SOE 12: Poster

Posters can - and should - be on display the whole day. Posters 13-17 accompany the Focus Session on Dynamics of Multilayer Networks.

Time: Tuesday 16:00–19:00 Location: Poster A

SOE 12.1 Tue 16:00 Poster A

Statistical patterns of Lithuanian municipality elections — •Aleksejus Kononovicius — Institute of Theoretical Physics and Astronomy, Vilnius University, Lithuania

In this contribution we will present an analysis of statistical patterns observed during Lithuanian municipality elections. We consider parties' vote share at the polling station level. We perform a comparison across the different municipalities with an aim to understand whether the vote share samples could have come from the same distribution. This approach is based on our earlier works in which we have considered Lithuanian parliamentary elections [1,2].

[1] A. Kononovicius, Complexity 2017: 7354642 (2017). doi: 10.1155/2017/7354642. arXiv: 1704.02101 [physics.soc-ph].

[2] A. Kononovicius, APPA 133 (6): 1450 (2018). doi: 10.12693/APhysPolA.133.1450. arXiv: 1709.07655 [physics.soc-ph].

SOE 12.2 Tue 16:00 Poster A

The Hidden Physics of Human Progress and Poverty — •Stephen I. Ternyik — POB.201 D-82043 Munich

The economic pathologies of current acute problems in social systems evolution do point to a very unhealthy state of the body economic; the global economy is in a dismal condition. Inequitable distribution of labor and income, extreme monetary excesses, highly growing debts, spreading bureaucratic planning and accumulating ecological externalities are the widely circulating diseases, which seem to be insoluble symptoms of a deeply sick economy. The Sisyphean root cause (history repeating) of these joint economic maladies is the gradually exceeding volume of economic rent (unearned income), which is extracted from the working body economic. This economic version of phlebotomy (blood-letting) seems to occur in cyclical patterns (slowdown after boom), when financial investments are massively directed into physical assets (land location value, real estate), which reduces vital liquidity for further economic growth. The only 'medical' remedy against this cyclical phenomenon is to tax economic rent and to recapture it as public revenue.

SOE 12.3 Tue 16:00 Poster A

Deep Reinforcement Learning in World-Earth-System Models Exploring Sustainable Behavior — •Felix Strnad[1,2], Wolfram Barfuss[1], Jonathan F. Donges[1,3], and Jobst Heitzig[1] — [1]Potsdam Institute for Climate Impact Research, Germany — [2]Department of Physics, University of Göttingen, Germany — [3]Stockholm Resilience Centre, Stockholm University, Sweden

Pathways to global sustainability need to account for critical feedbacks between the socio-cultural World and the biophysical Earth system. These feedbacks may require novel, yet undiscovered global policies for the governance leading towards a safe and just operating space. Currently the combination of agent-based modeling, reinforcement learning and deep neural networks, called Deep Reinforcement Learning (DRL), has become increasingly popular. DRL-algorithms have been shown to learn policies up to super-human performance in a variety of different environments.

In this work, we apply DRL within stylized World-Earth models. We developed an agent that is able to act and learn in variable manageable non-linear complex environments. We trained our agent with a deep Q-network (DQN) using experience replay and periodically updated target networks. We systematically investigated the effect of various parameters for the learning success, such as the discount factor, the training data set size or the exploration-exploitation trade-off. By using this optimized parameter set, we find that our agent is able to learn novel policies towards sustainable regions in multiple conceptual models of the World-Earth system.

SOE 12.4 Tue 16:00 Poster A

Mapping mathematical models for language shift to linguistic reality — •Katharina Prochazka[1,2], Michael Leitner[3], and Gero Vogl[1] — [1]Fakultät für Physik & VDSP, Universität Wien, 1090 Wien, Austria — [2]Institut für Slawistik, Universität Wien, 1090 Wien, Austria — [3]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, 85748 Garching, Germany

When people stop speaking one language and adopt another, this is called language shift. In language shift, the "new" language spreads while the "old" one retreats. To describe this process and see how and why it happens, mathematical models can be used. These models are often based on the analogy between the spread of particles (physical diffusion) and languages (language diffusion) and comprise differential equations (macroscopic reaction–diffusion systems) as well as agent-based approaches (microscopic models as in [1]).

In this contribution, we focus on the interpretation of such models: How do abstract parameters correspond to what is actually going on during language shift? What can be learned from models which do not incorporate empirical data? And on the other hand: Which model is appropriate under which conditions?

More concretely, we explore the modelling of different processes of language shift by using empirical data from two examples in Austria and Hungary. For these cases, we show how the available data and conditions such as geographical structure inform the choice of a certain model.

