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Abstract booklet

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Plenaries

Mario Molina

Climate Change: Science, Policy and Solutions

SPEAKER: *Mario Molina*

ABSTRACT. Climate change is the most serious environmental challenge facing society in the 21st century. The average temperature of the Earth's surface has increased so far by about one degree Celsius since the Industrial Revolution, and the intensity of extreme weather events such as heat waves and floods is also increasing, most likely as a consequence of this temperature change. The consensus among climate change experts is that it is very likely that human activities, mainly burning fossil fuels, are causing the observed changes in the Earth's climate in recent decades. The basic science is very clear, although there are scientific uncertainties, because the Earth's climate is a complex system. The risk of causing dangerous changes to the climate system increases rapidly if the average temperature rises more than two or three degrees Celsius; society faces an enormous challenge to effectively reduce greenhouse gas emissions to avoid such dangerous interference with the climate system. To achieve this goal, it is important to consider not only the science, but also economic, social and policy issues connected with climate change.

Luis Bettencourt

Cities as Open-Ended Complex Adaptive Systems

SPEAKER: *Luis Bettencourt*

ABSTRACT. There are many examples of complex systems sharing both common and different properties, from organisms to ecosystems, or from firms to cities. In this talk, I will emphasize particular open-ended complex systems - such as ecosystems or cities - and the especially interesting demands they pose on modeling and theory. I will show how many properties of cities can be understood in terms of modern network models of coupled social and spatial processes, such as scaling or agglomeration effects. However, I will also demonstrate that such models are not sufficient to understand the evolution and growth of cities overtime, nor aspects of their heterogeneity and inequalities.

To address these issues, I will show that one requires a new type of statistical mechanics that bridges statistical physics and evolutionary theory. Such theory has universal properties that allow us to derive the general statistics of cities, even in the presence of fast and open-ended growth.

Marta C. Gónzales

A Complex Systems approach to study Human Mobility

SPEAKER: *Marta C. Gónzales*

ABSTRACT. I present a complex system approach applied to large data sets. I characterize how humans interact with built environment and to plan for better usage of urban resources. First I present a modeling framework, TimeGeo, that generates individual trajectories in high spatial-temporal resolutions, with interpretable mechanisms and parameters capturing heterogeneous individual travel choices at urban scale. Then I assign these trips to the streets. I demonstrate that the percentage of time lost in congestion is a function of the proportion of vehicular travel demand to road infrastructure capacity, and can be studied in the framework of non-equilibrium phase transitions.

Antonio Lazcano

Prebiotic evolution and the emergence of life: Did it all happen in a warm little pond?

SPEAKER: *Antonio Lazcano*

ABSTRACT. Analysis of carbon-rich meteorites and the laboratory simulations of the primitive Earth suggest that prior to the emergence of the first living systems the prebiotic environment was indeed rich in a large suite of organic compounds of biochemical significance, many organic and inorganic catalysts, purines and pyrimidines, i.e., the potential for template-dependent polymerization reactions; and membrane-forming compounds. The remarkable coincidence between the monomeric constituents of living organisms and those synthesized in Miller-type experiments appears to be too striking to be fortuitous and strongly supports the possibility that life emerged from such a mixture. There is little doubt that self-organization phenomena played a role in the emergence of life from such primitive soup as shown, for instance, by the remarkable spontaneous assembly of amphiphiles into micelles and bilayer membranes, as well as the dynamical self-assembly properties of nucleic acids. Biological evolution, however, requires an intracellular genetic apparatus able to store, express and, upon reproduction, transmit to its progeny information capable of undergoing evolutionary change. Current biology indicates that the biosphere could have not evolved in the absence of a genetic replicating mechanism insuring the stability and diversification of its basic components. How did such replicating genetic polymers appear?

Stefano Battiston

Price of Complexity and Complexity of Price in Financial Networks

SPEAKER: *Stefano Battiston*

ABSTRACT. Financial institutions form multiplex networks by engaging in contracts with each other and by holding exposures to common assets. As a result probabilities of default and prices of assets are interdependent. While some level of financial complexity is useful it comes at the cost of several unintended consequences, including financial instability, inequality and allocation of capital at odd with the goal of sustainability. What can we learn from network science to make the financial system more resilient to shocks and bubbles, and to make it better serve society by channeling funds towards environmentally and socially sustainable investments?

Raissa D'Souza

Collective behaviors at three scales: nanoscale oscillators, interdependent infrastructure, and macaque societies (Springer Complexity Lecture).

SPEAKER: *Raissa D'Souza*

ABSTRACT. Results from a multi-year research effort aimed at understanding the behaviors of interdependent complex networks, and ultimately controlling their resulting collective phenomena, will be presented. Our advances focus on systems at three different scales. Probing into more classic nonlinear dynamics, we study both theoretically and empirically the attractor space of synchronization for a ring of reactively coupled nanoelectromechanical (NEMs) oscillators. The goal is to understand attractor switching networks and to design small control interventions. At the scale of critical infrastructure, consisting of collections of power girds, water networks and gas networks, our focus is on understanding interdependence and leveraging it for resilience and restoration efforts. This work relies on system identification techniques, optimization methods and graphs products. Finally at the scale of social systems we study the multilayered interactions found in macaque monkey societies, including aggression, grooming, policing and huddling networks. Our focus is on multi-layered ranking metrics, mechanisms underlying formation of hierarchy, and multilayered interactions leading to abrupt societal collapse.

This work is a collaboration between research teams at UC Davis, California Institute of Technology, Rice University, and University of Washington, funded by the ARO MURI program with coauthors Brianne Beisner, Airlie Chapman, Jim Crutchfield, Leonardo Duenas-Osorio, Jeff Emenheiser, Warren Fon, Andres Gonzalez, Darcy Hannibal, Matthew Matheny, Brenda McCowan, Mehran Mesbahi, Marton Posfai, Michael Roukes, and Anastasiya Salova.

Alex Arenas

Multilayer Interconnected Complex Networks

SPEAKER: *Alex Arenas*

ABSTRACT. Multilayer networks are attracting large interest because they describe complex systems in formed by several networks indicating interaction of different nature. Examples are ubiquitous from infrastructure to transportation and biological networks. We will describe the state of the art for characterizing and modelling the structure of multilayer networks and for studying their robustness properties.

Ranulfo Romo

Neural coding of subjective sensory experience and uncertainty of perceptual decisions

SPEAKER: *Ranulfo Romo*

ABSTRACT. When a near-threshold sensory stimulus is presented, a sensory percept may or may not be produced. The unpredictable outcome of such perceptual judgment is believed to be determined by the activity of neurons in early sensory cortex. We found that these responses did not covary with the subjects' perceptual reports. In contrast, the activity of frontal lobe neurons did covary with trial-by-trial judgments. Further control and micro-stimulation experiments indicated that frontal lobe neurons are closely related to the subjects, subjective experiences during sensory detection.

César Hidalgo

Collective Learning in Society and the Economy

SPEAKER: *César Hidalgo*

ABSTRACT. How do teams, organizations, cities, and nations learn? How can we create tools to facilitate collective learning? In this presentation I will show research establishing the universal role of relatedness in the diffusion of productive knowledge, and on the creation of commercial relationships. Also, I will present software tools designed to improve the collective learning capacities of teams, organizations, and nations.

Kristina Lerman

Cognitive Biases and the Limits of Crowd Wisdom

SPEAKER: *Kristina Lerman*

ABSTRACT. The many decisions people make about what information to attend to affect emerging trends, the diffusion of information in social media, and performance of crowds in peer evaluation tasks. Due to constraints of available time and cognitive resources, the ease of discovery strongly affects how people allocate their attention. Through empirical analysis and online experiments, we identify some of the cognitive heuristics that influence individual decisions to allocate attention to online content and quantify their impact on individual and collective behavior. Specifically, we show that the position of information in the user interface strongly affects whether it is seen, while explicit social signals about its popularity increase the likelihood of response. These heuristics become even more important in explaining and predicting behavior as cognitive load increases. The findings suggest that cognitive heuristics and information overload bias collective outcomes and undermine the "wisdom of crowds" effect.

