SOE 7: Poster

Time: Monday 18:00–20:30 Location: Poster D

SOE 7.1 Mon 18:00 Poster D

Bayesian Detection of Mesoscale Structures in Pathway Data on Graphs — •Vincenzo Perri[1], Luka V. Petrović[2], and Ingo Scholtes[1] — [1]University of Würzburg, Würzburg, Germany — [2]University of Zürich, Zürich, Switzerland

Mesoscale structures are an integral part of the abstraction and analysis of complex systems. For example, they can represent communities in social or citation networks, roles in corporate interactions, or core-periphery structures in transportation networks. Many methods to detect mesoscale structures are founded on the assumption that the interactions are independent. However, when complex systems are dynamic, the dynamics of interactions can invalidate this assumption and jeopardize the analysis. In this work, we derive a Bayesian approach that simultaneously models the optimal partitioning of nodes in groups and the optimal higher-order network dynamics between the groups. This model can capture mesoscale structures with higher-order patterns, which allows us to coarse grain pathway data, and analyse them at the level of groups of nodes. In synthetic data, we show that our method can recover both standard static patterns and dynamic patterns invisible to baselines. In empirical data, we find higher-order patterns at group levels, underlying the practical importance of our method. Finally, we demonstrate the interpretability of our method in an application on a language corpus and detection of vowel-consonant dynamics. From a broader perspective, our approach allows interpretable analysis of a complex system and facilitates our understanding of its structural and temporal patterns.

SOE 7.2 Mon 18:00 Poster D

Describing the Urban Heat Island effect with every-pair interactions — Yunfei Li[1], Fabiano L. Ribeiro[2], Bin Zhou[3], and •Diego Rybski[1] — [1]Potsdam Institute for Climate Impact Research (PIK), P.O. Box 601203, 14412 Potsdam, Germany — [2]Department of Physics (DFI), Federal University of Lavras (UFLA), Lavras MG, Brazil — [3]Faculty of Medicine, University of Augsburg, Augsburg, Germany

At the macroscopic scale, city size represents the most important determinant of the urban heat island (UHI) intensity. We propose an every-pair-interaction model, which incorporates urban form in a meaningful manner, to characterize the UHI intensity. We extract surface UHI intensity estimates from remote sensing data and employ the fractal dimension (obtained from urban land cover data) to characterize the urban form. Fitting the every-pair-interaction model to the data, we find that it performs better than a simple linear combination of logarithmic size and fractal dimension. Interestingly, the every-pair-interaction model represents a generalization as it includes (a) power-law, (b) logarithmic, and (c) saturating size dependence. Our theoretical framework indicates that the UHI intensity saturates with size at least for the considered surface temperature data.

SOE 7.3 Mon 18:00 Poster D

Rank dynamics in compartmental voter model — •Justas Kvedaravicius[1] and Aleksejus Kononovicius[2] — [1]Vilnius university, Faculty of Physics, Vilnius, Lithuania — [2]Vilnius university, Institute of Theoretical Physics and Astronomy, Vilnius, Lithuania

Traditional approaches to modelling opinion dynamics focus on temporal evolution of the system. While this approach is easy to model, it proves difficult to validate using empirical data, as it is more detailed in spatial resolutions rather than temporal ones. Statistics of data at various resolutions (scales) can reveal regularity and randomness in the spatial distributions. Attempts to define spatial and temporal dynamics have been suggested in [1, 2].

For models imbued with spatial distributions rank-size description is preferable to the timeseries point of view. We employ a generalization of rank-size description [3] to analyze dynamics of the compartmental voter model and approximate the dynamics using Fokker-Planck equation.

[1] Kononovicius, J. Stat. Mech. 2019: 073402 (2019). [2] Fernandez-Gracia et al., Phys. Rev. Lett. 112: 158701 (2014). [3] Iniguez et al., Nat. Commun. 13: 1646 (2022).