[1] K. Prochazka and G. Vogl, PNAS 114, 4365 (2017)

SOE 12.5 Tue 16:00 Poster A

From utility functions to many-particle Hamiltonians (and back). — •Michael Schnabel and Daniel Diermeier — University of Chicago, Chicago, USA

As a simple model of binary opinion formation we consider a population of N interacting agents that can select among two different states. We assume that the individual choices are made based on maximizing some underlying utility function that depends on the current distribution of opinions in the population, but otherwise can have arbitrary shape. The resulting stationary distribution of opinions can be written as a Gibbs-Boltzmann distribution with an effective Hamiltonian that describes the interactions occurring at the microscopic scale. We present a method how to obtain the interaction coefficients and describe their scaling behavior as a function of the population size N. Moreover we derive a criterium to tell for what type of utility function the pairwise approximation will be applicable (or not).

SOE 12.6 Tue 16:00 Poster A

Demand Responsive Ride Pooling: Theory and Simulation — •Felix Jung[1,2] and Stephan Herminghaus[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Institute for Nonlinear Dynamics, University of 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 by means of computer simulation of such systems [2].

[1] Herminghaus, Transportation Research Part A **119** (2019)

[2] Sorge et al., Proceedings of the 2015 Winter Simulation Conference

SOE 12.7 Tue 16:00 Poster A

Evaluation of Real Life Taxi Data regarding Demand Responsive Ride Pooling — •Michael Sternbach[1,2] and Stephan Herminghaus[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Georg-August-Universität Göttingen Institut für Nichtlineare Dynamik

One of the most important upcoming challenges of our society are the climate change and shortage of resources, such as energy and clean air. Motorized individual traffic (MIV), which is particularly wasteful

in this respect, can potentially be outcompeted by (more parsimonious) ride pooling systems. To achieve this goal, the latter must be provided economically and with sufficient customer comfort. We investigate this possibility by feeding real life taxi data to a demand responsive ride pooling model [1]. We simulate attempts to serve the incoming requests, which in real life were serviced by taxis, in a way such as to pool as many rides as possible under suitable constraints on the tortuosity of the route. This is used to quantify the poolability of the corresponding taxi requests. Optimization of operation under variable cost functions is investigated.
[1] Herminghaus, Transportation Research Part A **119** (2019)

SOE 12.8 Tue 16:00 Poster A

Continuous increases or decreases in city sizes observed in Japanese telephone directory data — •Takaaki Ohnishi[1], Takayuki Mizuno[2], and Tsutomu Watanabe[1] — [1]The University of Tokyo, Tokyo, Japan — [2]National Institute of Informatics, Tokyo, Japan

In order to investigate urban development and decline, we empirically study the number of shops and facilities $x(t)$ at municipality level in Japan observed in fixed-line telephone directory data from 2011 to 2017. Observation of the scatter plot for $x(t)$ and the annual growth rates $r(t) = \log(x(t+1)/x(t))$ supports that $r(t)$ decrease with its size $x(t)$. Both Kendall rank correlation coefficient and Pearson correlation coefficient show significant negative correlation between them, indicating deviations from Gibrat's law. This result is similar to what is found for population growth. There is significant positive correlation between two successive annual growth rates $r(t)$ and $r(t+1)$, implying that cities with large (small) $r(t)$ tend to be larger (smaller) in the next year. Then, we evaluate the conditional probability of size increase (decrease) in the next size change after n successive size increase (decrease) and find that the probability is significantly larger than 0.5. As n becomes larger, the probability gradually increases. Probabilities of successive negative size changes are slightly higher than that of positive size changes. We observe these properties even for each industry as well as for each prefecture. These findings suggest that city sizes are more likely to continue increasing or decreasing, which help to characterize urban dynamics.

SOE 12.9 Tue 16:00 Poster A

Validation of dynamic social network models by real-world network data — •Jakob Lochner[1,2], Jobst Heitzig[1], Marc Wiedermann[1], Jonathan Donges[1], and Jürgen Vollmer[2] — [1]Institut für Klimafolgenforschung, Potsdam, Deutschland — [2]Institut für Theoretische Physik, Leipzig, Deutschland

Everyday experience suggest that individual opinions and identities play an important role for establishing or aborting social relations. Such processes are partially implemented in conceptual dynamic network models, e.g., the adaptive voter model (Holme et al., 2006). Our study aims at a validation of these models and their underlying assumptions about the feedbacks between individual opinions and the topology of the underlying network. To this end we perform a statistical regression analysis of behavior and network data collected at MIT in 2008. The data was recorded by sensors in mobile phones that were given to 80 students. The phones measured proximity to other phones via Bluetooth, and collected communication data from calls and messages. Furthermore the students submitted questionnaires about health, political interest, musical preferences and relationships to other participants. The study monitors their behaviour and opinions over a total period of approximately nine months. We show that, our regression analysis allows to identify underlying social processes like homophily. Forthcoming work will address data from larger social networks and compare it to proxy data generated by numerical implementations of specific models.