Dirk Brockmann

Networks, Complexity and Disease Dynamics

SPEAKER: *Dirk Brockmann*

ABSTRACT. The spread and proliferation of emergent human-to-human transmissable infectious diseases are complex phenomenona that are driven by a broad range of factors that act on different time- and spatial scales. On a basic level we have to understand how individuals interact within populations and how they move between them. I will report on ways in which network science has contributed to our understanding of disease dynamics on a global scale, based on the notion of effective distance, and how network science can help understand contagion processes within single populations. I will also report how new technologies permit epidemiological experiments in human populations that can aid on-going eradication programs, e.g. for polio and measles.

John Quackenbush

Using Networks to Link Genotype to Phenotype

SPEAKER: *John Quackenbush*

ABSTRACT. One of the central tenants of biology is that our genetics—our genotype—influences the physical characteristics we manifest—our phenotype. But with more than 25,000 human genes and more than 6,000,000 common genetic variants mapped in our genome, finding associations between our genotype and phenotype is an ongoing challenge. Indeed, genome-wide association studies have found thousands of small effect size genetic variants that are associated with phenotypic traits and disease. The simplest explanation is that these genetic variants work synergistically to help define phenotype and to regulate processes that are responsible for phenotypic state transitions. We will use gene expression and genetic data to explore gene regulatory networks, to study phenotypic state transitions, and to analyze the connections between genotype, gene expression, and phenotyope. We have found that the networks, and their structure, provide unique insight into how genetic elements interact with each other and the structure of the network has predictive power for identifying SNPs likely to be associated with phenotype through genome wide association studies. I will show multiple examples, drawing on my work in cancer, in chronic obstructive pulmonary disease, and in the analysis of data from thirty-eight tissues provided by the Genotype-Tissue Expression (GTEx) project.

Jaime Urrutia Fucugauchi

Chicxulub asteroid impact and the extintion of dinosaurs

SPEAKER: *Jaime Urrutia Fucugauchi*

ABSTRACT. Crater-forming impacts represent a class of extreme events involving high energy release and short time scales. Impacts constitute major geologic processes shaping the surfaces and evolution of planetary bodies. Formation of large craters involves high pressures and temperatures resulting in intense deformation, fracturing and melting. Impacts produce deep transient cavities, with excavation to deep levels in the crust, fragmentation, and removal of large volumes of rock. Here, we analyze the Chicxulub impact and its effects on the Earth´s climate, environment and life-support systems, in relation to the Cretaceous/Paleogene boundary. The boundary represents one of the major extinction events in the Phanerozoic, which affected ~75 % of species in the continental and marine realms. Effects of the impact have been intensely investigated, where the affectation in the evolution patterns was profound and long-lasting. The disappearance of large numbers of species including complete groups severely affected the biodiversity and ecosystem composition in the marine and continental realms. There are several aspects involved in addressing the Chicxulub impact as an extreme event, which involves a complex interplay of processes in the Earth´s system. First we examine the impact event and cratering, time scales involved and energy released. Next, we assess the impact´s regional and global effects, which involve major perturbations in the ocean and atmosphere, including feedback mechanisms and nonlinear effects. From here, we discuss how and to what extent life-support systems are affected by large impacts, and what the fossil record tells about the extinction event and biotic turnover. In particular, how sudden or extended are the processes, the extinction event and the biodiversity recovery processes.

Albert-Lászlo Bárabási

Senior Award talk

SPEAKER: *Albert-Lászlo Bárabási*

Parallel

Francesco Parino, Mariano Beiro and Laetitia Gauvin

Characterization of the adopters of the Bitcoin

SPEAKER: Laetitia Gauvin

ABSTRACT. Bitcoin is a cryptocurrency which became very popular during the recent years. The bitcoin transactions are recorded in a public ledger, the bitcoin blockchain, and can be collected since its creation. The bitcoin blockhain works without a central authority but is based on a peer-to-peer system. The transactions take place between users directly and not necessarily with a transaction fee. More exactly the bitcoins exchanged during a transaction are sent from an address to another, each address belonging to a user. One of the challenge to study such a system and understand the behaviour of users in this new transaction system is the possibility for any user to generate multiple addresses. Here we propose a preliminary analysis to get a sense of the users of the bitcoin despite the high degree of anonymity inherent to the system. We do not attempt to identify single users but to charaterize the spatial distribution of users at the country level. Even though it is not possible to link an IP address to the authors of a transaction, one can obtain the IP of the first user which relays the transaction. The current literature on the bitcoin blockchain would tend to support that this IP has some chance to be the IP of the source of the transactions. As a first attempt we thus assume that these IP addresses allow to estimate where the users come from. In order to test this assumption, we compare the countries of provenance of the IP addresses to the geolocalization of the user downloading wallets which are softwares to access the bitcoin technology. We observed a good agreement between the two. This confirms that the IP address that relay transactions can be used to some extent as a good proxy to identify the provenance of the users. However due in particular to the increasing broadcasting of transactions by services instead of single users, the IP addresses are only accessible for a given time interval. For this reason, in order to characterize the evolution of the adoption in different countries we use Google Trends data to quantify the collec- tive attention for the bitcoin, this appears as good proxy when compared to the unique IP addresses. Looking at the evolution of the bitcoin search through Google trends for different countries we can have an hint on the early and new adopters. To complete the study we also build the network of users where a link is given by a transaction and look at the bilateral exchanges among countries using the IP addresses mentioned earlier as well as some heuristic developed in the literature to assign a country to each transaction. We finally compare this to a null model to extract what are the preferred relationships between countries for transactions. To summarize, we propose a way to measure the collective interest for the bitcoin at the level of the country and to understand how the transactions are distributed among the countries.

Pablo Moriano, Jorge Finke and Yong-Yeol Ahn

Community-based anomalous event detection in temporal networks

SPEAKER: Pablo Moriano

ABSTRACT. Communication networks exhibit community structure based on demographic, geographic, and topical homophily. Members of each community tend to have common interests and to share most contents primarily within their community, exhibiting behavioral characteristics of complex contagion. By contrast, previous studies have shown that viral contents tend to behave like simple contagion, easily crossing community boundaries. We hypothesize that contents about an important event tend to be viral because they are relevant to a large fraction of people in the network, and that the increase in viral contents due to the event will trigger more communication across existing communities. We confirm our hypothesis and demonstrate that it can be used to detect anomalous events from temporal communication network structure, namely by monitoring and comparing the communication volume within and across communities. We use two examples-the collapse of Enron and the Boston Marathon bombing-to show that the communication volume across communities indeed increases when the information about the events was spreading across the communication network.

Arturo Serrano, Veronica Alexandra Rojas-Mendizabal and Anamaria Escofet

Telecommunications as a Socio-Technical System: The Transport of Information from a Complexity Perspective

SPEAKER: Arturo Serrano

ABSTRACT. This contribution attempts to describe, by means of the principles of complexity, the telecommunications ecosystem of a particular context. To accomplish our purpose, we consider telecommunications –the transport of information- as a socio-technical system. The dynamics of this system is highly dependent on the interactions and articulations with the environment, i.e., on its inner subsystems and boundary conditions. We open the possibilities to addressing the problems of the telecommunications sector from an interdisciplinary approach to provide operational solutions that take into account the participation of different areas and agents to arrive at alternative readings of reality beyond the current disciplinary views and tools. Our challenge is how to instill complexity thinking into the telecommunications empirical domain. In other words, “acting” on complexity to look for pragmatic socio-technical interventions and implementations exposed to an overwhelming technology change. We suggest that a socio-technical system, such as telecommunications, should not be regarded only as a mechanism or infrastructure, but as an entity with feedback processes, emergence and interdependence, which are distinctive features of dynamic complex systems, as well as human interactions. Likewise, this perspective can lead to further findings toward the construction of frameworks involving the roles and information flows of the most relevant agents in the various levels of operation and management of this ecosystem. We propose that the telecommunications ecosystem can be fruitfully analyzed in three dimensions: Information Theory, Network Theory and Convergence. In that regard, our analysis covers the structure, content, and nature and scope of the ecosystem interactions.

