UBICS DAY 2022

8 September 2022

Aula Magna (Edifici Històric)

PROGRAM

9:30 - 10:00 Welcome

10:00 – 11:00 Dr. Jürgen Kurths (Potsdam Institute for Climate Impact Research & Humboldt University, Department of Physics, Berlin)

"Climate Meets Complex Systems: Exploring Predictability of Extreme Climate Events via a Complex Network Approach"

Coffee break

11:30 – 12:30 Dra. Ulrike Feudel (ICBM, University of Oldenburg)

"Transient chaos in complex networked systems"

12:30 – 13:30 Dr. Dan Dediu (Investigador ICREA, Facultat de Filologia i Comunicació UB)

"Language and languages: complex systems (co-)evolving at the intersection of biology, environment and culture"

Lunch

15:30 – 16:30 Thesis in 3 minutes Competition

16:30 – 17:30 Dra. Chantal Valeriani (Departamento de Estructura de la Materia, Fisica Termica y Electronica, UCM)

"The role played by interactions in the assembly of active colloids: discovering dynamic laws from observations."

Dinner at Moritz (20h)

Author

Dr. Jürgen Kurths (Potsdam Institute for Climate Impact Research & Humboldt University, Department of Physics, Berlin)

Title

Climate Meets Complex Systems: Exploring Predictability of Extreme Climate Events via a Complex Network Approach

Abstract

The Earth system is a very complex and dynamical one basing on various feedbacks. This makes predictions and risk analysis even of very strong (sometime extreme) events as floods, landslides, and heatwaves etc. a challenging task. Additionally, there is a strongly increasing number of extreme events due to climate change.

After introducing physical models for weather forecast already in 1922 by L.F. Richardson, a fundamental open problem has been the understanding of basic physical mechanisms and exploring anthropogenic influences on climate. In 2021 Hasselmann and Manabe got the Physics Nobel Price for their pioneering works on this. I will shortly review their main seminal contributions.

Next, I will present a recently developed innovative approach via complex networks mainly to analyze strong climate events. This leads to an inverse problem: Is there a backbone-like structure underlying the climate system? To treat this problem, we have proposed a method to reconstruct and analyze a complex network from spatio-temporal data. This approach enables us to uncover relations to global and regional circulation patterns in oceans and atmosphere, which leads to construct substantially better predictions, in particular for the onset of the Indian Summer Monsoon, extreme rainfall in South America, the Indian Ocean Dipole and tropical cyclones but also to understand phase transition in the past climate.

References:

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Author

Dr. Dan Dediu (Investigador ICREA, Facultat de Filologia i Comunicació UB)

Title

Language and languages: complex systems (co-)evolving at the intersection of biology, environment and culture

Abstract

There is a certain tendency to focus on the "universal" properties of "language" and forget that, in fact, there are very few of those properties and not in the places one would expect to find them, while language turns out to dissolve in the few thousand languages currently used (and a bit more that have ever been used). Here I will argue that linguistic diversity is highly structured and meaningful, the result of very complex, multi-level co-evolutionary processes involving our bodies (vocal tracts, faces, hands...), minds and brains, the multi-faceted environment that we inhabit (ecology, climate...) and the wider culture. In fact, languages can be usefully seen as a sort of immaterial organisms, culturally evolving under various constraints and affordances and generating, in turn, constraints and affordances not only for the evolution of the wider culture but also for our genes and the environment. While metaphors are often misleading and many can apply to language, cultural nice construction and gene-culture coevolution are good starts in thinking about it. However, I will not remain at this very abstract level, but I will present concrete examples of how linguistic diversity is influenced, at different levels, by the physical environment we inhabit and by our biology, and how the structure of our communicative networks and the repeated use and transmission of language help the emergence and maintenance of diversity by amplifying tiny inter-individual differences (non-pathological idiosyncrasies). I conclude with a call for inter-disciplinary work bringing together modelling, experimental and statistical approaches to advance our understanding of these multi-faceted and complex phenomena.

Author

Dra. Chantal Valeriani (Departamento de Estructura de la Materia, Fisica Termica y Electronica, UCM)

Title

"The role played by interactions in the assembly of active colloids: discovering dynamic laws from observations."

Author

Dra. Ulrike Feudel (ICBM, University of Oldenburg)

Title

"Transient chaos in complex networked systems"

Abstract

Transient chaos is a well-known phenomenon in low-dimensional systems which is related to the existence of unstable chaotic sets, so-called chaotic saddles, in state space. Such saddles result from global bifurcations changing substantially the overall dynamics of a system. Chaotic saddles can either be created in a basin boundary metamorphosis, when smooth basin boundaries are turned into fractal ones and as a result of a boundary crisis where a chaotic attractor loses its stability. The implications of the two different kinds of chaotic saddles on the dynamics of networks are manifold. The networks considered here consist of nodes possessing different dynamical states, mainly periodic, but sometimes also chaotic, while the links are related to diffusive or delay coupling. We will discuss three phenomena: (i) the switching between various network patterns realized by a chaotic saddle containing three different space-time patterns including extreme events; (ii) desynchronization in globally stable networks of identical oscillators due to perturbation and (iii) state-dependent vulnerability of synchronization. In the first two cases fractal and riddled basins of attraction play a fundamental role in the formation of a chaotic saddle leading to extremely long chaotic transients. In the last two cases that chaotic saddle is embedded in the basin of attraction of the globally stable attractor. We show exemplarily the complexity of the dynamics resulting from the transient chaos in the system and discuss methods to analyze it:

For a network of non-identical relaxation oscillators we report on self-induced switching between multiple distinct space–time patterns in the dynamics of a spatially extended excitable system [1]. These switchings between low-amplitude oscillations, nonlinear waves, and extreme events strongly resemble a random process, although the system is deterministic. We show that a chaotic saddle—which contains all the patterns as well as channel-like structures that mediate the transitions between them—is the backbone of such a pattern switching dynamics. Our analyses indicate that essential ingredients for the observed phenomena are that the system behaves like an inhomogeneous oscillatory medium that is capable of self-generating spatially localized excitations and that is dominated by short-range connections but also features long-range connections. Our findings contribute to an improvement of our understanding of pattern switching in spatially extended natural dynamical systems like the brain and the heart.

Furthermore, we analyze the final state sensitivity of nonlocal networks of Duffing oscillators with respect to the initial conditions of their units. By changing the initial conditions of a *single* network unit, we perturb an initially synchronized state, which is the only, globally stable attractor for a single unit. Depending on the perturbation strength, we observe the existence of two possible network long-term states: (i) The network neutralizes the perturbation effects and returns to its synchronized configuration. (ii) The perturbation leads the network to an alternative desynchronized state. By computing uncertainty exponents of a two-dimensional cross section of the state space, we find the existence of a fractal set of initial conditions

converging to this desynchronized solution, which appears to be either a new attractor or a chaotic saddle, i.e. an unstable chaotic set on which trajectories persist for extremely long times [2,3]. Finally, we report the existence of an intricate time dependence of the vulnerability of the synchronized states in a network composed of identical electronic circuits [3,4]. By perturbing the synchronized dynamics in consecutive instants of time, we find that synchronization breaks down for some time instants while it persists for others.

All those phenomena highlight the crucial role played by unstable chaotic set leading to transient chaotic dynamics in networked systems. Most of these phenomena are generic for large classes of nonlinear dynamical systems.

References:

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