SOE 12.10 Tue 16:00 Poster A

Dynamics of interacting generalized tipping elements on complex networks — •Jonathan Krönke[1,2], Nico Wunderling[1,2,3], Jonathan F. Donges[1,4], and Ricarda Winkelmann[1,2] — [1]Earth System Analysis, Potsdam Institute for Climate Impact Research, Potsdam, Germany — [2]Institute of Physics, Potsdam University, Potsdam, Germany — [3]Department of Physics, Humboldt University, Berlin, Germany — [4]Stockholm Resilience Centre, University of Stockholm, Stockholm, Sweden

Critical transitions have increasingly become a topic of interest in the last decades and many systems with critical transitions have been identified in nature and society (Scheffer, et al. 2009). Such phenomena are often described as tipping elements (Lenton, et al. 2008). Recently the focus of attention has also shifted to the interactions of tipping elements (Brummit et al., 2015, Dekker et al., 2018) and the potential of cascading tipping that originates from such interactions (Steffen, et al. 2018).

Here, we study complex networks of generalized tipping elements as linearly coupled systems of ordinary differential equations. We investigate cascading effects in different network topologies and find that network topologies with a higher clustering tend to be more vulnerable to tipping cascades. Furthermore we investigate how this could be a destabilizing mechanism in spatially extended systems.

SOE 12.11 Tue 16:00 Poster A

Edge directionality properties in complex spherical networks — •Frederik Wolf[1,2], Catrin Kirsch[1], and Reik Donner[1,3] — [1]Potsdam Institute for Climate Impact Research, Research Domain 4 — [2]HU Berlin, Department of Physics — [3]Hochschule Magdeburg-Stendal, Department of Water, Environment, Construction and Safety

Spatially embedded networks have recently attracted increasing attention. In their context, new types of network characteristics have been introduced recently which explicitly take spatial information into account. Among others, edge directionality properties have gained particular interest.

In this work, we introduce the mean edge direction, local anisotropy and local mean angle as new broadly applicable geometric network measures for spatial networks. Subsequently, we illustrate characteristic features of these edge directionality measures by applying them to two different examples of real-world spherical networks describing air transportation and global trade.

In the air transportation network, we identify distinct traffic zones in Europe, North and South America as well as in East Asia. In the world trade network, we confirm the important role of the European Union for global trade by identifying convergent edge directionality pattern. In addition, we reveal different roles of various countries in the world trade system by comparing import and export networks. The employed method provides a framework to utilize the geographical information encoded in spatially embedded networks and thus contributes to a better understanding of real-world networks using a geometric approach.

SOE 12.12 Tue 16:00 Poster A

Network reconstruction based on event timing in spreading processes — Forough Hassanibesheli[1,2] and •Reik V. Donner[1,3] — [1]PIK Potsdam, Germany — [2]Humboldt University, Potsdam, Germany — [3]Magdeburg-Stendal University of Applied Sciences, Magdeburg, Germany

Spreading phenomena like opinion formation or disease propagation commonly follow the links of some underlying network structure. While the effect of network topology on spreading efficiency has already been vastly studied, we here address the inverse problem whether we can infer an unknown network structure from the timing of events at different nodes. For this purpose, we consider a simple model of nodes exhibiting two types of activity: spontaneous events that are generated via mutually independent Poisson processes, and triggered events that occur with a certain probability whenever one of the neighboring nodes exhibits any of these two kinds of events. Based on simulations of this model for different types of networks, we study the similarity between the timings of events at all pairs of nodes by means of event synchronization and event coincidence analysis as two wide-spread methods for studying simultaneity in event series. By taking strong mutual similarities as proxies for actual physical links, we demonstrate that both approaches lead to similar prediction accuracy. In general, sparser networks can be reconstructed more accurately than denser ones, especially in case of larger networks.

SOE 12.13 Tue 16:00 Poster A

Interplay of adaptivity and multiplexing in networks of coupled oscillators — Rico Berner[1,2], •Jakub Sawicki[1], Anna Zakharova[1], and Eckehard Schöll[1] — [1]Institute of Theoretical Physics, Technische Universität Berlin, Germany — [2]Institute of Mathematics, Technische Universität Berlin, Germany

Research on multilayer networks has recently opened up new aspects, providing a description of systems interconnected through different types of links. One class of interactions are within the layers, and additionally other types of interactions occur between the network nodes from different layers. In addition, dynamical systems on networks with time dependent topology have attracted a lot of attention in studies of neural networks, power grids as well as social groups. We study the

impact of multiplexing on the collective dynamics in adaptive layers. Building on these investigations the analysis of self-organized emergent symmetric networks is lifted to multiplex structures. We show that multiplex networks give rise to promising new control schemes.