SOE 7.4 Mon 18:00 Poster D

Quantifying Tipping Risks in Power Grids and beyond — •Martin Hessler[1,2] and Oliver Kamps[2] — [1]University of Münster, Institute of Theoretical Physics, Germany — [2]Center for Nonlinear Science, Münster, Germany

Critical transitions, ubiquitous in nature and technology, necessitate anticipation to avert adverse outcomes. While many studies focus on bifurcation-induced tipping, where a control parameter change leads to destabilization, alternative scenarios are conceivable, e.g. noise-induced tipping by an increasing noise level in a multi-stable system. Although the generating mechanisms can be different, the observed time series can exhibit similar characteristics. Therefore, we propose a Bayesian Langevin approach (BL-estimation), implemented in an open-source tool, which is capable of quantifying both deterministic and intrinsic stochastic dynamics simultaneously. We analyse two bus voltage frequency time series of the historic North America Western Interconnection blackout on 10th August 1996. Our results unveil the intricate interplay of changing resilience and noise influence. A comparison with the blackout's timeline supports our frequency dynamics Langevin model, with the BL-estimation indicating a permanent grid state change already two minutes before the officially defined triggering event. A tree-related high impedance fault or sudden load increases may serve as earlier triggers during this event, as suggested by our findings. This study underscores the importance of distinguishing destabilizing factors for a reliable anticipation of critical transitions, offering a tool for better understanding such events across various disciplines.

SOE 7.5 Mon 18:00 Poster D

Inclusion of Social Norms and Groups in a Stylised Social-Ecological Multilayer Network Model restructures safe operating spaces in renewable resource management — •Max Bechthold and Jonathan Donges — Potsdam Institute for Climate Impact Research, Telegrafenberg A 31, 14473 Potsdam

Social norms are a main socio-cultural influence on human behaviour, one of the primary drivers of climate change in the Anthropocene. As a potential social tipping element, they are suggested to play a pivotal role in politics and governance and thus form a possible intervention point for global-scale collective action problems in the World-Earth system. This contribution presents a multi-level network framework for conceptualised social norms. It focuses on a complex contagion process that mimics the presence of social norms, which are further divided into the sub-concepts of descriptive and injunctive norms. The framework also incorporates social groups as an important feature. This allows to capture cases in which, for example, social groups may include norms into their identity, accelerating or slowing down the uptake of new social norms in their members. Building upon this framework, a model with coupled social-ecological dynamics and a closed feedback loop is constructed in the copan:CORE framework for world-Earth modelling. The results of computational investigation of the influence of social norms, social groups and social inertia in the model and the resulting safe operating spaces for management of a renewable resource are presented in this contribution.

SOE 7.6 Mon 18:00 Poster D

Forecasting confidence regions for marine animal movement with machine learning. — •Jorge M. Hernandez[1], Jorge P. Rodriguez[1], Ana M. M. Sequeira[2], and Victor M. Eguiluz[3] — [1]Institute for Cross-Disciplinary Physics and Complex Systems - IFISC (UIB-CSIC) — [2]Australian National University (ANU) — [3]Basque Centre for Climate Change (BC3)

Oceans, the largest ecosystems and crucial climate regulators, are environments where a diversity of human activities threaten marine life. To achieve effective conservation, it is crucial to comprehend the movement patterns of these animals. Home to around 36,000 species among marine mammals, fish, birds, and penguins, these habitats present a scientific challenge in movement forecasting.

Our study harnesses the Temporal Fusion Transformer (TFT) to predict marine animal movements, leveraging a dataset of 13,000 trajectories from over 100 species. Unlike traditional methods aiming for precise location prediction, our model determines a confidence region where an animal is likely to be, using quantiles and the quantile loss function. We emphasize model explainability. The analysis of the attention mechanism to understand data influence, shows a focus on recent and five-day prior data. SHAP values reveal key environmental

factors like bathymetry, temperature, and wave characteristics influencing predictions.

This research aids in understanding animal movement, improving navigation safety, and enriching ecological research. Future developments aim to create more accurate elipsoidal confidence regions.

SOE 7.7 Mon 18:00 Poster D

Disaggregating temporal properties of individual income dynamics using first passage under resetting approach — •Petar Jolakoski[1,2], Arnab Pal[3,4], Trifce Sandev[1,5,6], Ljupco Kocarev[1], Ralf Metzler[5,7], and Viktor Stojkoski[6,8] — [1]Macedonian Academy of Sciences and Arts, Skopje, Macedonia — [2]Brainster Next College, Skopje, Macedonia — [3]The Institute of Mathematical Sciences, Chennai, India — [4]Homi Bhabha National Institute, Mumbai, India — [5]Institute of Physics & Astronomy, Potsdam, Germany — [6]Ss. Cyril and Methodius University in Skopje, Macedonia — [7]Asia Pacific Centre for Theoretical Physics, Pohang, Republic of Korea — [8]Center for Collective Learning, ANITI, University of Toulouse, France

A comprehensive understanding of individual income dynamics is crucial for addressing the question of whether it is possible to improve one's income status over the course of a typical working life. This central question essentially involves observing an individual's status and its transition between two points: the current income and the desired income. These temporal changes are usually studied by using income transition matrices which only provide *aggregated quantities* for the time properties of income. As a result, we are unable to differentiate the fortunes of workers that are members of the same quantile. To bridge this critical gap, we build an analytical framework for *disaggregating* the MFPT to the *level of an individual worker* in the economy. We exploit the properties of an established stochastic process used for modelling income dynamics namely the geometric BM with resetting.

