Steinacker, David Storch, Marc Timme, and Malte Schröder — Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), TU Dresden

Individual transport in cities is most commonly enabled by private cars, an unsustainable status quo both ecologically and socially. In particular on intra-city length scales, cycling constitutes a broadly accessible and more sustainable alternative. However, insufficient and poorly designed bike lanes often hinder more prevalent bike use.

Here, we aim at identifying bike lane networks that enable fast and safe bicycle travel in cities. Evaluating bike-sharing data on millions of city trips, we estimate bike travel demand and find optimally bike-friendly network topologies. In a reverse percolation process starting from ideal conditions of a complete bike lane network, we successively neglect the least used bicycle paths. Intriguingly, even just a few bike paths, if chosen wisely, may already result in a strongly bike-friendly network. Our results may support the planning of street networks towards more sustainable individual transport.

SOE 15.2 Thu 12:45 GÖR 226

Fluctuation-induced nonlinear dynamics in networks coupled street traffic — •Verena Krall[1,5], Max Günthner[2,3,4,5], Malte

Schröder[1], and Marc Timme[1] — [1]Chair for Network Dynamics, Center for Advancing Electronics Dresden (cfaed), Institute of Theoretical Physics, Technical University Dresden — [2]Institute of Theoretical Physics, University of Tübingen — [3]Werner Reichardt Center for Integrative Neuroscience — [4]Bernstein Center for Computational Neuroscience — [5]Both authors contributed equally

It is long known that traffic congestions may emerge spontaneously – out of nowhere. However, statistical physics studies, while providing both qualitative and quantitative insights, were so far mostly restricted to the consequences of interactions between cars on individual streets and neglected traffic flow patterns in coupled street networks.

Here we present a simple model system of interacting streets in which congestion spontaneously suddenly appears due to fluctuations in the rate of incoming cars. Agent-based simulations indicate an instability even in regimes where mean field theory predicts stable traffic flow patterns.

Our results thus underline the limitations of mean field predictions in noisy, nonlinear systems, in particular for predicting the collective nonlinear dynamics of mobility systems.

SOE 15.3 Thu 13:00 GÖR 226

Intrinsic inefficiencies in on-demand ride-hailing — Philip Marszal[1], •Malte Schröder[1], Debsankha Manik[2], and Marc Timme[1] — [1]Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), TU Dresden — [2]Max-Planck-Institute for Dynamics and Self-Organization, Göttingen

Efficient mobility services constitute essential prerequisites for making cities sustainable, both economically and ecologically. Widespread accessibility to mobile communication has given rise to a number of new ride-hailing services. Yet, many services, in particular classic taxis, still operate based on first-come-first-served basis. Combining a statistical physics analysis with data-driven modeling, we demonstrate the intrinsic inefficiency of such a service. Given a fixed number of taxis, the system can handle only a limited number of requests. Once this capacity is reached, the system not only overloads, it also stays overloaded until the request rate decreases substantially below the onset rate of overload. This hysteresis effectively reduces the capacity of the service by up to 50% compared to ideal operation. We illustrate how both, clever route pre-planning and including ride-sharing, remove this inefficiency and may contribute to fair and efficient mobility in the future.

SOE 16: Evolutionary Game Theory and Networks (joint SOE/DY/BP)

Time: Thursday 15:00–16:00 Location: GÖR 226

SOE 16.1 Thu 15:00 GÖR 226

Game-theoretic stability and meaning of communities in networks — •Armin Pournaki, Felix Gaisbauer, Eckehard Olbrich, and Sven Banisch — Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany

Community detection is a widely used tool for observing modular structures in networks. A large variety of algorithms exist - each with their own advantages - for finding these structures based on modularity optimisation, graph-spectral methods or stochastic block modeling, to name a few.
The talk aims to provide an interpretation of such communities in relation to game-theoretic modeling. We investigate the stability of given partitions by considering coordination games on networks. In this context, we ask how many communities different network configurations support and if there are structural patterns enabling the emergence or disappearance of communities. We relate the findings to empirical data on social networks.

