International Workshop on Complex Systems and Networks 2019

Berlin, September 23rd - 26th 2019

Abstracts

Huang, Tingwen , Texas A&M University at Qatar, Qatar

Efficient Computational Approaches and Their Applications in Smart Grid

In this talk, efficient computational approaches to game theoretic model, large scale optimization problem and Q-learning framework will be introduced to solving different challenging problems. In a smart grid context, a demand response strategy of electric vehicle charging is modelled by a stochastic game, where a big data analytic framework is proposed for controlling the electric vehicle charging behaviors. Moreover, a two-stage stochastic game theoretical model is proposed for energy trading problem in a multi-energy microgrid system. In these two work, the risk measurement technique, conditional value at risk (CVaR), is harnessed to estimate the overload risk during the peak hour and the overbidding risk while distributed alternating direction method of multipliers (ADMM) is accelerated by Nesterov gradient method to solve two game models. Concerning the privacy, a research branch of reinforcement learning (RL) that dominates distributed learning for years will be presented by making the first attempt to apply RL-based algorithms in the energy trading game among smart microgrids where no information concerning the distribution of payoffs is a priori available and the strategy chosen by each microgrid is private to opponents, even trading partners. To solve this challenge, a new energy trading framework based on the repeated game that enables each microgrid to individually and randomly choose a strategy with probability to trade the energy in an independent market so as to maximize his/her average revenue. In addition, for a large scale economic dispatch problem, different distributed optimization algorithms are developed, including a fast event-triggered scheme and consensus based multiagent methods.

Kapitaniak, Tomasz, Lodz University of Technology, Poland

Traveling amplitude death in coupled pendula

We investigate the phenomenon of amplitude death (in two scenarios -- traveling (TAD) and stationary (SAD)) in coupled pendula with escapement mechanisms. The possible dynamics of the network is examined in coupling parameters' plane and the corresponding examples of attractors are discussed. We analyze the properties of the observed patterns, studying the period of one full cycle of TAD under the influence of system's parameters, as well as the mechanism of its existence. It is shown, using the energy balance method that the strict energy transfer between the pendula determines the direction in which the amplitude death travels from one unit to another. The occurrence of TAD is investigated as the result of a simple perturbation procedure, which shows that the transient dynamics on the road from complete synchronization to amplitude death is not straightforward. The pendula behaviour during the transient processes is studied and the influence of parameters and perturbation magnitude on the possible network's response is described. Finally, we analyze the energy transfer during the transient motion, indicating the potential triggers leading to the desired state. The obtained results suggest that the occurrence of traveling amplitude death is related to the chaotic dynamics and the phenomenon appears as a result of completely random process.

Kocarev Ljupco, Cyrill and Methodius University, Skopje, Macedonia

Bayesian Consensus Clustering in Networks

In the first part of the talk I will review the concept of exchangeability in statistics. An infinite exchangeable sequence is strictly stationary and therefore a law of large numbers in the form of Birkhoff–Khinchin theorem applies. The close relationship between exchangeable sequences of random variables and the i.i.d. will be described as well as its connection to Bruno de Finetti's development of predictive inference and to Bayesian statistics. In the second part of the talk I will discuss multiplayer stochastic blockmodel which uses Bayesian consensus clustering.

Prof. Jianquan Lu., Southeast University, China

On controllability of Boolean control networks

Semi-tensor product of matrices has now become a useful tool to study Boolean networks and some other topics (graph coloring, nonlinear feedback shift registers, power systems, networked evolutionary games, Petri networks, cluster consensus). In this talk, we will mainly discuss the pinning controllability and sampled-data control of Boolean networks. Pinning controllability here means that the whole Boolean network can be forced to desired state by only controlling a small fraction of nodes. Besides the structure matrix of the logical function, the original network structure is also utilized for pinning control in order to reduce computational complexity. Stabilization problem of BCNs will also be discussed under aperiodic sampled-data control.

Porfiri, Maurizio, New York University, USA

Epidemic processes in activity-driven networks

The complex nature of human-to-human interactions in social systems has an important role in shaping the evolution of epidemic outbreaks. Describing and quantifying this role is critical toward the formulation of mathematical models for the spread of epidemic diseases. However, a common assumption of existing models is the time-scale separation between the evolution of the network and the epidemic process unfolding in its fabric. Activity-driven networks have emerged as a paradigm of choice to model temporal networks and overcome such a limiting assumption. In activity-driven networks, the link rewiring mechanism and the epidemic outbreaks share a common time-scale. In this talk, we illustrate the extension of this paradigm to embrace the complexity of social interactions within an analytically tractable framework. Through a series of case studies, we examine preferential connections, burstiness, and self-exciting mechanisms in the link formation process.

Michael Small, University of Western Australia, Australia

A surrogate for Markov chains: Testing for determinism in symbolic dynamics on transition networks

Surrogate methods provide algorithms to generate ensembles of time series data consistent with a specific null hypothesis, but also otherwise similar to an original time series. Hence,

one is able to test the observed time series against the null hypothesis that any ``interesting'' behaviour can be adequately explain by the posited null. There now exist several methods to construct networks which represent the behaviour of an underlying dynamical system as a sequence of transition between discrete states. In this context, a natural question which arises is whether specific symbolic time series can be adequately explained by a Markov process of finite order n, or whether more complicated nonlinear determinism should be invoked. In this contribution we describe a new surrogate generation algorithm which, from a proposed symbolic time series, generates ensembles of surrogate symbolic time series which are similar to that original (in the sense that the Markov processes of order up to n have the exactly the same marginal distribution when estimated from either time series) but are otherwise random. We demonstrate this technique with reference to our recent work analysing the work of J.S. Bach and hence answer the question: ``Is Bach's brain a Markov chain?''

Dr. Veronika Stolbova, ETH Zurich, Switzerland

Complex Networks in Finance&Climate: How do complex networks help in solving current problems of Finance&Climate?

As a result of climate policies supporting green technologies and discouraging brown technologies, large portions of assets of financial institutions are potentially subject to positive or negative re-evaluation. Despite this fact, there are no monetary estimates of the potential financial gains and losses of the economy due to decarbonization. Here, we develop a financial network-based methodology to estimate direct and indirect exposures of institutional sectors (e.g. non-financial corporations, investment funds, banks, insurance and pension funds, other financial institutions, governments, and households) to climate policy risks through equity holdings, corporate and sovereign bonds, and loans. We apply this methodology to the micro level (firms) and macro-level data of financial contracts between firms worldwide and estimate climate policy risks for the Euro Area and its implications for the financial stability.

Xu Yong, Northwestern Polytechnical University, China

Averaging principles and noise-induced dynamics in the presence of Non-Gaussian levy noise

Averaging principle is a kind of theorem that can simplify the original system with its solution converging to the so-called averaged system in the sense of probability. The stochastic averaging method is developed to obtain the response solutions including the probability density function and sample path solutions where the reduced system is usually established via the stochastic averaging technique. Then the noise-induced dynamics for different conceptual dynamical system will be presented. In this talk, we will talk about the Non-Gaussian Levy noise which describes the model of random fluctuations beyond the Gaussian noise. The averaging principle in the presence of Levy noise will be proposed mathematically for SDEs/SPDEs under (non)Lipschitz conditions, and here these main results will support the method of stochastic averaging theoretically. Based on the developed techniques we will further talk the levy noise-induced dynamics including the stochastic bifurcation and transitions. The different effects of levy noise from Gaussian case will be demonstrated especially for the alpha stable Levy noise.

Yu Wenwu, Southeast University, China

Recent Advances and New Challenges for Distributed Cooperative Control and Optimization in Networked Collective Intelligence

In this talk, the distributed control and optimization based networked collective intelligence is introduced. First, networked collective intelligence is briefly discussed. Then, the recent advances on multi-agent collective behaviors, control, optimization, and some of their potential applications are also briefly reviewed. Furthermore, the new directions and challenges for the research work on this topic will be discussed.

Yuan Ye, Huazhong University of Science and Technology, China

Data-driven Discovery of Cyber-Physical Systems

A major cross-disciplinary challenge concerns the need to adequately model cyber-physical systems (CPSs). CPSs, which embed software into the physical world (for example, in smart grids, robotics, intelligent manufacture and medical monitoring), have proved resistant to modeling due to the intrinsic complexity arising from (a) the combination of physical and cyber components and (b) the interaction between systems. This study proposes a solution in the form of a general framework for reverse engineering CPSs from data without prior knowledge. The method, which draws from artificial intelligence, involves the identification of physical systems as well as the inference of computer logics using sparse identification. The novel framework, which has been applied successfully to a number of real-world examples, seeks to enable researchers to make predictions concerning the trajectory of CPSs based on the discovered model. Such information may prove essential for the assessment of the performance of CPS and the design of failure-proof CPS. We can also use the proposed framework for the creation of design guidelines for new CPSs.