SOE 7.8 Mon 18:00 Poster D

Ising model of binary election with a split society phase — Olivier Devauchelle[1], Piotr Szymczak[2], and •Piotr Nowakowski[3,4] — [1]Université Paris Cité, Institut de Physique du Globe de Paris, Paris, France — [2]Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland — [3]Group for Computational Life Sciences, Division of Physical Chemistry, Ruđer Bošković Institute, Zagreb, Croatia — [4]Max Planck Institute for Intelligent Systems, Stuttgart, Germany

In modern democracies, the outcome of elections and referendums is often remarkably tight. To explain this phenomenon we propose a simple model of binary elections based on an Ising model of voters with ferromagnetic coupling of the neighbors and an additional weak antiferromagnetic coupling of every voter to the opinion poll. The model exhibits a new split society phase which properties seems to resemble those observed in some real binary elections: the voters are geographically separated into two groups (domains) with opposite opinions, the total result is close to 50%-50%, and an interface between the domains is located along the lines where the coupling between neighboring voters is reduced (like borders of cities, natural barriers, or historical borders between countries). We discuss the physical properties of our model and study the conditions necessary for the system to be in the split society phase. By analyzing the results of binary elections in various countries we are able to roughly estimate the values of the parameters describing our model.

SOE 7.9 Mon 18:00 Poster D

Emergent inequalities in a primitive agent-based good-exchange model — •Nirbhay Patil[1,2], Jean-Pierre Nadal[1,3], and Jean-Philippe Bouchaud[2,4] — [1]Ecole Normale Superieure, Paris — [2]Chair Econophysix, Ecole Polytechnique, Massy-Palaisseau — [3]École des hautes études en sciences sociales, Paris — [4]Capital Fund Management, Paris

Rising inequalities around the globe bring into question our economic systems, and the source of these inequalities. Here we try to understand the economy using an agent-based model where each entity is simultaneously producing and consuming goods, like a farmer or a firm.

To optimize utility, agents buy products in decreasing order of utility per unit price till they buy everything they can. Utilities are drawn from random distributions to reflect personal tastes and convenience. To optimise sales, agents adjust prices by comparing supply and demand. This is a complete description of the model, which we then simplify in various ways to make it analytically tractable. We come up with ways to find the stability of the resulting system that constitutes a new ensemble of random matrices not studied before.

We find that the system exhibits a phase transition between states of equality and strong inequalities based on the production capacity of each person. For higher production values this society becomes extremely unequal. We explore ways to alleviate poverty in this model and whether they have real life significance.

SOE 7.10 Mon 18:00 Poster D

Predicting the Dynamics of Behavioral Contagion in Human Groups with an Increment Drift-Diffusion Model — •Maryam Karimian[1,2,3], Fabio Reeh[1,2], and Pawel Romanczuk[1,2,3] — [1]Institute for Theoretical Biology, Humboldt-Universität zu Berlin — [2]Science of Intelligence, Research Cluster of Excellence, Berlin — [3]Bernstein Center for Computational Neuroscience, Berlin

Behavioral contagion is an interesting topic for cognitive science and collective behavior. While studies in Cognitive science overlook the impact of collective dynamics on decision processes, collective behavior studies mainly focus on simplified models of social interactions and neglect the cognitive complexity of individual agents. Hence, there is a gap in studying behavioral contagion, which incorporates not only complex individual decision processes but also concurrent social interactions that influence and are influenced by individual decisions. To address this gap, we employ a computational model to simulate virtual reality experiments (VR), unifying cognitive intricacies with collective dynamics. In this model, interaction networks are defined based on visual occupancy of agents from a first-person perspective. We aim to simulate VR experiments to explore how virtual agents responding to environmental signals influence human participants. Decision processes of participants are modeled using an extended drift-diffusion model, considering real-time updates in response to changing environmental and social signals. Our work investigates how network characteristics and temporal patterns of decision-making by virtual agents affect contagion dynamics.