SOE 16.2 Thu 15:15 GÖR 226

Quantum Game Theory for Power-, Heat- and Traffic- Networks — •Matthias Hanauske[1,2], Markus Schlott[1], Alexander Kies[1], Fabian Hofmann[1], and Horst Stöcker[1,2] — [1]Frankfurt Institute for Advanced Studies — [2]Institut für Theoretische Physik, Frankfurt, Germany

Energy networks for the combined electricity, heating and transportation sectors transform towards renewable energy sources. The electric power networks depend particularly sensitively on the decisions of various stakeholders of these complex networks. Our game-theoretical approach for the entire sector-coupled energy system for Europe depends on country-specifc socialogical, political and economical decisions. Last, not least, the success of this strategy depends on the behaviour of the population, the carbon dioxide consumers. The focus of this work is on the impact of social pressure for the behavior of the individual consumers. Classical Evolutionary Game Theory, simulations of spatial games and Evolutionary Quantum Game theory are used to study the dynamics of the transformation process towards a carbon neutral society.

SOE 16.3 Thu 15:30 GÖR 226

Reinforcement learning dynamics in the infinite memory limit — •Wolfram Barfuss — Max Planck Institute for Mathematics in the Sciences, Leipzig

Reinforcement learning algorithms have been shown to converge to the classic replicator dynamics of evolutionary game theory, which describe the evolutionary process in the limit of an infinite population. However, it is not clear how to interpret these dynamics from the perspective of a learning agent. In this work we propose a data-inefficient batch-learning algorithm for temporal difference Q learning and show that it converges to a recently proposed deterministic limit of temporal difference reinforcement learning. In a second step, we state a data-efficient learning algorithm, that uses a form of experience replay, and show that it retains core features of the batch learning algorithm. Thus, we propose an agent-interpretation for the learning dynamics: What is the infinite population limit of evolutionary dynamics is the infinite memory limit of learning dynamics.

SOE 16.4 Thu 15:45 GÖR 226

Degenerated mirror strategies extort extortioners — Haowei Shi[1,2], Sergey Sosnovskiy[1], Florian Ellsässer[1], Gregory Wheeler[3], and •Jan Nagler[1] — [1]Deep Dynamics Group and Centre for Human and Machine Intelligence, Frankfurt School of Finance and Management, Frankfurt, Germany — [2]School of International Economics, China Foreign Affairs University, Beijing, China — [3]Centre for Human and Machine Intelligence, Frankfurt School of Finance and Management, Frankfurt, Germany

In iterated games the payoff a player receives in a given round depends on the player's own action and the action of his opponent. Thus, it came as a surprise when Press and Dyson in [PNAS 109:10409 (2012)] introduced so-called extortion zero-determinant (extZD) strategies that - independently of the opponent's strategy - ensure an equal or higher expected payoff. Here, we introduce degenerated mirror strategies that, with a trembling hand that may accidentally take unintended actions, extort any extZD strategy, thereby persistently receiving a higher expected payoff than extortioners. We also show that degenerated mirror strategies outperform the most successful traditional strategies and do well against adaptive strategies. In particular, we demonstrate that they perform equal to or better than a memory-n player that may use the past n actions to determine her next move, where n may be arbitrarily large. Nevertheless, degenerated mirror strategies may be generous when mirroring cooperative strategies.

SOE 17: Traffic, Urban and Regional Systems I

Time: Thursday 16:00–17:30 Location: GÖR 226

SOE 17.1 Thu 16:00 GÖR 226

Topological universality of on-demand ride-sharing efficiency — •Nora Molkenthin, Malte Schröder, and Marc Timme — Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), Technical University of Dresden, 01069 Dresden

Ride-sharing has been suggested as a solution to a wide range of challenges in personal transportation, ranging from avoiding traffic jams and pollution in cities to improving the availability of public transport in rural areas. However, the dynamics and scaling of such systems are not yet fully understood and definitions of efficiency of ride-sharing are often conflated with the demand. Here we introduce a demand-independent efficiency measure and use it to evaluate the scaling of the efficiency of ride-sharing with the number of buses for different street network topologies. We find and explain universal behaviour of efficiency with vehicle number.