Elbert Macau, Federal University of Sao Paulo, Brazil

A measure for synchronization in power-grid models of Kuramoto-like oscillators

In the context of power-grid models of Kuramoto-like oscillators, synchronization is defined as the matching of the angular velocities of the oscillators, such that synchronized oscillators evolve most likely out of phase but with equal angular velocities. As such, coherence is usually measured by means of an order parameter in the interval [0,1], which is a function of synchronization quality and persistence over time. In this work, we take as basis previous studies on Kuramoto model to develop analytical results on the critical coupling in networks of Kuramoto-like oscillators and evaluate them against an order parameter rf defined as the normalized sum of absolute values of phase deviations of the oscillators over time. As case studies, we evaluate networks with 2, 3, 4 and 6 nodes and with generator-consumer connections of different values. The investigation of frequency synchronization over the subsets of the parameter space of power-grid models of Kuramoto-like oscillators is carried out, from which we conclude that the analytical results are in good agreement with the results observed in the numerical simulations.

Peter Ditlevsen, University of Copenhagen, Denmark

TBA

Maurizio Porfiri, New York University, USA

Media coverage and firearm acquisition in the aftermath of a mass shooting

We are experiencing an unprecedented surge of mass shooting events in the U.S. These events often elicit heated discussion among the public, polarizing opinions on firearm control, as seen and amplified in the media. Previous studies have demonstrated a strong, positive correlation between the frequency of mass shootings and increased firearm prevalence in the U.S. We present an information-theoretic framework, which goes beyond correlational analysis to unravel causal links between mass shootings, media coverage on firearm control, and firearm prevalence. Using empirical data covering from 1999 to 2017, we demonstrate directional information transfer between the time-series of media coverage and the number of background checks, suggesting that media coverage may increase public fear of more stringent firearm control and, in turn, drive firearm prevalence. In others words, people might rush to buy guns because they fear that new regulations may come into effect and their right to acquire a weapon be challenged.

Marc Timme, TU Dresden, Germany

Network dynamics as an inverse problem

Knowing the interaction topology and state of a network dynamical system crucially underlies its collective function [1,2,3]. Specifically, the number N of dynamical variables making up a system arguably constitutes one of its most fundamental properties. Typically, however, N is unknown, because only a small subset of n <N variables is perceptible. For instance, in power grids in which switches can be open or closed, the size of its connected components reveal information about switch states. Here we introduce a detection matrix that suitably arranges repeatedly observed time series to detect N via matching rank constraints [4]. The proposed method relies on basic linear algebra and as such is model-free, applicable across system types and interaction topologies, and nonstationary dynamics near fixed points. We further offer extensions to periodic and chaotic collective motion. Even if only a small minority of variables is observable and for systems simultaneously exhibiting nonlinearities, heterogeneities, and noise, exact detection is feasible.

[1] Review: Marc Timme & Jose Casadiego, J. Phys. A 47:343001 (2014).
[2] Casadiego et al., Nature Comm. 8:2192 (2017)
[3] Nitzan et al., *Science Adv. 3:*e1600396 (2017):
[4] Hauke Haehne et al.,Phys. Rev. Lett. 122:158301 (2019).

Prof., Pereira Tiago, University of São Paulo, Brazil

Stochastically driven hubs induce coherence resonance and synchronisation

Disparate real-world networked systems share an important structural feature: they have a few highly connected nodes called hubs. We study noise driven self-sustained oscillations coupled through a network with hubs. We show that stochastic effects synergize with the heterogeneous structure to create nonlinear phenomena such as noise-induced synchronization and coherence resonance. That is, collective transitions would not be possible by the sole presence of noise and sole network structure. This reveals that nonlinear interaction between network structure and stochastic effects play a fundamental role in complex systems.

Dr. Hildeberto Jardon, Technical University of Munich, Germany

Dynamic consensus networks with two time scales.

Consensus problems over a network concern interacting agents looking to achieve a common goal. Commonly, consensus problems are considered over graphs with fixed non-negative weights. In this talk we analyze a simple dynamic consensus problem defined over an undirected graph. The novelty is that one of the edges is dynamic itself taking values over the real numbers. Furthermore, it is assumed that the weight depends on a slow exogenous variable. This setting leads to the study of a fast-slow dynamical system defined over a network.

We show that due to the dynamic nature of the weight, transition through a transcritical singularity leads to loss of consensus and possibly resulting in clustering. A detailed analysis and description of the transition through the singularity is performed based on the blow-up method. We also show that the blow-up method preserves the network's structure. Interesting dynamic behavior including canard cycles shall be described as well.

Dr. Fernando S. Borges, CMCC/UFABC, Brazil

Bistable firing patterns: one way to understand how epileptic seizures are triggered

Excessively high, neural synchronisation has been associated with epileptic seizures, one of the most common brain diseases worldwide. Previous researchers have argued which epileptic and normal neuronal activity are support by the same physiological structure. However, to understand how neuronal systems transit between these regimes is a wide question to be answered. In this work, we study neuronal synchronisation in a random network where nodes are neurons with excitatory and inhibitory synapses, and neural activity for each node is provided by the adaptive exponential integrate-and-fire model. In this framework, we verify that the decrease in the influence of inhibition can generate synchronisation originating from a pattern of desynchronised spikes. The transition from desynchronous spikes to synchronous bursts of activity, induced by varying the synaptic coupling, emerges in a hysteresis loop due to bistability where abnormal (excessively high synchronous) regimes exist. We verify that, for parameters in the bistability regime, a square current pulse can trigger excessively high (abnormal) synchronisation, a process that can reproduce features of epileptic seizures. Then, we show that it is possible to suppress such abnormal synchronisation by applying a small-amplitude external current on less than 10% of the neurons in the network. Our results demonstrate that external electrical stimulation not only can trigger synchronous behaviour, but more importantly, it can be used as a means to reduce abnormal synchronisation and thus, control or treat effectively epileptic seizures.

Prof. Sune, Lehmann, Technical University of Denmark,

Fundamental Structures in Temporal Communication Networks

In this talk I introduce a framework for modeling temporal communication networks and dynamical processes unfolding on such networks. The framework originates from the observation that there is a meaningful division of temporal communication networks into six dynamic classes, where the class of a network is determined by its generating process. In particular, each class is characterized by a fundamental structure: a temporal-topological network motif, which corresponds to the network structure of communication events in that class of network.

The fundamental structures constrain network configurations to those possible within a dynamic class. In this way the framework presented here highlights strong constraints on network structures, which simplify analyses and shape network flows.Therefore the fundamental structures hold the potential to impact how we model temporal networks in general. I argue that networks within the same class can be meaningfully compared, and modeled using similar techniques, but that integrating statistics across networks belonging to separate classes is not meaningful in general.

Nadezhda Semenova, Saratov State University, Russia

Noise induced solitary and chimera states in network of excitable systems

In the present work we study an ensemble of FitzHugh-Nagumo systems in presence of noise with local, global and nonlocal coupling. Such system has been already studied in oscillatory regime. We are interested in excitable regime. It is shown that for some types of coupling such network can demonstrate noise induced chimera states of two types. The first one is coherence resonance chimera. It is the spatio-temporal pattern combining the peculiarities of coherence resonance and chimera states and is characterized by switching position of incoherence domains. The second one chimera is characterized by stationary position of coherence and incoherence areas, but it is also induced by noise and can be obtained for another values of control parameters. Moreover, changing the coupling parameters one can obtain solitary states, when neighboring partial elements can demonstrate two different types of motion. We study the impact of white Gaussian noise on these three spatio-temporal regimes and how the noise controls them.

