SOE 15: Networks: From Topology to Dynamics III (joint session DY/SOE)

Time: Thursday 11:15–12:45 Location: ZEU/0118

SOE 15.1 Thu 11:15 ZEU/0118

Remote Tipping in Networks — •Philip Marszal[1], Malte Schröder[1], and Marc Timme[1,2] — [1]Chair of Network Dynamics, Center for Advancing Electronics Dresden (cfaed) and Institute of Theoretical Physics, TUD Dresden University of Technology, 01062 Dresden, Germany — [2]Lakeside Labs, Lakeside B04b , 9020 Klagenfurt, Austria

Tipping of a single unit in a complex networked system can trigger large-scale cascades that shift the system's macroscopic state. Typically, such cascades propagate diffusively, with each tipping event destabilizing adjacent units.

Here we report a novel form of tipping cascade in systems of coupled bistable oscillators, that results in the tipping of non-adjacent nodes. One node can trigger transitions in distant nodes while intermediate neighbors remain unaffected. Which nodes tip and which ones remain unaffected depends intricately on the local oscillator dynamics and the underlying network structure. We study the transition between locally spreading and non-local cascades and characterize the conditions necessary for the emergence of non-local cascades.

SOE 15.2 Thu 11:30 ZEU/0118

Ponderomotive Route to Tipping in Open Networks — Seungjae Lee[1], •Marisa Fischer[1], and Marc Timme[1,2,3] — [1]Chair for Network Dynamics, Institute of Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), Technische Universität Dresden, 01062 Dresden, Germany — [2]Center Synergy of Systems, Technische Universität Dresden, 01062 Dresden, Germany — [3]Lakeside Labs, Lakeside B04b, 9020 Klagenfurt, Austria

External fluctuations impact the dynamics of complex networked systems, from cells and ecosystems to engineered infrastructures. Strong external forcing may cause tipping that compromises such systems' functionality. Here, we identify a generic ponderomotive route to tipping in open, periodically driven systems. Upon increasing the driving amplitude, the time-average of the oscillatory responses persistently shifts away from the original system's operating point – a system-level ponderomotive effect. We characterize the shift as the fixed-point solution of a slow dynamics resulting from a two-time-scale analysis. A bifurcation point of the shift defines the tipping point beyond which the system settles into another collective state, diverges gradually, or exhibits finite-time blow-up. The ponderomotive shift together with its bifurcation yields the novel type of *ponderomotive tipping*. It generically emerges across disparate systems from science and engineering and is independent of their diverse post-tipping dynamics.

SOE 15.3 Thu 11:45 ZEU/0118

Linear dynamics on infinite networks — •Bernd Michael Fernengel — HIFMB, Oldenburg, Germany

Linear evolutionary equations are often used to describe the time evolution of a physical system. Their solution operator can be written in an exponential form of exp(t A), with some generator A. When the generator is a finite dimensional matrix, we can interpret its time evolution as a hopping dynamics on a finite network, where the dynamics of the network can be transferred to the dynamics of the solution operator.

In order to study special types of solution operators for non-interacting systems of countable dimensions, we construct countable, infinitely large networks using the iterated Cartesian product of finite graphs, where the dynamics is known. We discuss the possibilities to infer properties like the time evolution and the stationary solution of the infinite network from finite approximations via the thermodynamic limit. This is closely related to the question, under which conditions it is possible to approximate a countable, infinite system by finite subsystems.

SOE 15.4 Thu 12:00 ZEU/0118

Localizing sparse perturbation sources in driven nonlinear networks — •Julian Luca Fleck, Jose Casadiego, and Marc Timme — Chair of Network Dynamics, Center for Advancing Electronics Dresden (cfaed) and Institute of Theoretical Physics, TUD Dresden University of Technology, 01062 Dresden, Germany

Network dynamical systems under the influence of external perturbations abound in nature and engineered systems, ranging from neural circuits to electrical power grids. The external driving can drastically change the system's operating mode and be fatal for system stability. Localizing sources of perturbations in a network is crucial to mitigate systems failure. We present a linear response approach to infer the location from a multivariate time series of a recorded subset of nodes. We employ a compressed-sensing algorithm to locate one or multiple perturbation sources utilizing the sparsity of such locations. The approach additionally yields the time series of the unmeasured nodes and the external driving. We test for random linear systems, and illustrate the applicability to electrical power grids.

SOE 15.5 Thu 12:15 ZEU/0118

Elucidating structure-function relationships in physical networks via ensnarlment — •Yu Tian[1,2,3,4], Chinmayi Subramanya[1,3,4], and Carl Modes[1,3,4] — [1]Center for Systems Biology Dresden, Dresden, Germany — [2]Max Planck Institute for the Physics of Complex Systems — [3]Max Planck Institute of Molecular Cell Biology and Genetics — [4]Dresden University of Technology, Dresden, Germany

Understanding physical networks – whose structure is constrained by the physical properties of their nodes and links – is a growing interdisciplinary challenge, especially in biological systems. Physical constraints such as volume exclusion and non-crossing conditions, along with biological functionality, can drive these networks into non-optimal spatial configurations. One prominent feature is that cycles may go through each other's interior space, which may not be unraveled without removing edges, leading to an ensnarled state. Characterizing the ensnarlment in the space, and its interplay with the functional behaviours of the network, is essential for revealing structure-function relationships in such systems. In this work, we introduce a graph-theoretic framework based on the linking operator, obtained by the Gauss linking integral applied to the cycles in the network. This approach enables a multiscale analysis of entanglement, spanning local, intermediate, and global structures. Our goal is to reveal how topological complexity shapes, and is shaped by, biological functions, providing new insights into the organizational principles of physical and biological networks.

SOE 15.6 Thu 12:30 ZEU/0118

Transient stability properties for transitions between stationary power flows — •Leo Heidweiler[1,2] and Frank Hellmann[2] — [1]TU Dresden — [2]Potsdam Institute for Climate Impact Research

The increasing incorporation of renewable energy sources into electrical power grids fundamentally changes their dynamical behaviour and introduces new challenges for system stability. While network expansion and operation are traditionally based on stationary power flow analysis, dynamical effects following line faults, such as loss of synchronization of a single generator or whole part of the network, may occur even when a stable post-fault power flow exists and operational constraints are fulfilled. Direct assessment of transient stability, however, requires time-resolved simulations that are computationally expensive and unsuitable for large-scale planning and real-time applications. This motivates the question of whether transient stability properties can be inferred from static characteristics of the network, such as power flow solutions and topology.

In this work, we develop stability indicators for the IEEE39 Bus power system and investigate their predictability using PowerDynamics.jl, a Julia Library for numerical Power Grid simulations. In particular, we make use of the complex oscillator formulation of Power Systems and machine learning. This helps us assess whether stability margins can be predicted from stationary quantities alone or whether intrinsically dynamical information is indispensable. If so, we can deduce what minimal dynamical information is sufficient for reliable prediction.