SOE 17.2 Thu 16:15 GÖR 226

Anomalous Diffusion in Ridesharing? — •Philip Marszal, Malte Schröder, Nora Molkenthin, and Marc Timme — Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), TU Dresden

A multitude of new transport approaches hold a promise of more flexible and more sustainable mobility. Ridesharing, combining trips to simultanenously share rides of several people on the same vehicle, aims to reduce the number of vehicles on the street and the distance traveled by each individual vehicle. Despite already being offered by service providers, the collective dynamics of ridesharing systems are not well understood. Here we study the spatio-temporal dynamics of ridesharing buses by interpreting their routes as random walks whose properties depend on the system size and load. We identify scaling relations characterizing the area served by a bus and its effective velocity, changing from ballistic trajectories on short timescales to anomalous diffusive motion on long timescales. As differences in scaling drastically affect system performance, these insights suggest a novel path towards optimizing ride-sharing systems.

SOE 17.3 Thu 16:30 GÖR 226

Traffic flow splitting from digital decision support — •David-Maximilian Storch, Malte Schröder, and Marc Timme — Chair for Network Dynamics, Center for Advancing Electronics Dresden (cfaed), Technical University of Dresden, 01062 Dresden, Germany

Digital technology is fundamentally transforming human mobility. Mode and route choices are greatly affected by a variety of smartphone-based trip planning applications. In uncertain or overwhelmingly complex traffic situations such software tools provide valuable decision support to their users. Yet, it is unclear how widespread adoption of digital routing technologies alters the collective dynamics of the population's mode and route choices. Here, we answer this question for the dynamics of urban commuting under digital decision support.

We formulate the commuting dynamics as a repeated congestion game where a fraction of the population relies on, but also contributes to, crowdsourced traffic information. Informational nudges provided by the decision support tool modify the commuters' route choice rationale and their traffic assignment. If the tool simply distributes the crowdsourced traffic information, we uncover a separation of commuter flows into technology and non-technology users, fueling systemic inefficiencies. An alternative class of route suggestion protocols may overcome this problem and promote socially optimal mobility outcomes.

These results highlight new research directions in the field of algorithmic design of mode-route choice decision support protocols to help fight congestion, emissions and other systemic inefficiencies in the course of increasing urbanization, digitization and autonomy.

SOE 17.4 Thu 16:45 GÖR 226

How efficient is ridesharing? — •Robin Maximilian Zech, Nora Molkenthin, Marc Timme, and Malte Schröder — Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), TU Dresden

Ride-sharing may substantially contribute to make future mobility flexible, fair and sustainable. Recent work (Molkenthin et al., arXiv:1908.05929) proposed a generic measure of ride-sharing efficiency that is based on the intrinsic ride-sharing dynamics and follows a universal scaling law across network topologies. Here we ask how limited passenger capacity of ride sharing vehicles (busses) alters this universality. Using queueing theory, we present an analytic solution to a minimal model with requests served on a two node graph. For more complex street networks, we compute an effective number of busses by considering the probability of one bus having to delay a request due to capacity constraints. We find that for large numbers of busses and a suitably redefined topological factor, universality extends to finite capacity systems.

SOE 17.5 Thu 17:00 GÖR 226

Efficient and resilient ride sharing by stop pooling — •Charlotte Lotze, Malte Schröder, and Marc Timme — Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), TU Dresden

Mobility faces three main challenges: emissions, social inequality and congestion. One potential solution currently discussed to address these challenges is ride sharing, i.e. the combination of multiple similar trips of customers to the same vehicle.

Here we present basic dynamic implications of stop pooling – a promising modification of door-to-door ride-sharing services. The main idea is to aggregate individual passenger's stop locations (e.g. have passengers walk a short distance to or from their stop) to save vehicle travel and stopping times and to thereby achieve a more efficient service. In a simple model, we quantify how efficiency increases as a function of both stop pooling radius and number of passengers per vehicle to estimate the impact of ride sharing with stop pooling on economic, sustainable, fair and resilient future mobility options. We also discuss potential positive consequences on sharability [1-3] and resilience. In conclusion, stop pooling may further optimize the benefits gained by the novel mobility option ride sharing.