Dr. Ugur Ozturk, The Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences, Germany

Depicting scale properties of extreme rainfalls over Japan using complex networks

Despite the scientific efforts in monitoring extreme rainfall, it is a challenge to predict the spatial dynamics of the fast-evolving atmospheric events that trigger extreme rainfall such as tropical storms. It is essential to understand the spatial dynamics of such weather systems to develop and improve the prediction methods. Metrics of complex networks can decipher hidden spatial patterns in large-scale rainfall data, and consequently, identify corresponding atmospheric instabilities that cause extreme rainfall. Such methods have already been used to detect spatially persistent atmospheric patterns that generate extreme rainfall over different regions, such as South America and Indian subcontinent. We have explored network metrics in conjunction with a nonlinear correlation measures of event synchronization to depict the unique spatial features of extreme rainfall over Japan using satellite-derived rainfall data, TRMM (Tropical Rainfall Measuring Mission). The tropical and frontal (Baiu) storms dominate extreme events in two discrete seasons; the Baiu front controls the rainfall events from June to July, whereas tropical storms activity peak at August, and are active until November. Rainfall events triggered by these two systems show contrasting spatial features. We found four communities for the frontal storm-driven rainfall during the Baiu season, one of which captures the area where the Baiu frontal triggered rainfalls are most active. The Baiu rains extend zonally (east-west) rather than meridionally (north-south), which is reflected by the horizontal extension of this community. During the tropical storm season we detected two distinct regions where two different tropical storm tracks cluster. Another interesting finding was consistently larger spatial scales involved in the Baiu driven rainfall extremes, when compared to tropical storms. This is likely linked to the synoptic processes behind the frontal development.

Wolfram, Barfuss, Max Planck Institute for Mathematics in the Sciences, Germany

Long-term collective action under risk of collapse

Long-term collective action is required to avoid the collapse into an unfavorable Earth system state. However, there is a research gap of how time preferences influence the success of such a collective action problem. We contribute to filling this research gap by theoretically investigating the interdependence of the three components of the problem, these are i) time scales and time preferences, ii) the magnitude of the collapse impact and iii) the size of the collective. We find that under a sufficiently negative collapse impact an actor's time preference (how much they care for future rewards) can act as a social tipping element. This actor's characteristic alone can transform the game from a tragedy of the commons, to a coordination challenge, up to even a comedy of the commons in which cooperation dominates. If there is no chance of recovery from collapse, caring for the future can even eliminate the tragedy. At the limit of a large number of participating agents we find that the critical collapse impacts, where these game regimes change, converge to a fixed value of collapse impact per actor, and that these values are independent of the public good's enhancement factor. Our results not only call for experimental inspection, they also offer an explanation why the polarization in the beliefs about human made climate change can threaten global cooperation agreements.

Dr. Hartmut Lentz, Friedrich-Loeffler-Institute, Greifswald,Germany

Spread of infectious diseases in temporal networks

Many networks are treated as static objects, although they are in fact strongly time-dependent. This can have a dramatic impact on the possible spreading patterns of infectious diseases. The temporal nature of networks is of particular interest for livestock trade, where diseases can spread over long distances and infect highly susceptible hosts in dense populations. We focus on livestock trade networks, however, the methods shown here can be easily transferred to other systems.
A static (aggregated) trade network is constructed as follows: if two nodes are connected directly to each other in a time-dependent network, the same connection is present in the static network. A fundamental difference between the static and the time dependent view however, is the consideration of paths, i.e. indirect connections over more than one edge. Concerning paths, the causality of the edges used plays an essential role. In an aggregated network, paths can seem causal, although they do not follow a time-respecting sequence of edges in the real system. This leads to a systematic overestimation of outbreak sizes, if time-dependent networks are treated as static.
We introduce a new method, which allows for the computation of the total causal path structure of a temporal network (represented by its accessibility graph) using the adjacency matrices of its snapshots. In addition, information about the timescales required for path traversal can be derived from the step-by-step derivation of the accessibility graph of the network. This procedure directly yields the distribution of shortest path durations in a temporal network. In addition, we define the new measure causal fidelity that compares the number of paths in a temporal network with its aggregated counterpart. This measure allows a quantitative assessment of how well a temporal network can be approximated by a static aggregated one.
The methods presented here require only basic knowledge linear algebra and can be implemented efficiently. Their capability is demonstrated for three examples: networks of social contacts, livestock trade, and sexual contacts.

Dr. Marc, Wiedermann, Potsdam Institute for Climate Impact Research, Germany

A network-based microfoundation of Granovetter's threshold model for social tipping

Granovetter's threshold model is one go-to reference for studying collective behaviour where actors make one decision depending on the number of others that do so, too. While this widely acknowledged framework is of generic nature it has up to now mostly been employed for illustrative purposes as opposed to an actual conceptual modeling tool. We identify two major sets of issues that hinder such an application and proposes intuitive extensions as a resolution. The first set of issues addresses the fact that plausible, e.g., normal, distributions of thresholds always unrealistically predict either noone or the entire population to act. The second set of issues touches aspects of the underlying, yet unexplained, threshold distribution. Addressing both sets of issues by utilizing a generic network cascade model allows to conceptually explain the emergence of social tipping as a saddle-node bifurcation in which minority groups can trigger large shares of the entire population to make a certain decision.

Dr. Alejandro, Tejedor, Max Planck Institute for the Physics of Complex Sytems, Germany

A network-theory approach for studying Earth-surface processes

Recent developments in understanding the structure and dynamics of networks have transformed research in many fields, however, geomorphology has not benefited much from this conceptual framework. I will use river deltas as a case study to illustrate the potential of an integrated approach that relies on network theory, remote sensing and modelling tools to understand and predict the structure and dynamics of geomorphic systems. By studying river deltas through the lens of their channel networks, I will show how we can make significant strides toward solving the inverse problem of inferring process from form, establish a methodology to compare, contrast and classify river deltas, and understand and predict their dynamic response under different forcing scenarios. Finally, I will show new results from the application of multiplex networks for studying geomorphic systems where connectivity emerges from the interaction of diverse (in nature and temporal scales) process.

Prof. Ambika G, Indian Institute of Science Education and Research (IISER), India

Weighted recurrence networks and entropy measure for analysis of data

The processes underlying the complexity of many real-world systems are to be understood basically from their observational data or average responses over time. Hence developing methods to analyze the data so as to understand such systems is very relevant and important. In this context, recurrence networks and related measures are efficient and powerful tools for analyzing nonlinear time series or data. Most often such networks constructed from data are undirected and unweighted. Here we propose a method to construct a 'weighted recurrence network' from a time series and show how it can reveal useful information regarding the underlying dynamics which the usual unweighted network cannot provide. We extend the definitions of standard network measures to weighted networks and show that the node strength distribution, from data of standard chaotic systems follows a power law with an exponential tail, and an index characteristic of their fractal structure. This introduces a new class of complex networks. We also show that using the computed generalized clustering coefficient and characteristic path length, the various types of dynamics can be classified into groups. The methods are illustrated by considering observational data for variable stars. Our results indicate the usefulness of this approach in analyzing short and noisy time series data. We propose an entropy measure for the analysis unweighted recurrence networks that converges to a constant value with increase in the number of data points or size of the constructed network. The measure quantifies the information loss associated with the structural change of a chaotic attractor in terms of the difference in the link density of the corresponding recurrence networks. This can clearly be used as a discriminating measure in the analysis of real world data. We indicate how the proposed measure is relevant in the general theory of complex networks.

Dr. Johannes Lohmann, University of Copenhagen, Denmark

Predictability of Dansgaard-Oeschger events from Greenland ice cores

The Dansgaard-Oeschger (DO) events of the last glacial period provide a unique example of large-scale climate change on centennial time scales. These abrupt climate changes have been convincingly connected to changes in the Atlantic overturning circulation, possibly amplified by changes in sea ice cover over the North Atlantic. Despite significant progress in modeling DO-like transitions with realistic climate models, it is still unclear what ultimately drives these changes.
It is an outstanding problem whether they are driven by a self-sustained oscillation of the earth system, or by stochastic perturbations in terms of freshwater discharges into the North Atlantic or extremes in atmospheric dynamics. We address this problem with a data-driven approach focusing on ice core data. The complex temporal pattern of DO events has been investigated previously to suggest that the transitions in between cold (stadial) and warm (interstadial) phases are purely noise-induced and thus unpredictable. In contrast, we present evidence that trends in proxy records of Greenland ice cores within the stadial and interstadial phases pre-determine the impending abrupt transitions. As a result, they cannot be purely noise-induced and are predictable to a certain degree.
While we do not identify their physical cause, the observed proxy trends are likely a manifestation of the climate system reorganizing at a specific time scale. With few exceptions, each DO event forms a consistent cycle with two independent time scales seen in proxy trends, and rapid transitions in between. The complex temporal pattern, i.e., what sets the time scale of the individual DO excursions remains to be explained. Nevertheless, the identification of the dynamics underlying these abrupt climate changes are an important step in the determination of their causes.