Flavio L. Pinheiro, Cristian Candia-Castro-Vallejos, Sara Encarnação and César A. Hidalgo

Mapping the Higher Education System

SPEAKER: Flavio L. Pinheiro

ABSTRACT. It is widely accepted to exist a perception gap between theskills acquired by individuals during higher education and thedemands of the labor market. This has a profound impact inthe individuals' careers, by constraining their future earningsand labor mobility, but it also presents a signicant constraintto a country economic growth.In recent years, the impact of degree programs and/orhigher education institutions on graduates future payoffs hasbeen broadly studied. In contrast, the quantication of the per-ception that different agents such as, policy makers, highereducation candidates, and employers, have on the relationshipamong skills available, has received little attention. An ap-proach to quantify the perception gap of skills between candi-dates and employers, would benet and facilitate the effective-ness on education and labor public policies.TheInternational Standard Classication of Education(ISCED) classication scheme – proposed and maintained byUNESCO – is the standard adopted by many countries andacademic studies as the basic structure for producing com-parable statistical data between different educational systems.The ISCED represents thede factostructure as perceived bypolicy makers and it is constructed through a rationale of com-paring the contents of the different degree programs. How-ever, this classification presents some problems. Take for in-stance Architecture, although classified as part of the Engi-neering field it is, in fact, much closer to Arts and Designwhen applicants preferences patterns are taken into accountIn this work, we use data on 380.375 candidates' applica-tions to degree programs between 2008 and 2015 from thePortuguese Public Higher Education System. Each appli-cation corresponds to a list of up to six preferences of de-gree programs. We propose a complex networks approach toexplore the relationships between different degree programsbased on the perceptions of the candidates. We identify prox-imity between degree programs by nding which pairs of pro-grams exhibit a statistically signicant pattern of co-occurrencein the candidates preferences list. The resulting structure has649 nodes and 3,067 edges, and it shows a strong modu-lar character with 10 communities exhibiting a modularity ofQ=0.70. Our data-driven approach shows significant differ-ences in respect to the ISCED scheme.Although this structure does not represent skills, it repre-sents the the choice space of candidates. Indeed, degree pro-a)Electronic mail: flaviopp@mit.edugrammes are essentially a package of skills and are an impor-tant aspect of the applicants' decision making when applyingto higher education. In that context, we compare the impact ofour structure by studying the spatial patterns of gender dom-inance, applicants' scores and expected unemployment levelsby program. All showing a strong positive assortment, i.e.spatial correlations. These findings leads us to conclude twothings. First, the choices of candidates are strongly condi-tioned to the candidates' properties (gender and scores), andsecondly, the choice of degree program strongly constrains theentry in the labor market of candidates and can hinder their fu-ture.Ongoing work aims at quantify how employers perceivethe relationship between the degree programs; to quantify themismatches between the perceptions of policy makers, candi-dates, and employers; and finally the economic impact of suchdisparities.

Sijuan Ma, *Ling Feng*, *Choy Heng Lai* and *Christopher Pineda Monterola*

Information spreading on Twitter network

SPEAKER: Sijuan Ma

ABSTRACT. Online social networks are becoming major platforms for people to exchange opinions and information. As social media marketing becomes more and more popular, their spreading dynamics is fully tractable. This enables us to study the fundamental mechanisms driving their spreading, and use such knowledge for better understanding and prediction. Based on the analysis of empirical user-generated data from the Twitter network, we find that the spreading of messages follows a mechanism that differs from the spread of disease. We introduce model extended from the FSIR model for the spreading behavior. In this mech- anism, users with more friends have less probability to retweet a specific message due to competition for limited attention. By analyzing multiple popular tweet messages and their retweet process, we find those characteristic properties are consistent with the proposed FSIR model, including the degree distribution of retweeted users. Besides, we introduce the variable attractiveness to describe how attractive the messages are for users and this determines the overall willingness of retweet. Intuitively, attractive messages have higher probabilities to be retweeted. We find that the attractiveness decrease with time. Based on FSIR model and retrieved attractiveness of specific tweet, our future work is to do classification and prediction of final retweet population.

Michela Del Vicario, *Fabiana Zollo*, *Ana Lucia Schmidt*, *Guido Caldarelli*, *Antonio Scala* and *Walter Quattrociocchi*

Mapping Social Dynamics on Online Social Media

SPEAKER: *Fabiana Zollo*

ABSTRACT. Information, rumors, and debates may shape and impact public opinion. In the latest years several concerns have been expressed about social influence on the Internet and the outcome that online debates might have on real-world processes. Indeed, on online social networks users tend to select information that is coherent to their system of beliefs and to form groups of like-minded people --i.e., echo chambers-- where they reinforce and polarize their opinions. In this way the potential benefits coming from the exposure to different points of view may be reduced dramatically and individuals' views may become always more extreme. Such a context fosters misinformation spreading, which has always represented a socio-political and economic risk. The persistence of unsubstantiated rumors suggests that social media do have the power to misinform, manipulate, or control public opinion. Current approaches such as debunking efforts or algorithmic-driven solutions based on the reputation of the source seem to prove ineffective against collective superstition. Indeed, experimental evidence shows that confirmatory information gets accepted even when containing deliberately false claims, while dissenting information is mainly ignored, influences users' emotions negatively and may even increase group polarization. Ideed, confirmation bias has been shown to play a pivotal role in information cascades. Nevertheless, mitigation strategies have to be adopted. To better understand the dynamics behind information spreading, we perform a tight, quantitative analysis to investigate the behavior of more than 300M users w.r.t. news consumption on Facebook. Through a massive analysis on 920 news outlets pages, we are able to characterize the anatomy of news consumption on a global and international scale. We show that users tend to focus on a limited set of pages (selective exposure) eliciting a sharp and polarized community structure among news outlets. Indeed, there is a natural tendency of the users to confine their activity on a limited set of pages. According to our findings, news consumption on Facebook is dominated by selective exposure. Similar patterns emerge around the Brexit --the British referendum to leave the European Union-- debate, where our analysis underlines the spontaneous emergence of two well-separated and polarized communities around Brexit pages. Our findings provide interesting insights about the determinants of polarization and the evolution of core narratives on online debating. Our main aim is to understand and map the information space on online social media by identifying non-trivial proxies for the early detection of massive informational cascades. Furthermore, by combining users traces we are finally able to draft the main concepts and beliefs of the core narrative of an echo chamber and its related perceptions.

Alberto Antonioni and *Alessio Cardillo*

Coevolution of synchronization and cooperation in costly networked interactions

SPEAKER: *Alberto Antonioni*

ABSTRACT. The synchronization of coupled oscillating systems is a phenomenon that has received considerable attention from the scientific community given the wide range of domain. More specifically, the pattern of interaction among the oscillators has been proven to play a crucial role in promoting the conditions for the emergence of a synchronized state. Such interaction pattern may be encoded as a graph and several studies investigating the emergence of synchronization have been performed in groups of oscillators on complex networks.

Despite the amount of studies made so far, all the approaches were based on the hypothesis that the variation of the state for an oscillator, which is a fundamental requirement to attain synchronization, is costless. Yet, it seems reasonable to assume that when an oscillator alters its state this frequency variation involves an adjustment cost that, in turns, impacts on the dynamics. The introduction of such adjustment cost leads to the formulation of a dichotomous scenario. In this framework, an oscillator may decide to pay the cost necessary to alter its state and make it more similar to that of the others or, alternatively, keep it unaltered hoping that the others adjust their states to its own. The former behavior can be considered as an act of cooperation while the latter as a defection one; both of them constitute the basic action profiles of a Prisoner's Dilemma game. Hence, the emergence of synchronization may be seen as the outcome of an evolutionary game in which the oscillators can strategically decide which behavior they will adopt according to the payoff they received in the previous synchronization stage. Complex networks play a key role in the emergence of cooperation and, in particular, the presence of hubs in scale-free networks fosters even more such phenomenon. Thus, it is worth to study the underlying mechanisms responsible for the onset of synchronization in systems where the single oscillators are placed on the nodes of a network and can decide to cooperate, by synchronizing their state with that of their neighbors, or not. This leads to a coevolutionary approach where the synchronization dynamics and the evolution of cooperation influence each other. Coevolutionary approaches represent the natural extension of the actual models in order to achieve a better description of complex systems. More specifically, we consider a system of Kuramoto oscillators that are able to decide which strategy between cooperation and defection they will adopt upon the evaluation of their payoff. We consider that an oscillator assumes a cost that is tuned by a model parameter alpha and it is proportional to the absolute value of the difference between the previous and the current frequency of the oscillator. On the other hand, the positive payoff, i.e. the benefit, is given by the synchronization achieved within the oscillator neighborhood. The emergence of both cooperation and synchronization is studied for three different topologies, namely: Erdös-Rényi random graphs, Random Geometric Graphs and Barabási-Albert scale-free networks.