[1] Santi P., et al. (2014) PNAS 111 : 13290-13294.
[2] Tachet R., et al. (2017) Sci. Rep. 7 : 42868.
[3] Molkenthin N., et al. (2019) arXiv : 1908.05929

15 min. break

SOE 18: Networks - From Topology to Dynamics II (joint SOE/DY/BP)

Time: Thursday 17:30–18:30 Location: GÖR 226

SOE 18.1 Thu 17:30 GÖR 226

Exact Ising partition function computed on networks of low tree-width — •Konstantin Klemm — IFISC (CSIC-UIB), Campus Universitat de les Illes Balears, Palma de Mallorca, Spain

Tree-like approximation is a method commonly used in computing dynamic properties of quenched finite network realizations, including empirical networks. Such properties include expected percolation cluster sizes, epidemic thresholds, and Ising/Potts partition functions. That method is exact only when the network is a tree: removal of one node leaves the network disconnected and this separation recursively holds on the connected components obtained, until reaching the base case of a component with two nodes only. A generalization of this recursive separation is called tree-decompsition of width k, allowing a set of up to k nodes as a separator in each step. In this talk, we show the use of tree-decompositions to obtain exact equilibrium properties for the Ising model and other stochastic processes with detailed balance. On empirical networks of up to 1000 edges, it takes a few seconds to compute the exact value of the Ising/Potts partition function at a given temperature. Computation time is proven linear in size for networks grown by attachment to cliques, such as the Klemm-Eguíluz

model [PRE, 2002] and the simplest scale-free network [Dorogovtsev et al, PRE, 2001]. Next to these results, we discuss possibilities and obstacles in generalizing the concept to non-equilibrium processes.

SOE 18.2 Thu 17:45 GÖR 226

Evolution and Transformation of Knowledge over the Sphaera Corpus: A Network Study — •Maryam Zamani[1], Alejandro Tejedor[1], Matteo Valleriani[2], Florian Kräutli[2], Malte Vogl[2], and Holger Kantz[1] — [1]Max Planck Institute for the Physics of Complex Systems — [2]Max Planck Institute for the History of Science

The present work investigates the process of developing knowledge during early modern period by using complex networks method. The research is based on semantic, content-related data extracted from a corpus of 359 printed editions, mainly of textbooks used to teach cosmology at European universities between 1472 and 1650. A directed, multi-layer network is constructed in five layers whose structures are defined specifically for the research question at hand. The network is analysed, by making use of the aggregated graph, which accounts for the connectivity between books when any of the potential semantic relations are indistinctly considered. We assess the influence of the different books in the corpus by measuring the normalised node out-degree, as well as disruption factor. Results reveal the emergence of different communities in the aggregated graph that are compared based on different aspects, such as book's format, place of publication, etc. Further analysis demonstrates the time period when knowledge is converged and show its divergence afterwards.

SOE 18.3 Thu 18:00 GÖR 226

Complexified Kuramoto model I – synchrony in the asynchronous regime — Sheshagopal Marehalli Srinivas, Marc Timme, and •Moritz Thümler — Center for Advancing Electronics Dresden Chair for Network Dynamics 01062 Dresden Germany

The Kuramoto model constitutes a paradigmatic model for the emergence of temporal patterns – foremost synchrony – in coupled oscillator systems. Here we extend the Kuramoto model to complex dynamical variables and demonstrate a transition from traditional synchrony emerging for sufficiently large coupling strengths to a second type of synchrony that exists in the weak coupling regime, i.e. below the coupling required for the real model to synchronize, and that is commonly known from systems that are not dissipative but conservative, like the harmonic oscillator, see also [1,2].

[1] D. Witthaut and M Timme, Phys. Rev. E 90:032917 (2014) [2] D. Witthaut et al., Nature Comm. 8:14829 (2017)

SOE 18.4 Thu 18:15 GÖR 226

Complexified Kuramoto model II – abnormal network synchronization — •Moritz Thümler, Malte Schröder, Sheshagobal Marehalli Srinivas, and Marc Timme — Center for Advancing Electronics Dresden Chair for Network Dynamics 01062 Dresden Germany

Networks of Kuramoto oscillators commonly synchronize in the regime of sufficient coupling strengths. Extending the Kuramoto model to complex dynamical variables, and our previous contribution [1] to networks we here show under which choices of parameters we can expect synchrony. In particular we show the transition between the traditional real valued Kuramoto modell and its complex extension. Furthermore we are discussing the lack of a well defined order parameter in the comlex regime.