Dr. Deniz, Eroglu, Kadir Has University, Turkey

Multiplex Recurrence Networks

I will talk about a multiplex recurrence network approach by combining recurrence networks with the multiplex network approach in order to investigate multivariate time series. The potential use of this approach will be demonstrated on coupled map lattices and two climate related research problems. In examples, topological changes in the multiplex recurrence networks allow for the detection of regime changes in their dynamics.

Alessandra, Gouvêa. Federal University of São Paulo, Brazil

Benefits and challenges of dynamic community detection into analyzing of wildfires events

Analyzing data from the networks science perspective has been proven to be a useful approach in the various research area. In Earth Sciences, such approach has helped to identify valuable information on climate, especially on climate changes and its impact around the world. An environmental process which has been affected by global climate changes is the wildfire, concerning its frequency and severity. Wildfires may be described as a complex system hard to forecast, due to the many factors that influence its dynamics. As far as we know, little research was done to explore the use of networks science as a tool for the study of wildfires events occurred over time in a given geographical area. Through chronological network concept --- a temporal network where nodes are linked if two consecutive events occur between them--- this work investigates what kind of information the dynamic community structures could shed light on wildfires regarding its dynamics over time. As a study case, we use the MODIS dataset for fire events in the Amazon basin. Throughout the article, we explore the state-of-the-art dynamic community detection algorithms, the issues, and challenges of this approach, as well as, the lessons learned.

Dr. Oleh, Omel'chenko., University of Potsdam, Germany

Travelling chimera states

We report recent results about the travelling chimera states observed in a ring of non-locally coupled phase oscillators with broken reflection symmetry of the coupling kernel. These states manifest themselves as coherence-incoherence patterns moving along the ring. As the coupling asymmetry grows they undergo a sequence of transformations, which can be explained using the continuum limit integro-differential equation, called the Ott-Antonsen equation. In the context of this equation the chimera states are described by smooth travelling wave solutions. Using the mathematical methods from the PDE and integral equations theory we carry out asymptotic analysis of these travelling waves, describe an algorithm for their numerical continuation and explore the spectrum of the corresponding linearized equation. We show that travelling chimera states can lose their stability via fold and Hopf bifurcations. Some of the Hopf bifurcations turn out to be supercritical resulting in the observation of modulated (breathing) travelling chimera states.

Dr. Mehrnaz, Anvari, Max Planck Institute for the Physics of Complex Systems, Germany

Considering the dynamics of the power grid frequency

On one side the dependency of modern societies on the electricity and, moreover, some irrecoverable damages caused by power outages, lead to the vital need for a stable electric grid. On the other side, the ongoing energy transition towards renewable energies (RE) implies the essential need for better understanding the dynamics, control and variability of such a highly complex network. The utility frequency is the central observable for the control of AC electric power grids, as it directly reflects any disturbance. The most important sources of the emerging fluctuations in the power grid are the consumers, the RE and the energy market. Therefore, considering the stochastic characteristics of the power grid frequency, and introducing a suitable stochastic model able to reproduce these characteristics, could help understanding more deeply the impact of fluctuations on the dynamical features of the power grid system. In this talk we will present firstly some of the important stochastic characteristics of power grid frequency, and introduce a stochastic model able to generate a corresponding dataset.

Dr. Manoel, Cardoso, Brazilian Institute for Space Research, Brazil

INLAND estimation of surface properties relevant to climate studies in Brazil

The Integrated Model of Land Surface Processes (INLAND), in development at the Earth System Science Center of the Brazilian Institute for Space Research (CCST/INPE), is used to estimate vegetation cover and other surface properties that are useful to study the relations between climate and atmosphere conditions. In this work, it is shown model results for latent and sensible heat fluxes, surface albedo, and upper and lower vegetation leaf area indexes in central areas of the state of Rondonia, where forest loss is already pronounced. Model runs are able to evaluate potential differences in surface-atmosphere properties that result from deforestation and fire, showing important impacts of these disturbances similarly to results from observations by other field-based studies in the region. In addition, this work also aims on discussing methods based on Network science to analyze connections between variables that drive surface and atmospheric changes estimated by the model equations and experimental data.

Prof. Rene Orlando Medrano Torricos., Universidade Federal de São Paulo, Brazil

Inhomogeneous synchronized states in the Kuramoto--Sakaguchi model with identical oscillators symmetrically coupled.

In a network composed by equal phase oscillators interacting identically with the attraction and repulsion forces of the system, the common sense says that a synchronization is achieved with a symmetric distribution of the phase oscillators in the phase space. We report a surprising synchronization where a non-homogeneous configuration takes place in such strong homogeneous network. We consider the Kuramoto--Sakaguchi model composed by a finite number of identical phase oscillators symmetrically coupled. The phenomenon is described by the presence of non-hyperbolic states and it was recently observed in real world networks of nanoelectromechanical oscillators.

Dr. Bedartha Goswami, Potsdam Institute for Climate Impact Research, Germany
Recurrence networks reveal abrupt transitions in time series with uncertainties

The identification of sudden dynamical changes in time series is crucially impacted by the level of uncertainty in the data and by whether or not it is incorporated reliably in the analysis. We present here a new representation of time series that inherently take care of uncertainties in all subsequent analyses: Instead of considering a time series as a sequence of point-like objects (with or without additional error), we represent time series as a sequence of probability density functions. We show how this can be used to detect sudden changes in the time series using networks that encode the recurrence properties of the system.

Prof., Sujith Raman Pillai Indusekharan Nair, Indian Institute of Technology Madras, India

Recurrence Networks to Study Thermoacoustic Transitions in Turbulent Combustors

Thermoacoustic instability refers to the ruinously high-amplitude, pressure oscillations that occur in gas turbine engines and rockets. It occurs when there is positive coupling between the acoustic field and the heat release rate. These oscillations are detrimental to the structural integrity of the engines, cause shut downs, overwhelm the thermal protection system and contribute to losses that amounts to billions of dollars. Flame blowout occurs when the flame ceases to exist in the combustor. This can cause a sudden drop in altitude of an airplane and productivity loss in case of land based gas turbines. Hence, there is an exigency to study the transition to thermoacoustic instability and blowout. In this study, complex networks are used to study thermoacoustic system, in our case a turbulent combustor. Since recurrence is a fundamental property of any deterministic dynamical system, we construct the recurrence networks from the time series of acoustic pressure and global heat release rate time series acquired from the combustor. Univariate recurrence networks constructed from the acoustic time series capture the transitions to thermoacoustic instability and lean flame blowout. The singularities present in the time series are captured in the power law degree distributions present in the recurrence networks constructed from combustion noise and oscillations prior to flame blowout. The network measures such as characteristic path length, betweenness centrality change well before these transitions and hence can be used as early warning signals to forewarn thermoacoustic instability and lean blowout.
Since thermoacoustic instability is a result of positive coupling between the acoustic field and the turbulent reactive flow, we analyze the coupled behavior during the transition to thermoacoustic instability via intermittency (a state composed of bursts of large amplitude periodic oscillations appearing at irregular intervals amidst epochs of aperiodic fluctuations) using the framework of synchronization theory. We quantify the synchronization transitions using the measures derived from recurrences in phase space such as probability of recurrence plots, multivariate recurrence plots and networks. The directional dependence between the acoustic field and the turbulent reactive flow field is determined and a possible asymmetric bidirectional coupling between them is discovered with the heat release rate affecting the acoustic field more than vice versa. This paves a way for developing effective control strategies directed towards the unsteady flame to the mitigate thermoacoustic instability.

Dr. Naiming Yuan, Institute of Atmospheric Physics, China

On the impacts of ENSO events: A novel research based on complex climate network

In this work, impacts of ENSO events are studied from a new perspective, climate network. Sea surface air temperature (SAT) over the Pacific is constructed as a network, with each grid point as the node and the similarity of the SAT at each node as a measure of the link. The influences of sea surface temperature anomaly (SSTA) in the tropical central eastern Pacific (ENSO) are regarded as a kind of natural attack on the network. Using three different reanalysis datasets, a phase transition in the SAT network is revealed. That is, when the influences of El Niño/La Niña events are strong enough to isolate more than 48% of the nodes, the SAT network may abruptly be divided into many small pieces, indicating a change of the upper SAT field. In this case, the ENSO impacts can be further transferred to remote regions via an atmospheric bridge. This phase transition is considered as a new test bed, with which 15 CMIP5 models are evaluated. Of the 15 models, most of them are found incapable of capturing the observed phase transition at a proper critical point (48%). Only 4 models show some skills in the simulation. Since this phase transition of the SAT network is a useful phenomenon to study ENSO impacts, it deserves more attention for future model development.