The results of this study are published on Physical Review Letters.

Luís F Seoane and Ricard Sole

The morphospace of language networks

SPEAKER: Luís F Seoane

ABSTRACT. Language can be described as a network of interacting objects with different qualitative properties and complexity. These networks include semantic, syntactic, or phonological levels and have been found to provide a new picture of language complexity and its evolution. A general approach considers language from an information theory perspective that incorporates a speaker, a hearer, and a noisy channel. A key common element is a matrix (often binary) encoding which words name each one of the objects that exist [1]. This tool allows us to measure the cost of communication across the channel for hearers and speakers, and is at the core of a rich literature on least-effort language exploring the optimality of communication codes. Computational results suggest that human languages might lay at the critical point of a phase transition, simultaneously coping with several optimality constraints [1, 2, 3, 4]. The critical nature of this phase transition has not been confirmed before, and these results remain speculative as they lack empirical support from real languages.

The matrix at the heart of this theoretical framework naturally introduces networks mediating the communicating agents, but no systematic analysis of the underlying landscape of possible language graphs has been developed. Here [5] we present a detailed analysis of network properties on this generic model of communication codes. A rather complex and heterogeneous morphospace of language networks is revealed. This morphospace can be analyzed from the perspective of Pareto (or multiobjective) optimization attending to the different needs of speakers and hearers. Pareto optimality has been linked to statistical mechanics [6], which allows us to prove, for the first time and analytically, that the system does include a critical point separating a first order phase transition – also known as a hybrid phase transition. Additionally, we use curated data of English words to locate and evaluate a real language, for the first time, within this morphospace of communication codes. Our findings indicate a surprisingly simple structure unless referential particles are introduced in the vocabulary. This also opens up the exploration of the heterogeneity of the language morphospace.

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Jacobo Levy Abitbol, *Márton Karsai*, *Jean-Philippe Magué*, *Jean-Pierre Chevrot* and *Eric Fleury*

Optional realisation of the French negative particle (ne) on Twitter: Can big data reveal new sociolinguistic patterns?

SPEAKER: *Jacobo Levy Abitbol*

ABSTRACT. From the outset, real-world data has been essential to the empirical and theoretical development of the field of sociolinguistics (Labov, 1975). It is thus not surprising that this field recently joined the movement of computational social sciences (Lazer et al., 2009) that results from the ability to collect and model vast digital datasets concerning the behaviour of individuals in collective contexts. The emerging field of computational sociolinguistics (Nguyen et al., 2016) works on data obtained by sensors (proximity sensors, wearable recorders) or the digital communication that permits automatic, ongoing and unsupervised recording through the collection of traces on the web, in social media, or via portable devices.

In this work we exploit these advancements and use massive datasets to reveal sociolinguistic patterns that would remain unseen otherwise. More precisely, we analyse a dataset comprising of 15\% of all Twitter communications in France, recorded between June 2014 and January 2017 along with meta information emanating from the profiles of users. We focus on the usage of the sociolinguistic variable ``ne", assigning the correct form negation particularly in the French language. This variable appears with optional usage of the first morpheme of the negation (\textit{Je fume pas} vs. \textit{Je ne fume pas} - I do not smoke) for three reasons: ``ne" is a well-documented sociolinguistic marker of spoken French (Armstrong and Smith, 2002); inclusion and omission of ``ne" are visible in the written tweets; and finally ``ne" is always included within standard writing, enabling us to assess the adherence of each user to the written norms. We complete our dataset by identifying the home locations of 400K Twitter users to match their locations with spatially enabled socio-economic data collected during the 2016 census in France. This dataset, provided by INSEE\footnote{https://www.data.gouv.fr/en/datasets/donnees-carroyees-a-200-m-sur-la-population/}, includes the age structure of the population as well as the annual income for people located in square grids of 200m per 200m throughout the French territory.

Using these combined datasets we extract tweets that include a negative construction to present results in three directions. First, we signal the overall score of ``ne" realisation and its regional variation in France (approx. 16\% in the North and 28\% in the South). Second, we show that correct usage of negation continuously varies over the time of days and weeks, increasing in the morning, while decreasing during the night. Finally, we show evidences of a positive correlation between annual income and rate of usage of ``ne", i.e. the level of correctness in the way users express themselves. Our analysis focuses on the sociolinguistic implications of the results, including the close examination of the risk of bias. As a final argument we defend that thick data should be combined with big data in order to explain such unforeseen patterns of sociolinguistic variables (Wang, 2013).

Cheryl Abundo, *J. Stephen Lansing*, *Guy Jacobs*, *Elsa Guillot*, *Murray Cox*, *Sean Downey* and *Lock Yue Chew*

Kinship structures create persistent channels for language transmission

SPEAKER: *Cheryl Abundo*

ABSTRACT. Languages are transmitted through channels created by kinship systems. Persistence of these kinship channels leave traces in the genetic structure of a population. In the traditional societies of Sumba and Timor, movements among communities are driven by kinship practices which in turn shape both linguistic and genetic variations. Finely resolved co-phylogenies of languages and genes reveal persistent movements between stable speech communities facilitated by kinship channels, which play a critical role in stabilizing deep associations between languages and genes at small scales. This association, routinely found from local to global scales, can therefore be understood through microscopic cultural processes that define pathways of joint inheritance such as sustained adherence to kinship practices.

Bruno Gonçalves, Lucia Loureiro-Porto, Jose J. Ramasco and David Sanchez

The fall of the empire: The Americanization of English

SPEAKER: Bruno Gonçalves

ABSTRACT. With roots dating as far back as Cabot's explorations in the 15th century and the 1584 establishment of the ill-fated Roanoke colony in the New World, the British empire was one of the largest empires in Human History. At its zenith, it extended from North America to Asia, Africa and Australia deserving the moniker "the empire where the sun never sets". As history has shown countless times, the rise and fall of empires is a constant driven by a conundrum of internal and external forces. In the case of the British empire, it concurs the curious coincide that its preeminence faded as the United States of America --one of its first colonies-- took over its role in the global arena. As the empire spread so did its language and thanks to both its global extension, and the rise of the US as a global actor, English currently has an undisputed role as the global lingua franca serving as the default language of science, commerce and diplomacy. Given such an extended presence, it is only natural that English would absorb words, expressions and other features of local indigenous languages.

The transfer of political, economical and cultural power from Great Britain to the United States has progressed gradually over the course of more than half a century with the World War II being the final stepping stone in the establishment of American supremacy. The cultural rise of the United States also implied the export of their specific form of English resulting in a change of how English is written and spoken around the world. In fact, the "Americanization" of (global) English is one of the main processes of language variation in contemporary English. As an example, if we focus on spelling, some the original differences between British and American English orthography are somehow blurred and, for instance, the tendency for verbs and nouns to end in -ize and -ization in America is now common on both sides of the Atlantic. Likewise, a tendency for Postcolonial varieties of English in SE Asia to prefer American spelling over the British one, has also been pointed out. Electronic communication has indeed been considered to play a role in linguistic uniformity. This paper makes a contribution to the study of the Americanization of English, using a corpus of 213,086,831 geolocated tweets will be used to study the spread of American English spelling and vocabulary throughout the globe, including regions where English is used as a first, second and foreign language.

We study both the spatial and temporal variations of vocabulary and spelling of English using a large corpus of geolocated tweets and the Google Books datasets corresponding to books published in the US and the UK. We find that American English is the dominant form of written English outside the UK and that its influence is felt even within the UK borders. Finally, we analyze how this trend has evolved over time and the impact that some cultural events have had in shaping it.