[1] Shesha et al., Complexified Kuramoto model I – synchrony in the asynchronous regime, DPG abstracts, above (2020)

SOE 19: Data analytics for dynamical systems II (Focus Session joint with DY and BP) (joint session SOE/CPP/DY)

Time: Friday 9:30–10:00 Location: GÖR 226

SOE 19.1 Fri 9:30 GÖR 226

A Variational Perturbative Approach to Graph-based Multi-Agent Systems — •Dominik Linzner, Michael Schmidt, and Heinz Koeppl — TU Darmstadt, Germany

Understanding the behavior of multiple agents is a difficult task with numerous applications in the natural and social sciences. However, the number of possible configurations of such systems scales exponentially in the number of agents leaving many queries intractable – even if limiting interactions to a static interaction graph.

Variational approaches pave a principled way towards approximations of intractable distributions. Here, traditional approaches focus on directly constraining the class of variational distributions, e.g. in naïve mean-field statistical independence of all random variates is assumed. Variational perturbation theory (VPT) offers a different approach. Here, the similarity measure itself is approximated via a series expansion. A prominent example of this approach is Plefka's expansion [1,2]. The central assumption is that variables are only weakly coupled, i.e. the interaction of variables is scaled in some small perturbation parameter.

We derive a novel VPT for stochastic dynamics on static interaction graphs and use it to develop methods for different (inverse) problems such as system identification from data or optimal planning of coordination tasks.

[1] Plefka, T. (1982). Journal of Physics A, 15, 1971-1978. [2] Bachschmid-Romano et al. (2016). Journal of Physics A: Mathematical and Theoretical, 49(43), 434003-434033.

SOE 19.2 Fri 9:45 GÖR 226

A differentiable programming method for quantum control — •Frank Schäfer, Michal Kloc, Christoph Bruder, and Niels Lörch — Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

Precise control of quantum systems is highly desirable in many current experimental setups and quantum information technologies. In quantum control, by optimization of control pulse sequences, protocols that maximize a case-specific figure of merit are obtained. To solve quantum state control problems, we treat (closed) quantum systems as differentiable programs. Within a framework that combines machine learning and the knowledge of the differential equations governing the dynamics of the physical system, we employ predictive models for optimal parameter estimation. We analyse the sensitivity of this approach against noise in the initial states and verify the robustness of the method.

SOE 20: Partial Synchronization Patterns in Neuronal Networks II (Focus Session joint with DY / SOE / BP) (joint session SOE/DY)

Time: Friday 10:00–12:00 Location: GÖR 226

SOE 20.1 Fri 10:00 GÖR 226

Control of chimera states in multilayer networks of FitzHugh-Nagumo neurons — •Giulia Ruzzene and Ralph G. Andrzejak — Universitat Pompeu Fabra, Barcelona, Spain

Chimera states are a widely studied phenomenon in nonlinear science. In oscillator networks, a chimera state is defined as the coexistence of synchronous and aysnchronous groups of nodes. Many analogies have been established between chimeras and natural phenomena, especially with brain dynamics. Here we study the dynamics of a two-layer network of FitzHugh-Nagumo oscillators, which model neuronal dynamics. Chimera states have been observed in this configuration, but only a few studies also deal with the topic of control of chimeras in multilayer networks. Here we apply a control mechanism that we previously developed for chimeras in single-layer networks of phase oscillators. We study the interplay of the control method with the

multilayer configuration and show the parameter regions in which the control is effective.

SOE 20.2 Fri 10:30 GÖR 226

Effect of Topology upon Relay Synchronization in Triplex Neuronal Networks — •Fenja Drauschke, Iryna Omelchenko, Rico Berner, Jakub Sawicki, and Eckehard Schöll — Institute of Theoretical Physics, Technische Universität Berlin

Complex networks consisting of several interacting layers allow for remote synchronization of distant layers via an intermediate relay layer. We investigate relay synchronization in a three-layer neuronal network and study the effect of the topology of the layers upon the synchronization scenarios. Introducing random topologies either in the outer layers or in the middle (relay) layer leads to an increase of the range of inter-layer coupling strength for which the relay-synchronized state is preserved, compared with regular nonlocal coupling topologies.

