SOE 16: Tipping Points in Social and Climate Systems (accompanying session for SYTP)

Accompanying session to the Symposium in Tipping Points in Social and Climate Systems

Time: Thursday 11:30–12:45 Location: GÖR/0226

Invited Talk SOE 16.1 Thu 11:30 GÖR/0226

Tipping in Strongly Perturbed Open Networks — •Marc Timme[1,2], Georg Börner[1], Marisa Fischer[1], Julian Fleck[1], Seungjae Lee[1], Philip Marszal[1], Gwendolyn Quasebarth[1], Malte Schröder[1], and Moritz Thümler[1] — [1]Network Dynamics, TU Dresden, http://networkdynamics.info — [2]Lakeside Labs, Klagenfurt, Austria

Strong fluctuations impacting open systems may induce tipping and system-wide cascading failure, yet it remains unclear under which conditions, how, and at which point fluctuation-driven systems tip. Here we report theoretical and methodological progress about tipping and its precursors in a range of externally driven nonlinear networked systems, substantially generalizing and going beyond work on one- and two-dimensional systems [1,2]. We combine self-consistency conditions, insights from periodically driven systems in electrodynamics and tools from harmonic balance and asymptotic analysis to uncover generic routes to tipping, to predict intrinsically nonlinear response dynamics before tipping and estimate the tipping point semi-analytically. We highlight several application directions and a broad range of unsolved questions.

I acknowledge generous support by the German Science Foundation (DFG) through a Koselleck project (2025-2029, proj. # 544800752).

[1] M. Thümler et al., Nonlinear and divergent responses of fluctuation-driven systems, IFAC-PapersOnLine 55:254 (2022).

[2] G. Börner et al., Perturbation-response dynamics of coupled nonlinear systems, Chaos 34:103149 (2024).

SOE 16.2 Thu 12:00 GÖR/0226

Stability and decay of socio-political systems — •Vaishnavi Jayakumar[1], Matthew Wilson[2], and Karoline Wiesner[1] — [1]Institute for Physics and Astronomy, University of Potsdam, Germany — [2]Department of Political Science, University of South Carolina, Columbia, SC, USA

The government is a fundamental unit of modern societies. There have been many efforts to quantify different styles of governance, one of the most prominent being the V-Dem project. V-Dem provides a comprehensive set of indicators on governance quality, including the Electoral Democracy Index (EDI). Governing styles can be classified in various ways based on such indicators; this has led to many studies on the feasibility, stability, and resilience of such socio-political institutions. In our present work, we analyze the V-Dem database, spanning across 195 countries, and examine the effective lifetimes and decay dynamics of various governments and regimes. Using survival analysis methods, we model regime longevity in terms of half-life and mortality rates. We find that countries with an EDI > 0.5 approximate a fairly straightforward decay function with a well-defined half-life, whereas countries with an EDI < 0.5 display irregular lifetimes, with a trajectory that evades a simple steady-state description. This heterogeneity can be understood by accounting for the underlying drivers of both regime endurance and collapse. We further investigate how economic and institutional factors shape regime lifetimes and contribute to the observed variability. Our study thus sheds new light on the key ingredients that underpin regime stability and mortality.

SOE 16.3 Thu 12:15 GÖR/0226

Generating Representative Social Networks for modeling social tipping points — •Kamiel Gülpen and Vítor Vasconcelos — University of Amsterdam, Amsterdam, The Netherlands

Addressing some of today's most pressing challenges, from climate change to public health crises, requires triggering collective behavioral shifts through social tipping points (STPs). These phenomena have been extensively modeled using synthetic network topologies, which provide valuable theoretical insights but often incompletely represent the mixing patterns that influence tipping dynamics in real populations. Understanding when STPs occur thus requires real-world network data. While such data remains scarce, government agencies possess rich information on household, family, neighborhood, and work/school connections, but often in aggregated form due to privacy constraints. This aggregated data reveals group-level mixing patterns but lacks the individual network topology necessary for modeling diffusion processes. To bridge this gap, we present the Aggregated Social Network Unfolding (ASNU) framework, which generates representative multiplex social networks from aggregated demographic data. Applied to Amsterdam's population, ASNU reconstructs networks across social layers while preserving key structural properties. We also introduce the Social Relational Attachment (SRA) model for generating realistic social networks when aggregated edge data is unavailable. Unlike previous models relying solely on homophily, SRA incorporates both homophilic and heterophilic bonding through tunable demographic distance parameters.

SOE 16.4 Thu 12:30 GÖR/0226

Jacobian Reconstruction from Time-Series of an Opinion Dynamical Network Model and its Applicability as an Early Warning Signal for Tipping Points — •Tim Mauch — Helmholtz Institute for Functional Marine Biodiversity (HIFMB), Im Technologiepark 5, 26129 Oldenburg, Germany — Carl-von-Ossietzky University, Institute for Chemistry and Biology of the Marine Environment, Carl-von-Ossietzky Str. 9-11, 26129 Oldenburg, Germany

In social dynamical systems the early identification of critical transitions is a significant challenge. To address this, we formulate a new opinion model to enhance the understanding of tipping mechanisms in opinion dynamics and adopt a method for reconstructing the Jacobian matrix of the model from time-series data, testing its applicability for detecting critical transitions.

Inspired by meta community models from ecology, we study opinion formation using a network-based model in which nodes represent communities of interacting agents holding one of two competing opinions, and links represent avenues of migration. We analytically derive conditions for diffusion-driven pattern formation and identify a mechanism facilitating opinion diversity, where the minority opinion can reach local majority, thus creating regions of differing opinion dominance.

We then generate synthetic time series of the model and reconstruct the Jacobian matrix using only the time series data and the underlying network structure. We show that the reconstructed eigenvalues correctly capture the trend of the analytical eigenvalues when changing the model parameters towards critical transitions.