Andrea Zaccaria, Matthieu Cristelli, Andrea Tacchella and Luciano Pietronero

Following the Product Progression Network to Escape from the Poverty Trap

SPEAKER: Andrea Zaccaria

ABSTRACT. Is there a common path of development for different countries, or each one must follow its own way? In order to produce cars, one has to learn how to produce wheels before? How can countries escape from the poverty trap? Let us represent countries as walkers in a network made of goods, defined such that if a country steps on one product, it will export it. Initial configurations and paths can be very different: while Germany has already explored much of the available space, underdeveloped countries have a long road ahead. Which are the best paths in the product network? To answer these questions, we build a network of products using the UN-Comtrade data about the international trade flows. A possible approach is to connect two products if many countries produce both of them. Wanting to study the countries' dynamics, we want also our links to indicate if one product is necessary to produce the other. So our network is directed: a country usually goes from one product to another, but not vice versa, indicating a natural progression. We introduce an algorithm that, starting from the empirical bipartite country-product network, is able to extract this kind of information. In particular, we project the bipartite network in a filtered monopartite one in which a suitable normalization takes into account the nested structure of the system. We studied the temporal evolution of countries, finding that they follow the direction of the links during industrialization, and spotting which products are helpful to start to export new products. These results suggest paths in the product progression network which are easier to achieve, and so can drive countries' policies in the industrialization process and to exit from the poverty trap. In the standard view of the industrialization process of countries, these have to face a barrier to escape from the poverty trap, which is a monetary threshold defined in terms of average wage or physical capital. When such a threshold is reached, a self-feeding process quickly brings the country from one state of equilibrium (the poverty trap) to another, catching up with the fully developed countries. We use a non-monetary measure of the economic complexity of a country, called Fitness, and we show that complex economies start the industrialization process with a lower threshold. On the contrary, if the Fitness is low, a sustainable growth can be reached only if a higher standard, monetary threshold is reached. As a consequence, we can introduce the concept of a two-dimensional poverty trap: a country will start the industrialization process if it is not complex but rich, or if it is poor but very complex (exploiting this new dimension and laterally escaping from the poverty trap), or a linear combination of the two. Finally, we show that following the recommendations given by the product progression network is correlated with a systematic increase of Fitness, showing that such a strategy can lower the barrier to exit from the poverty trap.

Daniel Heymann

Macroeconomic Crises, Macroeconomic Analysis and Complex System Modeling

SPEAKER: *Daniel Heymann*

ABSTRACT. The celebrated notion “More is Different” certainly applies in social/ economic contexts. Economic activity consists of a highly intricate maze of countless interactions between agents with cognitive abilities comparable to those of the researcher, who are involved for practical purposes in processing information about their environment, just as the economist does in an analytical context. Such a system immediately raises questions about its features of self- organization and, reciprocally, about its potential for generating economy- wide coordination failures. Macroeconomics is intrinsically concerned with this tension. Given its subject matter, macro analysis must necessarily rely on drastically schematized representations of individual behaviors and patterns of interactions. If the all- encompassing theory is out of reach, one should expect a coexistence of models with variable features and presumed ranges of validity. The effort to adapt the analytical approach to the problem at hand would contrast with both dogmatism and loose eclecticism. In order to be relevant, macroeconomics must search for suitable approximations, especially regarding the study of large-scale, socially costly disturbances like deep recessions, debt crises or high inflations. Standard macroeconomics has mainly been based in the last decades on constructs that assume general equilibrium (conditioned by «frictions»), with a presumption that agents decide optimally given constraints, and forecast their future opportunities with rational expectations (typically viewed as correspondence between the perceived and actual distributions of the variables of interest). The massive volume of work done within that general framework cannot be ignored. But the approach presents serious shortcomings and limitations, of pertinence, especially for the study of critical phenomena, and also of logic. The presentation will discuss briefly, in particular terms, some of these issues, especially concerning consistency problems in the usual rational expectations models, which have concrete implications for the representation of the dynamics of the anticipations and beliefs of agents when dealing with processes associated with macro crises. Complex system analysis, especially in the form of multi- agent models (ABM´s), seems to offer a natural avenue for progress in macroeconomics. Indeed, quite interesting advances have been made in that direction, especially regarding the propagation of impulses in credit and input-output networks. However, the diffusion of macro ABM´s as an everyday tool has been relatively slow. The presentation will address specific topics concerning the evolution and prospects of macro theory, with reference to the study of large economic fluctuations and financial disturbances. The discussion will include: • Concrete illustrations, using old-standing elementary questions, of the centrality of coordination and information processing issues in macroeconomic settings, and of the pertinence of paying special attention to the range of applicability of arguments and models. • Evidence indicating analytically relevant elements of big macroeconomic fluctuations/disturbances: changing trends, frustrated expectations, buildups and sudden transitions. • Reflections on the potential of complex- system modeling in macroeconomics, and comments on some open issues regarding the representation of individual behaviors and systemic mechanisms.

Duc Thi Luu, *Mauro Napoletano*, *Paolo Barucca* and *Stefano Battiston*

Collateral Unchained: Rehypothecation networks, complexity and systemic effects.

SPEAKER: *Mauro Napoletano*

ABSTRACT. This paper investigates how the structure of rehypothecation networks affects the dynamics of endogenous total liquidity and the emergence of systemic risk within the financial system. Rehypothecation consists in the right of reusing the collateral of a transaction many times over. Rehypothecation increases the liquidity of market players, as those players can use the collateral received to honor another obligation. At the same time, rehypothecation lowers parties actual coverage against counterparty risk, because the same collateral secures more than one transaction, and it can therefore be a source of systemic risk. To study the above issues, we build a model where banks are linked by chains of repo contracts and use or re-use a fixed amount of initial collateral. In the model each bank sets the amount of collateral to hoard using a VaR criterion, and the fraction of collateral hoarded is a function of the fraction of collateral hoarded by the bank's neighbors. In this framework, we show that, first, the additional amount of collateral endogenously created in the system is positively related to the density of the network, revealing an important effect of market integration and diversification processes on collateral and liquidity creation. Second, the emergence of long chains and especially of cyclic structures is key to create a level of collateral that may far exceed the initial level of proprietary collateral of banks in the network. Furthermore, we study the amount of liquidity hoarding and of total collateral losses following uncertainty shocks hitting a small fraction banks in the system under different network structures. We show that core-periphery networks allow on the one hand the creation of endogenous collateral. On the other hand, they are more exposed to larger cascades of liquidity hoarding and to larger losses in collateral. This indicates that rehypothecation networks involving an unequal distribution of collateral in the system are also characterized by a trade-off between liquidity and systemic risk.

Nicolás Garrido

A Macroeconomic Computational Agent Based Model and its Social Accounting Matrix representation

SPEAKER: *Nicolás Garrido*

ABSTRACT. This paper explore the complementarities between two techniques to analyze an economy represented as a social complex system. On the one hand a Macreconomic Agent Based Model is built and simulated. On the other hand a Social Accounting Matrix (SAM) of the artificial economy is computed in each one of the simulated period. The Macroeconomic Agent Based Model allows a constructive representation of an economy, taking into account multiple nonlinearities and hetereogeneity related to adaptive behavior and endowments of the agents in the economy. The Social Accounting Matrix is a framework both for models of how an economy work as well as for the data which is useful to monitor its working. SAMs are widely employed in countries as the final product of the accounting of the society and the basic data representation to analyze the anticipate the effect of public policy. Therefore being able to explore how this system of information capture and represent an (artificial) economy provides useful insight for futures improvement in its representation. In the paper, some of the multipliers of the SAM matrix are used to anticipate the evolution of the simulated economy and preliminary conclusions are reported about how to improve the predictive capacity of these multipliers.

Ken Bastiaensen, Benjamin Vandermarliere, Milan van den Heuvel, Tarik Roukny, Tim Verdonck and Koen Schoors

client based view on the transmission of monetary policy

SPEAKER: Ken Bastiaensen

ABSTRACT. “Secular stagnation” currently constitutes one of the main debates in economics: Low economic growth, low inflation and low interest rates have become commonplace in many developed economies. One potential driving factor of secular stagnation is that monetary policy is, in the presence of ageing, no longer an effective tool to counter a deficient demand for investment goods in the economy. The question becomes then how monetary policy, as usual through the banking sector, impacts ultimately the behaviour of individual savers and investors.

We exploit a proprietary data set covering millions of clients over 10 years with all their personal characteristics, income, portfolio composition, loans and mortgages. In addition it contains all their financial transactions including transfers and withdrawals, giving a unique insight into their economic behaviour.

Our work focuses on saving and investment (S&I) decisions given the heterogeneity of individuals with regard to age, expected life expectancy, civil state, income level, income stability, wealth, indebtedness, spending patterns, etcetera. This question requires methods outside the realm of traditional economics. We use several tools from Statistical Learning and more traditional econometrics models such as local projection modelling.

With this approach we are able to gain insight into past behaviour, uncovering patterns in groups of individuals that are not obvious from aggregate observables. One example is the substitution of bonds for saving accounts during decreasing interest rate periods, which is the result of combining distinct behaviour of separate groups, not simply the extrapolation of a single behaviour (as with representative agents).