SOE 7.11 Mon 18:00 Poster D

Opinion Dynamics of Interacting Large Language Models — •Vincent Brockers, David Ehrlich, Andreas Schneider, and Viola Priesemann — Max-Planck-Institute for Dynamics and Self-Organization

Classical models of opinion dynamics rely on purely symbolic representations of arguments, claims and reasons, potentially oversimplifying certain aspects of complex human behavior. This complexity can better be captured with recent Large Language Models (LLMs), as these possess the ability to mimic sophisticated human-like interactions with semantic meaning. However, how these new tools can be effectively utilized to improve on classical models remains an open research question.

Our research focuses on the interactions of LLM agents with different personality types and opinions in discussion scenarios as seen as on social media platforms. We use the Big Five personality traits to define the LLMs character and assign an initial opinion for one certain topic. Letting agents discuss for multiple rounds allows us to measure their individual influence-response-functions, which give insights about the process of opinion change, depending on the agents agreeableness, initial opinion and discussion topic.

In our simulations we find similar mechanisms of opinion reinforcement as seen as in symbolic models and that the strength can be controlled via the agreeableness trait. These findings and further analysis, especially how such agents behave in larger networks, are crucial to assess the applicability of LLMs in this research area.

SOE 7.12 Mon 18:00 Poster D

Modeling the Interplay of Awareness and Epidemics: A Mean-Field Approach with Twitter Data Analysis on COVID-19 Dynamics — Sara Shabani[1,2], Sahar Jafarbegloo[1], Sadegh Raeisi[1], and •Fakhteh Ghanbarnejad[1,3] — [1]Sharif University of Technology, Tehran, Iran — [2]Virginia Tech, Blacksburg, USA — [3]Technical University of Dresden, Dresden,Germany

The recent exploration of the reciprocal impact between awareness and disease introduces notable challenges. The preventive actions individuals take and their awareness levels can significantly shape the dynamics of disease spread, while disease outbreaks can influence awareness. We propose an initial null model that couples two Susceptible-Infectious-Recovered (SIR) dynamics, employing a mean-field approach for analysis. We then explore the parameter space to quantify the mutual influence on various observables. Utilizing this null model, we empirically analyze Twitter data related to COVID-19 and confirmed cases

in American states.

Our findings reveal that in specific parameter space, increasing awareness can suppress the epidemic, leading us to investigate phase transitions. Moreover, our model showcases the ability to shift the dominant population group by adjusting parameters during the outbreak. Applying the model, we assign parameters to each state, unveiling changes at different pandemic peaks. Notably, a robust correlation emerges between states' Twitter activity and immunity parameters assigned using our model, emphasizing the crucial role of sustained awareness in disease progression from initial to subsequent peaks.

SOE 7.13 Mon 18:00 Poster D

Analysis of COVID-19 Related Misinformation Spread in Telegram Communities — •Roman David Ventzke, Sebastian Bernd Mohr, Andreas Schneider, and Viola Priesemann — Max-Planck-Institut für Dynamik und Selbstorganisation, Göttingen

To effectively combat the proliferation of misinformation in online social media, it is important to understand content spread in social networks. We therefore investigate the dynamics of (mis)information propagation via the Telegram messaging app, with the aim to improve quantitative understanding of dissemination processes in self-organized social network settings.

As a basis for this study, we employ a novel large dataset of messages from Telegram group chats and channels. This dataset comprises more than 2.3 billion messages from more than 150,000 different chats and focusses on COVID-19-related content during the time of the pandemic.

We track and analyze information avalanches propagating in this network of chats to quantify their spreading dynamics and compare the spreading processes of information from trustworthy news sources and misinformation. We also examine the impact of potentially spread-influencing factors such as content-fostered emotional engagement. Finally, we investigate through the lens of statistical physics whether the observed information avalanches within the telegram communities constitute an (almost) critical process.

SOE 7.14 Mon 18:00 Poster D

Information parity: a measure to quantify the influence of nodes in a network — Aline Viol[1] and •Philipp Hövel[2] — [1]Scuola Internazionale Superiore di Studi Avanzati di Trieste (SISSA), Italy — [2]Saarland University, Germany

A growing interest in complex networks theory results in an ongoing demand for analytical tools. In order to quantify the functional, statistical symmetries between nodes in a complex network, we propose *information parity* as an insightful measure. Unlike the usual approach to quantitative network analysis that considers only local or global scales, information parity instead quantifies pairwise statistical similarities over the entire network structure. Based on the statistics of geodesic distances, information parity assesses how similarly a pair of nodes can influence and be influenced by the network.