Dr. Frank Kwasniok, University of Exeter, UK

Data-driven analysis and prediction of Atlantic Meridional Overturning Circulation collapse using non-stationary optimal mode decomposition and non-linear modelling

The dynamics of the Atlantic Meridional Overturning Circulation (AMOC) are analysed in a data set from the fully coupled climate model FAMOUS. The system is subject to a linearly ramped freshwater hosing, leading to a collapse of the AMOC starting after about 800 years of simulation. Optimal mode decomposition (OMD) is applied in sliding windows in order to identify and track the least stable eigenvalues and the corresponding spatial modes of the system. A genuinely non-stationary OMD allows to extrapolate beyond the learning data window and to predict instabilities in the system. An oscillatory instability is identified as the leading instability. The analysis is refined by fitting a non-linear model in the subspace of the oscillatory instability. The transition from the 'on' state to the 'off' state appears to occur via subcritical Hopf bifurcation. The basin of attraction of the 'on' state of the AMOC is shrinking close to the bifurcation which makes the system susceptible to noise-induced and/or rate-induced tipping and may explain why the AMOC collapse starts well ahead of the bifurcation point.

Dr. Laurent, Pagnier, University of Applied Sciences Western Switzerland (HESSO), Switzerland

Optimal placement of inertia and primary control: a matrix perturbation theory approach

The increasing penetration of inertialess new renewable energy sources reduces the overall mechanical inertia available in power grids and accordingly raises a number of issues of grid stability over short to medium time scales. It has been suggested that this reduction of overall inertia can be compensated to some extent by the deployment of substitution inertia - synthetic inertia, flywheels or synchronous condensers. Of particular importance is to optimize the placement of the limited available substitution inertia, to mitigate voltage angle and frequency disturbances following a fault such as an abrupt power loss. Performance measures in the form of H2-norms have been recently introduced to evaluate the overall magnitude of such disturbances on an electric power grid. However, despite the mathematical conveniance of these measures, analytical results can be obtained only under rather restrictive assumptions of uniform damping ratio, or homogeneous distribution of inertia and/or primary control in the system. Here, we introduce matrix perturbation theory to obtain analytical results for optimal inertia and primary control placement where both are heterogeneous. Armed with that efficient tool, we construct two simple algorithms that independently determine the optimal geographical distribution of inertia and primary control. These algorithms are then implemented on a model of the synchronous transmission grid of continental Europe. We find that the optimal distribution of inertia is geographically homogeneous but that primary control should be mainly located on the slow modes of the network, where the intrinsic grid dynamics takes more time to damp frequency disturbances.

Dr. Robin Delabays, HES-SO Valais, Switzerland

Rate of change of frequency under line contingencies in high voltage electric power networks with uncertainties

In modern electric power networks with fast evolving operational conditions, assessing the impact of contingencies is becoming more and more crucial. Contingencies of interest can be roughly classified into nodal power disturbances and line faults. Despite their higher relevance, line contingencies have been significantly less investigated analytically than nodal disturbances. The main reason for this is that nodal power disturbances are additive perturbations, while line contingencies are multiplicative perturbations, which modify the interaction graph of the network. They are therefore significantly more challenging to tackle analytically. In this talk, we will assess the direct impact of a line loss by means of the maximal Rate of Change of Frequency (RoCoF) incurred by the system. We will show that the RoCoF depends on the initial power flow on the removed line and on the inertia of the bus where it is measured. We will further derive analytical expressions for the expectation and variance of the maximal RoCoF, in terms of the expectations and variances of the power profile in the case of power systems with power uncertainties. This gives analytical tools to identify the most critical lines in an electric power grid.

Dr. Benjamin Schaefer, Queen Mary University London, UK

With data-driven modelling towards a successful energy transition

The Paris conference 2015 set a path to limit climate change to "well below 2°C". To reach this goal, integrating renewable energy sources into the electrical power grid is essential but poses an enormous challenge to the existing system, demanding new conceptional approaches. In this talk, I will introduce basics of the power grid operation and outline some pressing challenges to the power grid.
In particular, I present our latest research on power grid fluctuations and how they threaten robust grid operation. For our analysis, we collected frequency recordings from power grids in North America, Europe and Japan, noticing significant deviations from Gaussianity. We developed a coarse framework to analytically characterize the impact of arbitrary noise distributions as well as a superstatistical approach. This already gives an oppurtunity to plan future grids. Finally, I will outline my upcoming Marie-Curie project DAMOSET, which focusses on building up an open data base of measurements to deepen our understanding.

Katrin Schmietendorf, Universität Münster, Germany

On the impact of stochastic wind feed-in on frequency quality

Feed-in fluctuations are one of the major challenges for future electrical power grids with a high share of renewables. Wind power is one of the main renewable energy sources. It features turbulent-like non-Gaussian statistics including correlations, extreme events, Kolmogorov power spectrum, and intermittent increments. Short-term fluctuations are particularly problematic, as they are not counteracted by standard load balancing mechanisms.
In this talk, we give a brief overview on wind power statistics and present our results on frequency quality in Kuramoto-like power grids subjected to realistic wind power input. We further discuss the potential of local energy storage with respect to power quality improvement.

Dr. Jonathan F., Donges, Potsdam Institute for Climate Impact Research, Germany

Complex networks in Whole Earth System Analysis: from data crunching to dynamic modelling

Complex networks have found a multitude of uses for understanding the structure and dynamics of complex systems in many disciplines. I will present an overview of some of their fruitful applications in Earth system analysis, ranging from extracting the intricate patterns of causal interactions based on large climate data sets to detecting fingerprints and early warning signals for nonlinear regime shifts and tipping points in critical climate subsystems. I will then discuss the key value of networks in representing the dynamics of complex social structures (e.g. social networks of friendship ties, cooperation agreements, institutions etc.) in next generation social-ecological World-Earth system models that are needed to study the Anthropocene, the geological epoch now dominated by the human enterprise.

Dr. Franda Davide, Paris

Can we predict weather and project climate using machine learning techniques

Recurrent neural networks have been recently introduced to predict the behavior of chaotic systems. Surprisingly, they provide reliable forecasts up to the predictability limit without knowing the underlying equations of the systems. Here we focus on the predictability of rare trajectories leading to extreme events. We focus on different chaotic systems, ranging from toy models of the atmospheric dynamics, up to the re-forecast of sea-level pressure and temperature fields issued by ERA Interim and NCEP reanalysis datasets. Our results show that: i) the machine learning techniques can make reliable weather forecasts of global atmospheric fields up to 48-72h with a time step of 3-6h ii) long time forecasts do not diverge, they produce reliable climatology of the sea-level pressure and temperature fields iii) we can evaluate the coherence of extreme events generated via the machine learning with respect to the observed ones.

Dr. Francesco Ragone, ENS-Lyon, France

Sampling extreme heat waves in numerical climate models with a rare event algorithm

Studying rare extreme events with complex numerical climate models is computationally challenging, since very long simulations are needed to sample a number of events that is sufficient to provide a reliable statistics. I will discuss how the problem of sampling extremes in climate models can be tackled using rare event algorithms. Rare event algorithms are numerical tools developed in the past decades in mathematics and statistical physics, dedicated to the reduction of the computational effort required to sample rare events in dynamical systems. Typically they are designed as genetic algorithms, in which a set of killing and cloning rules are applied to an ensemble simulation in order to focus the computational effort on the trajectories leading to the events of interest. I will present a rare event algorithm developed in the context of large deviation theory, and I will show how it can be used to sample very efficiently time persistent events like extreme European heat waves in simulations with a climate model. This allows to characterise the statistics of heat waves with extremely large return times, with computational costs orders of magnitude smaller than with direct sampling. The algorithm samples a large number of trajectories leading to very rare events, which can be used to study their characteristic dynamics, allowing for example to highlight peculiar teleconnection patterns for the most extreme heat waves. This method allows also to observe ultra rare events that would have never been observed in a direct simulation for the same computational cost. I will then discuss how these techniques can be applied to study a wide range of different processes with complex climate models.