More importantly, we are able to predict future S&I decisions for each individual, under given future scenarios of macroeconomic conditions such as interest rate. Special care has been given to avoid overfitting. The behaviour arises solely from the experience of other agents without solving any structural economic model as assumed in traditional economics. Our approach has been employed with remarkable out-of-sample success (1 year ex post) on millions of real-world agents. Preliminary results show changing (non-linear) behaviour with regard to changing characteristics.

Our approach would be very valuable for understanding the effects of managing macroeconomic conditions such as monetary policy as well policies that directly impact the characteristics of individuals or their economic environment.

Zeus Guevara and Marco A. Márquez

The complexity in multi-regional economic systems

SPEAKER: Zeus Guevara

ABSTRACT. The complexity of economic systems can be understood as the level of interdependence between the elements that compose these systems (Lopes et al. 2012). This property is important to the analysis of economies as it is related to their dynamic response to exogenous shocks. Small, less sophisticated or close economies are thought to be less complex than large, more sophisticated or open (globalized) economies, respectively. Moreover, an economy consists of several regions, which are becoming more and more connected. The more interdependence connections are between regions, the more complexity that the economic system is expected to have. This raises the question about how the complexity evolve in a multi-regional economic system. In this respect, the objective of this study is to understand the trend of complexity in multi-regional economic systems with respect to the number of regions that compose them. To do so, we use the input-output methodological framework in combination with the CAI indicators, developed by Ferreira do Amaral et al. (2007), as a measurement of complexity. On the one hand, the input-output method offers a simple representation of structural interdependence between elements of the economy, described by inter-sectoral economic flows. On the other hand, the CAI indicators considers a network effect, based on the number of direct and indirect connections between elements; and a dependency effect, based on the influence of connections to the behavior of each element. It is worth mentioning that Lopes et al. (2012) compares the CAI indicators to other complexity indicators and concludes that the former are the most suitable to study complexity in input-output analysis. Our case study consists of the estimation of CAI indicators for the WIOD multi-country economic data for 2014 (Timmer et al. 2012), which is composed by 43 countries and the rest of the economy. First, indicators of each country are separately calculated. Then, to build the trend of complexity, indicators are calculated for multi-country systems, from a 2-country to a 43-country system (adding one country in each iteration). It is hypothesized that the trend of complexity of multi-regional systems grows geometrically with respect to the number of regions that compose these systems. The results of this study could provide insights into the understanding of complexity in multi-regional systems, of the effect of increased inter-regional connections on individual regions, and of the growing complexity of a globalized world.

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Jeremy Oon, Nasri Othman, Hong En Tan, Bao Jia Tan, Jian Sheng Yeung, Jason B. P. Lee, Erika Fille Legara, Muhamad Azfar Ramli and Christopher Monterola

Formulating a Resilience Index for Metro Systems

SPEAKER: Erika Fille Legara

ABSTRACT. In this invited talk, we present our latest work* on the formulation of the resilience index for mass rapid transit systems. To the authors' knowledge, there is no globally accepted indicator that can comprehensively and holistically quantify the resilience of metro rail networks. Most existing research in the field have focused on either adapting network centrality measures or by inferring various assumptions on the dynamics within the MRT. In our work, we propose several indicators that capture key attributes related to transit system resilience including vulnerability and redundancy. These attributes then guide the development of resilience indicators, which then compose the composite resilience index presented herewith. The framework proposed is able to account for non-homogenous rail networks incorporating considerations of lines with different capacities and stations with different demand characteristics. We apply our framework to multiple configurations of the Singapore rapid transit network and show that it effectively captures not only the overall improvements in resilience but also highlights areas within the network that require additional attention.

* This work is currently under review for presentation at TRB Annual Meeting 2018.

Marco A Rosas, *Alejandro Maldonado* and *Carlos Geshenson*

Share journey application summary (Puma ride)

SPEAKER: *Marco A Rosas*

ABSTRACT. Given the conditions of growth and development, mobility plays a preponderant role as a factor of change in the communities and a strategy to generate conditions of development and urban prosperity. In this context, the city in terms of mobility, is defined by two contrasting features, one is the importance of collective public transport, walking and cycling, and the other, the growing increase in motorization and congestion, investing a high percentage of public resources in urban and inter-urban infrastructure for private transport. The objective of this project is to develop a tool that allows the interaction to share trips, in the first instance within the university community, with the intention of not necessarily be an application to share vehicles, if not, in a wider way, share trips by public transport, bicycle or walking. Hoping that the interaction stimulates the coexistence in the university community within an environment of consciousness in the need of the improvement of the mobility, as much inside university city as in the city of Mexico. The development of the application will be in an open platform that allows not to depend on the use of commercial software licenses. These platforms are: • DJango, Leaftlet, Python, Android, Qgis, Open Street Maps In the interaction of application with the user two main algorithms are used, one for the generation of routes in which the criteria are the following: Mode of transport (car, public transport, pedestrian and bicycle), Travel Distance, Travel time, Number of transport mode changes (transshipments) The second algorithm is the pairing algorithm, the proposed criteria are as follows: Closest existing alternative routes, Distance to the origin of the alternative route, Distance to alternate route destination, Pairing timeout. The main platform is a GIS platform (geographic information systems) in which thematic layers will be built to a dynamic transport model in which dynamic routes and multimodal routes can be obtained. The UNAM's own mobility infrastructure is integrated into the Open Street Maps topology such as PUMAbus, cycle paths and PUMAbici Parking. The modes of transport included in the model and the joint transport topology are: Car, Public Transport (metro, metrobus, electric and buses), Pedestrian, Bicycle. The possible combinations for multimodal routes are: Auto-Bike, Public Transportation-Pedestrian, Pedestrian-Bicycle, Bicycle-Public Transport. The layers that compose the transport models and that allows the implementation of algorithms of routes are the following: • Roads (streets, pedestrian walkways, pedestrian bridges), cycle paths (including CU), Metro lines, Metrobus Lines, Metro stations, Metrobús stations, Electrical transportation, Collective transport lines, Collective transportation stops, Pumabus routes, Pumabus stops, PUMA bike modules, Points of interest (location of schools, institutes and infrastructure). Another important part of the application is the "CHAT" module through which users can interact to agree on places and times to carry out shared trips. This module allows the functionality to add, remove or block other users as well as manage the application history of each application.

Bernardo Monechi, Riccardo Di Clemente, Pietro Gravino and Vito Servedio

Modelling delay dynamics on railway networks

SPEAKER: Bernardo Monechi

ABSTRACT. Railways are a key infrastructure for any modern country, so that their state of development has even been used as a significant indicator of a country's economic advancement. Moreover, their importance has been growing in the last decades either because of the growing railway traffic and to governments investments, aiming at exploiting railways in order to reduce CO2 emissions and hence global warming. To the present day, many extreme events (i.e. major disruptions and large delays compromising the correct functioning of the system) occurs on a daily basis. However these phenomena have been approached, so far, from a transportation engineering point of view while a general theoretical understanding is still lacking. A better comprehension of these critical situation from a theoretical point of view could be undoubtedly useful in order to improve traffic handling policies. In this paper, we shall focus on the study of railway dynamics, addressing in particular the inefficiencies caused by delays of trains and their spreading dynamics throughout the network. {Research on delays and their dynamics in not anew. In (fleurquin 2013 systemic, campanelli 2014 modeling) the diffusion of delays in the Air Transport Network among different flights has been studied and modeled in the US and in the European Union, while in the railway transport system, a Rail Traffic Controller model has been used to asses the different factors contributing to the delay of a specific train, and a model aiming at predicting the positive delay in urban trains has been developed in (higgins 1998 modeling).

Here, we propose a novel approach by considering delay spreading as a proxy of contagion phenomena in a network of interacting individuals, which in our case are represented by trains diffusing over a railway network. This interpretation allows for the application of conceptual schemes and methodologies that have already been proved as fruitful in the study of epidemic spreading. We applied these tools to scheduled and real train timetables for Italy and Germany, which display some of the most dense railroad networks in Europe. We gathered these datasets through data-mining procedures by relying on official public APIs that constantly monitor the current situation of trains in the whole networks. We analysed the static network of stations and then dealt with the dynamics of real trains in order to unravel the mechanism of delay transmission from station to station, train to train, and its effects on the macro scale. We measured the delay distributions and cluster size of delayed trains, to give explicit and quantitative account of the effects of delays on the overall system performance. Finally, we conceived a simple model to simulate the delay spreading dynamics on real schedules and provided evidence for its accuracy and stability in terms of its forecasting features. By determining the criticalities in the network, we could identify major delay spreaders whose behavior crucially decreases the global performances of the railway transportation networks.