SOE 20.3 Fri 10:45 GÖR 226

High-order couplings in geometric complex networks of neurons — •Alejandro Tlaie[1,2,3], Inmaculada Leyva[1,2], and Irene Sendiña-Nadal[1,2] — [1]Complex Systems Group & GISC, Universidad Rey Juan Carlos, 28933 Móstoles, Madrid, Spain — [2]Center for Biomedical Technology, Universidad Politécnica de Madrid, Madrid, Spain — [3]Department of Applied Mathematics and Statistics, ETSIT Aeronáuticos, Universidad Politécnica de Madrid, 28040 Madrid, Spain

We explore the consequences of introducing higher-order interactions in a geometric complex network of Morris-Lecar neurons. We focus on the regime where traveling synchronization waves are observed from a first-neighbors-based coupling to evaluate the changes induced when higher-order dynamical interactions are included. We observe that the traveling-wave phenomenon gets enhanced by these interactions, allowing the activity to travel further in the system without generating pathological full synchronization states. This scheme could be a step toward a simple phenomenological modelization of neuroglial networks.

15 min. break

SOE 20.4 Fri 11:15 GÖR 226

Multilayer structures in adaptive oscillator networks — •Rico Berner[1,2], Jakub Sawicki[1], and Eckehard Schöll[1] — [1]Institute of Theoretical Physics, Technische Universität Berlin, Germany — [2]Institute of Mathematics, Technische Universität Berlin, Germany

Dynamical systems on networks with adaptive couplings appear naturally in real-world systems such as power grid networks, social networks as well as neuronal networks. We investigate collective behaviour in a paradigmatic network of adaptively coupled phase oscillators. The coupling topology of the network changes slowly depending on the dynamics of the oscillators on an all-to-all coupled background. We show that such a system gives rise to numerous complex dynamics, including relative equilibria and hierarchical multicluster states. Parameter regimes of high multistability are found. An analytic treatment for equilibria as well as multicluster states reveals that existence and stability are significantly influenced by the slow-fast time separation. Interactions between different clusters are further studied numerically and analytically in the framework of multiplex networks. Our results allow for the interpretation of equilibria as functional units in multicluster structures. The results contribute to the understanding of mechanisms for self-organized pattern formation in adaptive networks, such as the emergence of multilayer structure in neural systems and their interaction.

SOE 20.5 Fri 11:30 GÖR 226

Hierarchical clusters in adaptive networks with random topology — •Simon Vock[1], Rico Berner[1,2], Eckehard Schöll[1], and Serhiy Yanchuk[2] — [1]Institute of Theoretical Physics, Technische Universität Berlin — [2]Institute of Mathematics, Technische Universität Berlin

Networks of adaptively coupled oscillators show certain synchronization phenomena, such as multi-cluster states or traveling-wave states. While the emergence of these self-organised structures has been previously studied on all-to-all coupled networks, the type of connections and underlying network structure play an important role in the formation of these partially synchronized states. This work extends the investigations towards more complex networks, analysing the influence of random network topologies and changing adaption functions.

SOE 20.6 Fri 11:45 GÖR 226

Hierarchical frequency clusters in adaptive networks of phase oscillators — •Jan Fialkowski[1], Rico Berner[1,2], Serhiy Yanchuk[2], and Eckehard Schöll[1] — [1]Institute of Theoretical Physics, Technische Universität Berlin — [2]Institute of Mathematics, Technische Universität Berlin

Adaptive dynamical networks appear in various real-world systems. In this talk, we explain the basic mechanism behind the pattern formation in adaptive networks by considering a simple phenomenological phase oscillator model. Frequency synchronization is shown to be the key phenomenon for the emergence of hierarchical modular network structures. A particular class of phase clusters, called double antipodal clusters, are presented and shown to play an important role in the organization of the high dimensional dynamics. In the end, we also examine the importance of different timescales in the adaptive and oscillatory dynamics.