Sebastian Scher, Stockholm University, Sweden

Generalization properties of neural networks trained on Lorenz systems

We investigate the ability of neural networks to: 1) learn the behaviour of Lorenz systems from incomplete training data – incomplete meaning that only part of the system's phase space is covered -, and 2) learn the influence of an external forcing on the dynamics of the Lorenz systems. The neural networks trained on data covering only part of the system's phase space struggle to make skillful short-term forecasts in the regions missed during the training. Additionally, when making long series of consecutive forecasts, the networks mostly do not reproduce trajectories exploring regions beyond those seen in the training data. We also find that it is challenging for the standard network architectures to learn the influence of a slowly changing external forcing, highlighting the limitations of a network trained on a specific forcing regime for generalising a system's behaviour. These results outline challenges for a variety of machine-learning applications in climate science.

Prof. Epaminondas Rosa, Illinois State University, USA

Neuronal Synchronous Transitions Mediated by Chaos: Theory and Experiment

No matter how different networked neurons can be, they may work in synchrony performing functions that are crucial for the sustaining of life. In fact, it is not unusual for synchronous neurons to undergo transitions that allow them to execute physiological tasks related to changes in their firing rate and spiking pattern. In particular, transitions between tonic (fixed rate spiking) and bursting (trains of fast spiking alternated with quiescence) are present in several neurological processes, including thalamocortical neurons at sleep-wake transition states, and in sensory-motor nuclei generating tremors in neurodegenerative disorders. These neuronal transitions are of high relevance, but little is known about their underlying mechanisms.
In this talk I show results obtained using a biophysical mathematical model to investigate neuronal tonic-to-bursting transitions, exploring aspects found in the dynamical evolution of the firing rate. Computer simulations indicate that transitions of this nature evolve through a period doubling cascade going into chaos with the well-known windows of periodicity, and eventually reaching a rhythmic bursting regime. The transition from tonic to bursting is therefore mediated by chaos, where a critical firing rate is present. This critical firing rate found initially as a signature of the individual neuron is actually passed on to the collective of distinct networked synchronous neurons (Shaffer et al. PRE 2016; Shaffer et al. EPJST 2017; Follmann et al. Chaos 2018). I further discuss other interesting aspects, including how temperature may play a role in the setting off of the transition (Burek et al. Biosystems 2019).
Additionally, I discuss experimental results obtained by implementing neuropeptide-induced activity in the stomatogastric neuromotor system of the crab Cancer borealis. Working with individually identifiable networked neurons in the real biological system, we show that the neuropeptide increases the neuronal firing rate and elicits a tonic-to-bursting transition via an inward modulator induced current. Details of the neuronal network and of the experimental set up will be presented.

Prof. Tadic, Bosiljka Jozef Stefan Institute, Slovenia

Hidden Structure of Human Connectome

Networks representing complex systems often exhibit hierarchical architecture that can be described using the methods of the algebraic topology beyond standard graph-theoretic measures. Accurately, these structures are parameterized by simplexes (triangles, tetrahedrons and higher order cliques) that are interconnected to make more solid structures---simplicial complexes. While the composition of these basic geometry descriptors is unique, representing functional geometry of a particular network, their characteristic feature is emergent hyperbolicity or negative curvature, a measure of nodes proximity in the graph-metric space, which often associates with an improved function. Here, we analyze the simplicial complexes in brain networks [1] that suitably map the empirical fNMRI data collected within the Human Connectome Project and provided at Budapest server [2]. Precisely, using the techniques of the algebraic topology of graphs, we determine salient features of the human connectome by decomposition into simplicial complexes, which comprise the inner structure of the brain anatomical modules in both hemispheres [1]. We also determine the Gromov hyperbolicity parameter of these graphs at different resolution levels. Both topological features are expected to correlate with the functional properties of these brain networks, in analogy to the studies of EEG data mapping in [3,4]. However, how the hyperbolic geometry supports the network's capacity remains an open question that can be studied within concrete generative models [5] and dynamical properties of these structures. Another question that has been in the focus of the science of brain mapping is the empirically observed gender difference in human connectomes. By separately analyzing the gender-related data we use these new topological quantifiers to describe the robust gender differences within the higher-order connectivity.

[1] Bosiljka Tadić, Miroslav Andjelković, Roderick Melnik, Functional geometry of human connectome and robustness of gender differences, Arxiv:1904.03399v1 (2019)

[2] Balázs Szalkai, Csaba Kerepesi, Bálint Varga, Vince Grolmusz, Parameterizable Consensus Connectomes from the Human Connectome Project: The Budapest Reference Connectome Server v3.0, Cognitive Neurodynamics, (2016)

[3] Bosiljka Tadić, Miroslav Andjelković, Biljana M. Boškoska, Zoran Levnajić, Algebraic topology of multi-brain connectivity networks reveals dissimilarity in functional brain patterns during spoken communications, PLOSone 11, e0166787 (2016)

[4] Bosiljka Tadić, Miroslav Andjelković, Milovan Šuvakov, Origin of hyperbolicity in brain-to-brain coordination networks, Frontiers in Physics 6:7. (2018)

[5] Milovan Šuvakov, Miroslav Andjelković, Bosiljka Tadić, Hidden geometries of networks arising from cooperative self-assembly, Scientific Reports 8, 1987 (2018)

Dr. Vramori Mitra, Comenius University, Slovakia

Recurrence quantification analysis of microdroplets interacting with laser signal

When a liquid drop is subjected to a strong electric field it disintegrates into several charged droplets which is known as electro-spray or electrohydrodynamic atomization. This phenomenon has a long range of applications in various fields, especially medical and agriculture fields. In this work at two different fixed flow rates of de-ionized water pumped through a needle produces electro-spray of water in atmospheric pressure and reflects different dynamical transitions when interacts with laser signal for different applied voltages. To understand the physical phenomena recurrence quantification analysis (RQA) method is incorporated as a diagnostic. Recurrence plot and recurrence quantification variables significantly quantify the complexity of the laser signals interacting with micro droplets and explore the hidden physical mechanism. We also compare the results using multifractal detrended fluctuation analysis and show that the results are supportive to each other.

Kai Hauke Kraemer, Potsdam Institute for Climate Impact Research, Germany

Border effect corrections for diagonal line based Recurrence Quantification Analysis measures

Recurrence quantification analysis (RQA) is a powerful tool for the identification of characteristic dynamics and of regime changes. This approach is successfully applied in many scientific disciplines. Several measures of complexity are defined on features (such as diagonal and vertical lines) in the recurrence plot (RP) and the corresponding recurrence network (RN). These line structures represent typical dynamical behavior and can be related to certain properties of the dynamical system, e.g., chaotic or periodic dynamics. Therefore, their quantitative study by the RQA measures within sliding windows is a frequently used task for the detection of regime changes. However, as some RQA measures rely on the probability distribution of the lengths of the diagonal lines in an RP, the artificial alteration of these lines due to border effects, insufficient embedding, or a certain sampling setting can have a significant impact on these measures. A few ideas have been suggested to overcome problems. Here we review these ideas, propose novel correction schemes, and systematically compare them. Specifically, we investigate the proper estimation of the diagonal line length entropy for exemplary systems (discrete and continuous). We propose corrections schemes, which yield less biased estimates, especially under noise.

Dr. Guido Isabella, Max Planck Intitute for Dynamics and Self-organization, Germany

3D instabilities of active networks made of biopolymers and motor proteins.

Networks of biofilaments and motor proteins are important model systems for the understanding of the out-of-equilibrium behaviour of the cellular cytoskeleton. In Nature, they are involved in key processes in cells such as migration, division, mechanosensing and cytoplasmic transport. Designing in vitro setup of such systems can help their characterization thanks to the fewer components used and the possibility to introduce controlled perturbations. In the last years the active nematic behaviour of microtubules with kinesin motors confined on a 2D substrate was reported. In this study, we present experimental and theoretical results on 3D active networks of microtubules and motor proteins which present interesting collective behaviour due to their nematic order. In our setup the solution used for the assembling of the active system contains polymerized microtubule, multi-headed kinesin-1 motor proteins, poly(ethylene glycol) or PEG and ATP. The non-equilibrium nature of the system is due to kinesin-1 that in the presence of ATP moves along the microtubules. By adding the non-adsorbing polymer PEG attractive interactions between microtubules are induced through depletion force that leads to bundle formation. These bundles are subjected to the force exerted by the motors that crosslinked the microtubules and let them slide against each other, depending on their polarity. By confining the network into a PDMS channel we observe the formation of 3D wrinkling instabilities resulting from the contraction and the extension the network is subjected to. Indeed, it contracts in a sheet along the z-direction, which represents the height of the channel, and extends along the longitudinal axes of the channel. As the system is confined in the volume of the microfluidic device the extension due to the polarity sorting of the molecular motors induces a network buckling that generated 3D wrinkles in the z-direction. We believe that the requirements for the wrinkle instabilities is the bundle formation and their anisotropic orientation within the network, e.g. the nematic order we observed in the direction of the extensile force.