Roberto Ponce Lopez and *Joseph Ferreira Jr*

A Measurement of the Scale of Activity in Places with a High Proportion of Non-Work Destination Trips

SPEAKER: *Roberto Ponce Lopez*

ABSTRACT. This paper identifies places that concentrate a large proportion of non-work trips in Singapore, and then characterizes and classifies them according to their physical and social attributes. A more precise characterizations of non-work destinations is needed to improve activity based transportation models and the specification of travelers' choice sets.

Singapore is a transit oriented highly dense urban area. Over the last years, the city has been shifting towards a polycentric structure. Today, most places are accessible by transit; jobs cluster around various centers; mixed commercial and residential areas are common; while residential economic and ethnic segregation has been kept low. This spatial configuration impacts on people´s choices about non-work and non-residential destinations. For instance, people from a range of lifestyles find it accessible to congregate around popular non-work destinations, even if they are not always nearby home and work locations.

Methodologically, the problem lies in that non-work leisure destinations exhibit different temporal and spatial scales. As a result, the types of activities that take place, and the kinds of visitors whom they attract, tend to cluster at different spatio-temporal scales. For instance, a peak of activity might occur from 7 to 10 pm in one place, but 4-6:30 pm in another. Likewise, the peak of activity could encompass a one-block shopping mall, or a 2-kilometer long commercial and retail strip. Additionally, the distribution of human activity over a non-work destination does not distribute uniformly across such spatio-temporal scales. Nested sub-clusters are identifiable only at a finer scale of observation. The composition of sub-clusters inside a non-work destination adds another dimension to questions about social mixing and shared activities. The methodology has six parts. First, a spatial-temporal algorithm of pattern detection identifies about 120 patches in the city using cellphone data from SpotRank. The algorithm draws geographic and temporal boundaries for each cluster. Second, a transportation survey validates place selection and boundaries, ensuring that clusters contain a major portion of leisure destinations in the sample. Third, geographical data scrapped from Google Places API characterizes commercial activity within clusters (e.g. shopping malls, mix of establishments, among others). Fifth, analysis of scrapped data, combined with a synthetic population and basemaps, identifies and characterizes sub-patches within of each cluster. Finally, a k-means algorithm is used to classify the clusters, in order to develop a typology of non-work destinations that accounts for variations in spatial-temporal scales, sub-cluster structure, and activity mix.

Our study shows that there is rich variation in the spatial and temporal scales of non-work destinations, as well as their internal distribution and mix of activities. This difference brings us some clues about the lifestyles, income groups, and activities that these places seek to attract. The evidence also suggests that transportation surveys need an even finer level of geographical detail to characterize appropriately the activity patterns that occur at heterogeneous, popular non-work destinations in highly dense and mixed areas.

Alberto Aleta, *Sandro Meloni* and *Yamir Moreno*

A Multilayer perspective for the analysis of urban transportation systems

SPEAKER: *Alberto Aleta*

ABSTRACT. Public urban mobility systems are composed by several transportation modes connected together. Most studies in urban mobility and planning often ignore the multi-layer nature of transportation systems considering only aggregated versions of this complex scenario. It is easy to find very recent studies that rely on a complex notation to incorporate multiple modes or time, or that simply aggregate the whole network losing information regarding transfer times. The few previous studies on urban transportation systems as multiplex networks focus on addressing their multimodal nature, considering each layer as a transportation mode. Although useful for several purposes, this representation totally neglects transfer and waiting times, or requires complex notation to be able to incorporate them.

In this work we present a model for the representation of the transportation system of an entire city as a multiplex network in which each line is a layer. We will then see how we can group these layers according to the transportation mode they belong to, in a sort of superlayer, to recover the results of previous to studies. Using these two different perspectives, one in which each line is a layer and one in which lines of the same transportation mode are grouped together, we study the interconnected structure of 9 different cities in Europe ranging from small towns to mega-cities like London and Berlin. In particular, we will show that modifying slightly the definition of interdependency of a multiplex network we can proof that metro networks naturally speed up the system even without taking into account their greater average velocity or carrying capacity.

Finally, for the city of Zaragoza in Spain, we will add some publicly available data (in particular, data about service schedule and waiting times) to our model. This will allow us to create a simple yet realistic model for urban mobility able to reproduce real-world facts and to test for network improvements.

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Juste Raimbault

Modeling the Co-evolution of Urban Form and Transportation Networks

SPEAKER: *Juste Raimbault*

ABSTRACT. Urban settlements and transportation networks are widely admitted to be co-evolving in the thematic and empirical studies of territorial systems. However, modeling approaches of such dynamical interactions between networks and territories are less developed. We propose to study this issue at an intermediate scale, focusing on morphological and functional properties of the territorial system in a stylized way. We introduce a stochastic dynamical model of urban morphogenesis that couples the evolution of population density within grid cells with a growing road network. With an overall fixed growth rate, new population aggregate preferentially to a potential for which parameters control the dependance to various explicative variables, namely local density, distance to the network, centrality measures within the network and generalized accessibility. A continuous diffusion of population completes the aggregation to translate repulsion processes generally due to congestion. Because of the different time scales of evolution for urban scape and networks, the network grows at fixed time steps, with rules that can be switched in a multi-modeling fashion. A fixed rule ensure connectivity of newly populated patches to the existing network. Two different heuristics are then compared: one based on gravity potential breakdown for which links are created if a generalized interaction potential through a new candidate link exceeds a certain times the potential within the existing network; a second one implementing biological network growth, more precisely a slime mould model. Both are complementary since the gravity model would be more typical of planned top- down network evolution, whereas the biological model will translate bottom-up processes of network growth. The model is calibrated at the first order (indicators of urban form and network measures) and at the second order (correlations) with Eurostat population grid coupled with street network from OpenStreetMap through the following workflow: indicators (Moran index, mean distance, hierarchy, entropy for morphology, mean path length, centralities, performance for network) are computed on real areas of width 50km for all Europe (what corresponds to the typical scale of processes the model includes); parameter space of the model is explored using grid computing (with OpenMole model exploration software), from simple synthetic initial configurations (few connected punctual settlements), computing indicators on final simulated configurations; among candidate parameters for given contiguous (in space and indicator space) real areas on which correlations can be computed, the one with the closest correlation matrix computed on repetitions is chosen. We obtain a full coverage of real configurations with simulation results in a principal component plan for indicators, for which most of them a close correlation structure is found. Both network heuristics are necessary for the full coverage. The model is thus able to reproduce existing urban form and networks, but also their interaction in the sense of correlations. We furthermore study dynamical lagged correlations between normalized returns of population and network patch explicatives variables, exhibiting a large diversity of spatio-temporal causality regimes, where network can drive urban growth, the contrary, or more complex circular causalities, suggesting that the model effectively grasps the dynamical richness of interactions.

Christopher Monterola and *Bo Yang*

Developing an Effective Model for Traffic Dynamics with Realistic Driving Behaviours

SPEAKER: *Christopher Monterola*

ABSTRACT. It is of great interest, both theoretically and for practical applications, to understand via simple models the emergent behaviours of the complex systems containing a large number of interacting components. Examples like crowd dynamics, highway traffic systems, and in this particular case the urban traffic flows have attracted physicists, engineers and behavioural scientists for decades. In contrast to the traditional many-body physical systems, the traffic systems lack almost any symmetry at the microscopic level: even individual components are different from one another, with intrinsic stochasticity. There remains a lot of controversy in how to model the traffic flow properly, especially when the traffic is congested. Most, if not all, of the commercially available softwares use rather simplified interactions between vehicles, and the resulting simulations are only realistic when the traffic flow is moderate or small (so that the interactions are not so important, since the vehicles are far away from each other). To this end, we have collected and analysed more than eight months of data for the driving behaviours on the expressways in Singapore. We have shown that the data captures some of the salient features of traffic flow in the flow-density plot including the transitions from free flow to synchronized flow to wide moving jam. Further analysis of the data, allowed us to understand the specific roles played by the stochasticity among vehicles and drivers, and the extent at which we need to add stochastic terms in our traffic models from a practical point of view. In particular, we found that collective sensitivity of the drivers on their own velocity and the relative velocity is generally nonlinear and strongly dependendent on headways or gaps between moving vehicles. We use these observation to construct realistic effective models for traffic flows using renormalisation techniques and describe how such insights can be used to understand which detailed driving behaviors need to be modeled for the numerical simulations to be useful for practical implications.