Relating to neuroscience, for instance, we find an increase in the average information parity on brain networks of individuals under psychedelic influences. Notably, the information parity between regions from the limbic system and frontal cortex is consistently higher for all the individuals while under the psychedelic influence. These findings suggest that the resemblance of statistical influences between pair of brain regions activities tends to increase under Ayahuasca effects. This could be interpreted as a mechanism to maintain the network functional resilience.

[1] A. Viol et al. J. Phys. Complexity 4, 01LT02 (2023).
[2] A. Viol et al. Physica A 561, 125233 (2021).

SOE 7.15 Mon 18:00 Poster D

The diffusion map technique and its application to political regime types in the 20th century — •Sönke Beier[1], Paula Pirker-Diaz[1], Matthew Charles Wilson[2], and Karoline Wiesner[1] — [1]Institute of Physics and Astronomy, University of Potsdam, Germany — [2]Department of Political Science, University of South Carolina, U.S.

The V-Dem project provides a dataset of dozens of characteristics of political systems, such as press freedom or independence of electoral authorities, for almost all countries and years of the 20th century. But can these high-dimensional data be meaningfully represented in 2- or 3 dimensions and can such a representation help to get insight into the dynamics of political systems?

We have found that the non-linear dimension reduction method "diffusion map" is able to identify a meaningful representation of the data on a 2- dimensional manifold, which is robust over a large parameter range. It sorts countries from autocratic to democratic, also some sub-forms can be recognized. We clarify the influence of the diffusion-map parameters in general, providing insights that are relevant for the application of the technique to other real-word datasets.

In a next step we will use this visualization to analyse different dynamics, such as democratization processes, backsliding, or major disruptive changes.

SOE 7.16 Mon 18:00 Poster D

Transformer neural networks for the detection of artefacts in energy market data — •Henrike von Hülsen[1,2], Ulrich Oberhofer[2], Benjamin Schäfer[2], Oliver Lauwers[3], and Gust Verbruggen[4] — [1]50Hertz Transmissions GmbH, Berlin, Germany — [2]Institute for Automation and Applied Informatics, Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany — [3]Elia Group, Brussels, Belgium — [4]Microsoft, Brussels, Belgium

Participants in the Belgian electricity market are permitted to deviate from their scheduled production or consumption, if the deviation counteracts a current imbalance in the market. The interpretation of the emerging data on schedule deviations is disturbed by artefacts caused by ramping times of different assets.

Drawing inspiration from the success of transformer architectures in handling 1D imaging data, the hypothesis is that transformers can efficiently process the underlying time series data to identify and subsequently eliminate these artefacts. Removing the artefacts will directly contribute to the efficiency of the capacity market in Belgium.

We propose a method from the evolving filed of transformer applications in diverse data domains, that will reliably detect and remove ramping artefacts without diminishing the quality of the signal.

SOE 7.17 Mon 18:00 Poster D

An Open Source toolbox for Complex Systems Science: The 'pyunicorn' package — •Fritz Kühlein[1,2], Lukas Röhrich[1,3], and Jonathan Donges[1,4] — [1]Potsdam Institute for Climate Impact Research, Germany — [2]Martin-Luther-University Halle-Wittenberg, Germany — [3]Humboldt-University of Berlin, Germany — [4]Stockholm Resilience Center, Sweden

Pyunicorn is shorthand for the Python Unified Complex Network and Recurrence Analysis Toolbox. First developed at the Potsdam Institute for Climate Impact Research and published by Donges et al. (2015), it has since been under active further development as an open source project. Pyunicorn facilitates the innovative synthesis of methods from both network theory and nonlinear time series analysis in order to develop novel integrated methodologies. Such methodologies can be applied in various disciplines, such as climatology, neuroscience, social science, infrastructure or economics. Features of Pyunicorn include the construction and analysis of climate networks, interacting networks, recurrence networks and visibility graphs to name just a few, as well as event series analysis tools among the more recently included. The modular, object-oriented structure of Pyunicorn makes it highly versatile and intuitive to use. As we have been working on the latest revised version release of Pyunicorn, we primarily aim to present the package's features and applications in its current state, but also to share retrospective insight on the fruits and pitfalls of managing an open source project over almost a decade.