These results clearly show how microscopic interactions between biopolymers and motor proteins give rise to collective dynamics at a different scale in the macroscopic environment.

Dr. Fakhteh Ghanbarnejad, International Centre for Theoretical Physics, Italy

Disease Ecology: from the perspective of complex systems and network science

Here I will review my recent works [1-2] on modeling interacting contagious dynamics, for example coupled SIR or SIS dynamics, in mean field approximations and also on different random generated or empirical complex networks. I show and discuss how our recent results have been improving our understanding and prediction of epidemic dynamics and disease ecology while raising new questions and challenges in physics of critical phenomena.

[1] Nature Physics 11, 936–940 (2015), Europhys. Lett. 104, 50001 (2013), Phys. Rev. E 93, 042316 (2016), New J. Phys. 19, 103041(2017), Frontiers in Physics, V 5, P 46 (2017), Sci. Rep. 9, 6463 (2019), Physica A, 518, Pages 50-70 (2019), arXiv:1901.02702

[2] More papers in preparation; Some results are also presented in these MSc thesis: (S. Gholizadeh, Institute for Advanced Studies in Basic Sciences, 2017), (Evolution of Coinfection, TU Berlin, 2018), (E. Sajjadi, Interactive dynamics vs. bursty networks", SUT, 2019)

Dr. Giovanna zimatore, eCampus University, Italy

Recurrence Quantification Analysis of Heart Rate Variability during continuous incremental exercise test in obese subjects

We propose a new approach to identify the transition from aerobic to anaerobic metabolism during incremental exercise. Our approach is based on the analysis of the heart rate dynamics, due to the continuous adjustments to an unpredictable internal environment, by using the recurrence quantification analysis (RQA), a well-established nonlinear data analysis tools widely adopted to identify correlations and phase transitions. Methods: Breath by breath heart rate (HR), oxygen uptake (VO2), carbon dioxide production (VCO2) and ventilation (VE) of 10 subjects (41.00±12.28 years old, 4 males and 6 females) were measured by an automatic gas during a continuous incremental exercise test on a treadmill. From these values we can determine the individual ventilatory threshold (IVT) by a standard method (1), M1, that account for both (VE/ VO2) and (VE/ VCO2) time evolution.

Here we suggest that it is possible to identify the transition from aerobic to anaerobic metabolism by using RQA analysis. RQA, indeed, allows to identify changes in the correlation structure of the observed phenomenon that is known to precede the actual event. Furthermore, this method (M2) already successfully used in many different systems ranging from physiology and genetics to economics, by detecting changes in the correlation structure dynamics before obvious symptoms of crisis appear, allows to predict crisis.
Results: By using RQA analysis we can detect the time at which the transition occurred. The value obtained well compare with that calculated with standard method, but with much higher precision. A comparison of the time at which the transition occurred, T_IVT and T_RQA, shows a correlation with a r Pearson coefficient of r=0,79. From these time values we can define the workload parameters needed to training the subject in anaerobic metabolism state. Comparing the workload parameters obtained from both methods well match, with r Pearson coefficient r=0,94 for %inclination, r= 0,76 for speed.
Conclusions: The Recurrence Quantification analysis of heart rate variability appears to be a very useful tool that allows to precisely determinate the transition from aerobic to anaerobic metabolism simply from HRV data and without the need of a gas analyzer. This should be considered as a strong improvement in the area of health monitoring since pave the way to the widespread of this analysis to all that people using mobile and wearable monitoring system.

Dr. Jingfang, Fan, Potsdam Institute for Climate Impact Research, Germany

Climate network percolation reveals the expansion and weakening of the tropical component under global warming

Global climate warming poses a significant challenge to humanity; it is associated with, e.g., rising sea level and declining Arctic sea ice. Increasing extreme events are also considered to be a result of climate warming, and they may have widespread and diverse effects on health, agriculture, economics, and political conflicts. Still, the detection and quantification of climate change, both in observations and climate models, constitute a main focus of the scientific community. Here, we develop an approach based on network and percolation frameworks to study the impacts of climate changes in the past decades using historical models and reanalysis records, and we analyze the expected upcoming impacts using various future global warming scenarios. We find an abrupt transition during the evolution of the climate network, indicating a consistent poleward expansion of the largest cluster that corresponds to the tropical area, as well as the weakening of the strength of links in the tropic. This is found both in the reanalysis data and in the Coupled Model Intercomparison Project Phase 5 (CMIP5) 21st century climate change simulations. The analysis is based on high-resolution surface (2 m) air temperature field records. We discuss the underlying mechanism for the observed expansion of the tropical cluster and associate it with changes in atmospheric circulation represented by the weakening and expansion of the Hadley cell. Our framework can also be useful for forecasting the extent of the tropical cluster to detect its influence on different areas in response to global warming.

Dr. Jan, Saynisch, GFZ-Potsdam, Earth-System-Modelling, Germany

Neural Network Estimates of Global Oceanic Heat Content from Tidal Magnetic Fields

Ocean tides generate electromagnetic (EM) signals that are emitted into space and can be recorded with low-Earth-orbiting satellites. Observations of oceanic EM signals contain aggregated information about global transports of water, heat, and salinity. We utilize an artificial neural network (ANN) as a non-linear inversion scheme and demonstrate how to infer ocean heat content (OHC) estimates from magnetic signals of the lunar semi-diurnal (M2) tide. We show that the ANN can closely recover inter-annual and decadal OHC variations from simulated and observed tidal magnetic signals. The EM-OHC estimates can complement the already existing in-situ measurements of upper ocean temperature and could also allow insights into abyssal OHC, where in-situ data are still very scarce.

Dr. Alexander Pasternack, Freie University, Germany

Model selection for DeFoReSt: a strategy for recalibrating decadal predictions.

Near-term climate predictions such as decadal climate forecasts are increasingly being used to guide adaptation measures. Due to the uncertainties in initial conditions of weather and climate, forecasts are framed probabilistically. However, these forecasts still suffer from considerable systematic errors like lead-time dependent unconditional (drift), conditional biases and ensemble dispersion.
With DeFoReSt, we proposed a Decadal Climate Forecast Recalibration Strategy, a parametric post-processing approach to tackle these problems. The original approach of DeFoReSt assumes third order polynomials in lead time to capture conditional and unconditional biases, second order for dispersion, first order for start time dependency. Here, we propose not to restrict orders a priori but use a systematic model selection strategy to obtain model orders form the data based on non-homogeneous boosting. We apply DeFoReSt with model selection to the MiKlip system (Germany's initiative for decadal prediction) to identify the most relevant model variables for recalibrating this decadal prediction system.

Dr. Dominik Traxl., University of Potsdam, Germany

The Impact of Temperature on the Frequency and Characteristics of Extreme Storms

We present a data-driven analysis of the dependency of extreme rainfall on temperature. The basis of this study is a global, high-resolution (0.25°x0.25°, 3-hourly, 1998-2018) satellite product of rainfall measurements, combined with sea surface temperatures, and 2m atmospheric and dewpoint temperatures. First, we show our results of the temperature intensity scaling on a per-grid-cell basis. Then - using complex network methodologies - we integrate extreme rainfall measurements into spatiotemporally cohesive clusters (extreme storms), and look at the dependency of their frequency and characteristics (e.g., intensity, area, lifetime, spatiotemporal size) on the different types of temperatures.

Prof. Elena, Surovyatkina, Potsdam Institute for Climate Impact Research, Germany

Forecasting Indian Summer Monsoon: from Complex Network to Tipping elements approach

Almost half of the world's population depends on monsoon rainfall. Although the rainy season happens annually, the time of monsoon season's onset and withdrawal varies within a month from year to year. The important feature of the monsoon is that it starts and ends suddenly. Hence, despite enormous progress having been made in predicting monsoon since 1886, it remains a significant scientific challenge. In our study of the Indian monsoon season, we have found the evidence in observational data that we can consider the onset of monsoon as a critical transition from pre-monsoon to monsoon. We use the phenomenon of critical growth of fluctuations [2] to detect Tipping elements of monsoon. This finding allows us to develop the Tipping elements approach for prediction of onset and withdrawal dates of Indian summer monsoon [1]. Our prediction relies on observations of near-surface air temperature and relative humidity from both the ERA-40 and NCEP/NCAR reanalyzes.