SOE 12.14 Tue 16:00 Poster A

Noise-induced chimeras in dynamical networks: nonlocally coupled ring versus 2D modular fractal connectivity — •Anna Zakharova, Nikolas Heym, and Eckehard Schöll — Technische Universität Berlin

For a network of coupled neural elements in the excitable regime we show that chimera patterns can be induced by noise. We compare the results for two different network topologies: nonlocal coupling on a ring and 2D modular fractal connectivity, with the latter being relevant for modeling of the brain. In contrast to classical chimeras, occurring in noise-free oscillatory networks, these patterns have features of two phenomena: coherence resonance and chimera states. Therefore, we call them coherence-resonance chimeras [1]. They demonstrate the constructive role of noise and appear for intermediate values of noise intensity. We investigate the impact of time delay on coherence-resonance chimeras and show that time-delayed feedback can be used to control the noise-induced chimera states [2].

[1] N. Semenova, A. Zakharova, V. Anishchenko, E. Schöll, Coherence-resonance chimeras in a network of excitable elements, Phys. Rev. Lett. 117, 014102 (2016)

[2] A. Zakharova, N. Semenova, V. Anishchenko, E. Schöll, Time-delayed feedback control of coherence resonance chimeras, Chaos 27, 114320 (2017)

SOE 12.15 Tue 16:00 Poster A

Weak multiplexing in neural networks: Switching between chimera and solitary states — •Anna Zakharova[1], Maria Mikhaylenko[1,2], Lukas Ramlow[2], and Sarika Jalan[3] — [1]Technische Universität Berlin, Germany — [2]ITMO University, St.Petersburg, Russia — [3]IIT Indore, India

Using the model of a FitzHugh-Nagumo system in the oscillatory regime, we study spatio-temporal patterns occurring in a two-layer multiplex network, where each layer is represented by a non-locally coupled ring [1]. We show that weak multiplexing, i.e., when the coupling between the layers is smaller than that within the layers, can have a significant impact on the dynamics of the neural network. We develop control strategies based on weak multiplexing and demonstrate how the desired state in one layer can be achieved without manipulating its parameters, but only by adjusting the other layer. We find that weak multiplexing allows to induce or suppress chimera states. Interestingly, for small intra-layer coupling strength mismatch, solitary states can be induced throughout the whole network.

[1] M. Mikhailenko, L. Ramlow, S. Jalan and A. Zakharova, Weak multiplexing in neural networks: Switching between chimera and solitary states, arXiv:1809.07148 (2018)

SOE 12.16 Tue 16:00 Poster A

Partial synchronization in 2-community networks of FitzHugh-Nagumo oscillators with empirical structural connectivities — Lukas Ramlow, •Jakub Sawicki, and Eckehard Schöll — Institute of Theoretical Physics, Technische Universität Berlin, Germany

Partial synchronization includes patterns of coexistence of a synchronized and desynchronized subgroup of oscillators. A real world phenomenon where this can be found is uni-hemispheric slow-wave sleep where one hemisphere is asleep while the other remains awake. This state can also be characterized by simultaneous but spatially separated occurrence of high and low degree of synchronization in the sleeping and the awake hemisphere, respectively. Here we investigate the occurrence of partial synchronization patterns in empirical structural connectivities of the human brain. The connectivities consist of ninety regions of interest using the Automated Anatomical Labeling (AAL) Atlas, and were derived by magnetic resonance imaging (MRI) based probabilistic diffusion tractography. The local dynamics is modeled by FitzHugh-Nagumo oscillators. We demonstrate under which conditions partial synchronization patterns with respect to the brain hemispheres can be found.

SOE 12.17 Tue 16:00 Poster A

Synchronization of chimera states in multiplex networks of logistic maps — Marius Winkler, •Jakub Sawicki, Iryna Omelchenko, Anna Zakharova, and Eckehard Schöll — Institute of Theoretical Physics, Technische Universität Berlin, Germany

Complex networks consisting of several interacting layers allow for remote synchronization of distant layers via an intermediate relay layer. We extend the notion of relay synchronization to chimera states, and study the scenarios of relay synchronization in a three-layer network of logistic maps, where each layer has a nonlocal coupling topology. Varying the coupling strength in the inter-and intra-layer connections, we observe various complex spatio-temporal patterns of coexisting coherent and incoherent domains, i.e., chimera states, in the outer network layers. Special regimes where only the coherent domains of chimeras are synchronized, and the incoherent domains remain desynchronized, as well as transitions between different synchronization regimes are analyzed.