Our results show that our method allows predicting the monsoon as retrospectively (over the period 1951-2015), as well in the future. In 2016, 2017, 2018 we successfully predicted the onset and withdrawal dates of the Southwest monsoon over the central part of India for 40 and 70 days in advance respectively [3]. Hence, we proved that such early prediction of season timing is possible.

The Tipping Element Approach is a crucial step forward for forecasting monsoon that is of high social impact and significant contribution in atmospheric sciences. It is opening up new areas for inquiry, future research for frontier areas such as hydrology, agriculture, tropical meteorology.

[1] Stolbova, V., E. Surovyatkina, B. Bookhagen, and J. Kurths (2016): Tipping elements of the Indian monsoon: Prediction of onset and withdrawal. GRL 43, 1–9 [doi:10.1002/2016GL068392]

[2] Surovyatkina E.D., Kravtsov Yu. A. and Kurths Ju., (2005), Phys. Rev. E, 72, 046125 https://doi.org/10.1103/PhysRevE.72.046125

[3] https://www.pik-potsdam.de/services/infodesk/forecasting-indian-monsoon

Dr. Räth, Christoph, Deutsches Zentrum für Luft- und Raumfahrt (DLR) Germany

Predicting dynamical systems with echo state networks with different topology

The prediction of complex nonlinear dynamical systems with the help of machine learning techniques has become increasingly popular. In particular, the so-called echo state networks (ESN) turned out to be a very promising approach especially for the reproduction of the long-term properties of the system [1]. The heart of ESN is a network of nodes that is fed with input data and is connected with an output layer. So far only random Erdös-Renyi networks are used. However, there is a variety of conceivable other network topologies that may have an influence on the results. As a first step, we statistically analyze the quality of prediction - both the exact short term prediction as well as the reproduction of the long-term properties of the system as estimated by the correlation dimension and largest Lyapunov exponent for random, small world and scale-free networks. Using the Lorenz and the Rössler system we find significant variations of the results. The longterm prediction is worse for the scale-free network, where the differences between the network types are more pronounced in the Rössler system. Random and scale-free networks perform similar in both cases with slight advantages for the small world network [2]. Our results suggest that the network topology has significant influence on the performance of ESN. Studying the results for different networks in detail also gives new insights about the complexity of the underlying dynamical system.

[1] J. Pathak et al., Chaos, 27, 121102 (2017),

[2] A. Haluczszynski et al., Chaos, submitted.

Prof., Ulrich Parlitz, Max Planck Institute for Dynamics and Self-Organization, Germany

Dynamical networks and data analysis

In complex systems research dynamical networks can be both, the source of data and a means for processing them. We shall address both aspects and present network structures for predicting and classifying dynamical systems, as well as examples from neuro- and cardiac dynamics where changing structures in functional networks (for example, due to an external stimulus) are detected using advances time series analysis and machine learning tools.

Prof. Blaise Romeo Nana Nbendjo, University of Kassel, Germany

The concept of self-control of vibration in Physical system

The issue of vibration control on a case of mechanical structures located in an aggressive environment is investigated in this work. The design of such ssystem should integrated some component (or take into account some consideration) which is related to dynamics vibration absorbers make these structures behave as self-sustained system.

Dr. Nora Molkenthin, Potsdam Institut für Klimafolgenforschung, Germany

Topological universality of on-demand ride-sharing efficiency

Ride-sharing has been suggested as a solution to a wide ranges of challenges in personal transportation, ranging from avoiding 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.

Dr., Maike Sonnewald, MIT/Harvard

Decoding Ecological Complexity: Machine Learning reveals marine eco-provinces

The complex nature of ecology in the global ocean is leveraged to reveal emergent eco-provinces. The framework based on unsupervised machine learning is a crucial step towards improving the utility of chlorophyll as a metric for ecology and cascading impacts on higher trophic levels. Clustering and cutting-edge signal processing (t-SNE and DBSCAN) robustly determine 127±7 eco-provinces in the advanced global DARWIN model. The framework highlights emergent key interactions from the humanly-intractible decadal mean surface data, spanning 51 species with a range of trait-based functional types, nutrient fluxes (N, P, Si and Fe) and physics from the ECCO State Estimate. The full number of provinces remains overwhelming for global analysis, motivating further complexity reduction by nesting according to ecological similarity to identify aggregated eco-provinces (AEPs). The presented framework is applicable both globally and regionally, adjusting complexity according to the region of interest. A minimum complexity of 12 AEPs is determined, using the Longhurst provinces as a benchmark. A dynamic ocean ecology emerges, with oligotrophic gyres, Polar Regions, or regions of upwelling and strong seasonality. AEPs highlight where using chlorophyll naively is misleading as a measure for ecology, as similar biomass can have significantly different ecological composition. Biomass is seen to be a poor indicator for zooplankton and fish abundance in some AEPs. Using the AEPs as guidance paves the way for better monitoring as well as aiding assessment of how representative measurements from in-situ efforts are.

Dr. Tobias Grafke, Warwick Mathematics Institute, UK

Extreme Event Quantification for Rogue Waves in Deep Sea

A central problem in uncertainty quantification is how to characterize the impact that our incomplete knowledge about models has on the predictions we make from them. This question naturally lends itself to a probabilistic formulation, by making the unknown model parameters random with given statistics. Here this approach is used in concert with tools from large deviation theory (LDT) and optimal control to estimate the probability that some observables in a dynamical system go above a large threshold after some time, given the prior statistical information about the system's parameters and its initial conditions. We use this approach to quantify the likelihood of extreme surface elevation events for deep sea waves, so-called rogue waves, and compare the results to experimental measurements. We show that our approach offers a unified description of rogue wave events in the one-dimensional case, covering a vast range of paramters. In particular, this includes both the predominantly linear regime as well as the highly nonlinear regime as limiting cases, and is able to predict the experimental data regardless of the strength of the nonlinearity. The presented method of extreme event quantification is applicable to many other extreme events and metastability in climate, atmopshere, and ocean.

Nico, Wunderling, Potsdam-Institute for Climate Impact Research, Germany

Risk analysis of tipping cascades in the Climate system

Several large-scale regions in the Earth system have been identified to exhibit critical transitions at which a tiny perturbation can alter the state qualitatively. These regions, the so-called tipping elements (Lenton et al., 2008; Schellnhuber et al., 2016), can be viewed as a network, whose physical interaction structure has been identified in an expert elicitation for a subset of five tipping elements (Kriegler et al., 2009). Here, we identify how critical temperatures and the occurrence of tipping cascades change using a paradigmatic network approach. The network includes the Greenland Ice Sheet, the West Antarctic Ice Sheet, the Atlantic Meridional Overturning Circulation (AMOC), the El-Niño Southern Oscillation (ENSO) and the Amazon rainforest (Kriegler et al., 2009). We model the network with linearly coupled differential equations and propagate the uncertainty of the system via a Monte-Carlo ensemble. Overall, we find, dependent on the coupling strength, that the temperature for inducing critical transitions is lowered significantly for West Antarctica, AMOC, ENSO and the Amazon rainforest, but increased for the Greenland Ice Sheet. Furthermore, our analysis reveals that the large ice-sheets (Greenland and West Antarctica) are oftentimes the initiators of tipping cascades, while the AMOC seems to mediate tipping cascades. This implicates that the tipping of the large ice sheets, which might already be triggered within the Paris range, are of particular importance for the stability of the climate system with respect to tipping cascades.

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Detecting regime transitions of the nocturnal and Polar atmospheric boundary-layer.

Many experimental or natural systems undergo critical transitions, i.e. sudden shifts from one dynamical regime to another. In the climate system, the atmospheric boundary layer can experience sudden transitions between fully turbulent states and quiescent, quasi-laminar states. Such rapid transition are observed in Polar regions and at night when the atmospheric boundary layer is stably stratified, and have important consequences in the level of mixing with the higher levels of the atmosphere. To analyse the stable boundary layer, many approaches rely on the identification of regimes that are commonly denoted as weakly and very stable regimes. Detecting transitions between the regimes is crucial for modelling purposes.

A combination of methods from dynamical systems and statistical modelling is applied to study these regime transitions and develop an early-warning signal. The analysis is based on an indicator for the dynamical stability (i.e. the resilience of the equilibrium flow to perturbations) and a conceptual model for regime transitions of near-surface temperature inversion at night as well as in Arctic conditions. A focus lies on bifurcation points in the dynamics, points in which the stability of the system changes drastically. The performance of the stability indicator and its reliability as an early-warning signal are assessed on the basis of simulated and observation data, provided from nocturnal and Polar meteorological measurements.