Gustavo Martínez-Mekler, Alberto Darszon, Jesús Espinal-Enriquez, Adán Guerrero, Daniel Priego-Espinosa and Alejandro Aguado

Regulatory Biochemical Signaling Networks Related to Fertilization.

SPEAKER: Gustavo Martínez-Mekler

ABSTRACT. Fertilization is one of the fundamental processes of living systems. In this talk we address external marine fertilization and comment on some recent mammal studies. Our work on how sea urchin sperms swim towards the egg is based on experiments which have shown that fallegella [Ca2+] concentration, triggered by the binding of chemicals from the oocyte surroundings, modify sperm navigation and in some cases produce chemotaxis - transport guided by chemical gradients. For a better understanding of this process, we have constructed a family of logical regulatory networks for the [Ca2+] signaling pathway [1,2,3,4,5]. These discrete models reproduce electrophysiological behaviors previously observed and have provided predictions, some of which we have confirmed within our research group with new experiments, as shown in a couple of videos. We have gained insight on the operation of drugs that modify the calcium fluctuation temporal behavior and hence control sperm navigation, in some cases producing disorientation [2,3]. With our theoretical studies we have been able to predict that CatSper is the dominant calcium channel [5]. This channel, related to male contraception in mammals, is a matter of intense research. Overall, our results may be relevant to fertility issues. We also present preliminary work on mammals. Our systems biology approach poses issues such as network dynamics stability, redundancy and degeneracy. The finding that the discrete network dynamics operates at a critical regime, where robustness and evolvablity coexist is a matter for reflection and may be of evolutionary interest. Taking into account the dynamics attractor landscape and criticality considerations we have implemented a network reduction method. It is encouraging to find that the outcome of this process is a network that coincides with an alternative step by step constructive continuous model.

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Jose Aguilar-Rodriguez, *Leto Peel*, *Massimo Stella*, *Andreas Wagner* and *Joshua Payne*

The architecture of an empirical genotype-phenotype map

SPEAKER: Leto Peel

ABSTRACT. Characterizing the architecture of an empirical genotype-phenotype (GP) map is an outstanding challenge in the life sciences, with implications for our understanding of evolution, development, and disease. For most biological systems, our knowledge of the corresponding GP map remains too poor to tackle this challenge. Recent advances in high-throughput technologies are bringing the study of empirical GP maps to the fore. Here, we use data from protein binding microarrays to study an empirical GP map of transcription factor (TF) binding preferences. In this map, genotypes are DNA sequences and phenotypes are the TFs that bind these sequences. We study this GP map using genotype networks, in which nodes represent genotypes with the same phenotype, and edges connect nodes if their genotypes differ by a single small mutation: either a point mutation or an indel that shifts the entire, contiguous binding site by a single base.

We describe the structure and arrangement of genotype networks within the space of all possible binding sites for 527 TFs from three eukaryotic species encompassing three kingdoms of life: animal, plant, and fungi. Specifically, we examine 190 TFs from Mus musculus, 218 TFs from Arabidopsis thaliana, and 119 TFs from Neurospora crassa. These TFs collectively represent 45 unique DNA binding domains, which can be thought of as distinct biophysical mechanisms by which TFs interact with DNA.

We show that these genotype networks have a short characteristic path length relative to the diameter, and the high clustering coefficients, indicating that genotype networks of TF binding sites tend to fall within the family of “small world” networks. The majority of the genotype networks are assortative by degree, which may result in phenotypic entrapment, where the probability of leaving a genotype network decreases over time. We also find that these networks can be partitioned in multiple meaningful ways, and ubiquitously overlap and interface with one another. We thus provide a high-resolution depiction of the architecture of an empirical GP map and discuss our findings in the context of regulatory evolution.

Marc Santolini and *Albert-László Barabási*

Dynamics without kinetics: recovering perturbation patterns of biological networks from topology

SPEAKER: *Marc Santolini*

ABSTRACT. Modern biology has been greatly impacted by the advent of high-throughput technologies, allowing to gather an unprecedented wealth of quantitative data underlying the makeup of living systems. Notably, the systematic mapping of the relationships between biochemical entities has fueled a rapid development of network biology as a suitable framework to describe disease phenotypes and drug targeting. Yet, the gap to reach a predictive dynamical modeling framework seems daunting, due in part to the limited knowledge of the kinetic parameters underlying these interactions and the difficulty to foresee their systematic measurement before long. Here, we tackle this challenge by showing that kinetic-agnostic biochemical network spreading models are sufficient to precisely recover the strength and sign of the biochemical perturbation patterns observed in 87 diverse biological models for which the underlying kinetics is known. Surprisingly, a simple distance based model achieves on average 65% accuracy. We show that this predictive power is robust to topological and kinetic parameters perturbations, and highlight key network properties that foster high recovery rate of the ground truth perturbation patterns. Finally, we validate our approach in the chemotactic pathway in bacteria by showing that the network model of perturbation spreading predicts with ~80% accuracy the directionality of gene expression and phenotype changes in knock-out and overproduction experiments. These findings show that the steady refinement of biochemical interaction networks opens avenues for precise perturbation spread modeling, with direct implications for medicine and drug development.

Jeyashree Krishnan, Andreas Schuppert and Edoardo Di Napoli

Simulations of Phase Transitions in Gene-Gene Interaction Networks

SPEAKER: Jeyashree Krishnan

ABSTRACT. A key aim of biomedical research is to systematically catalogue all genes and their interactions within a living cell. The commonly adopted approach to study such complex interacting systems, reductionism, has dominated biological research and has given in depth insights about individual cellular components and their functions such as the formative work by [1]. A theoretical framework for the global linear response of such interaction networks on low local stress has been established as well [2]. An efficient approach to calculate the large scale response features from data without explicit unraveling of the detailed network base has been developed based on a coupling of linear response theory and statistical thermodynamics [3].

However it is increasingly clear that formulations where a single biological function attributed to an individual component are not accurate since most biological characteristics arise from strong interaction of biological entities in complex networks leading to unexpected biological responses on local modes of action. Therefore a thorough understanding as well as the availability of efficient tools for analysis and simulation of the behavior of the large scale networks with these generic biological topologies is a key for further progress in a wide variety of applications in computational biology.

Here we apply a new approach, at the intersection of network biology and statistical mechanics, to study the effect of local perturbations on the phase transition profiles of an Ising model network with sensitivity analysis of real-life data. The effects of stress is modeled as external noise that could lead to irreversible phase transition. The evolution of Ising states of network show critical points of phase transitions in analogy to thermodynamics. We present results for perturbations at interaction level, for different initial conditions of the Ising states; and perturbations at the topological level, the influence of a node or link in the network phase transition.

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George Bassel and Matthew Jackson

Topological analysis of multicellular complexity in the plant hypocotyl

SPEAKER: George Bassel

ABSTRACT. Multicellularity arose as a result of adaptive advantages conferred to complex cellular assemblies. The arrangement of cells within organs endows higher-order functionality through a structure-function relationship, though the organizational properties of these multicellular configurations remains poorly understood. We investigated the topological properties of multicellular organ construction by digitally capturing global cellular interactions in the plant embryonic stem (hypocotyl), and analyzing these using network science. Cellular organization in the hypocotyl is tightly controlled both within, and across, diverse wild-type genetic backgrounds and species, indicating the presence of developmental canalization at the level of global multicellular configurations with this organ. By analyzing cellular patterns in genetic patterning mutants, the quantitative contribution of gene activity towards the construction these multicellular topological features was determined. This quantitative analysis of global cellular patterning reveals how multicellular communities are structured in plant hypocotyls, and the principles of each optimized and possible cellular complexity in organ design.

Eugenio Azpeitia, Stalin Muñoz, Daniel Gonzalez-Tokman, Mariana Esther Martinez-Sanchez, Nathan Weinstein, Aurelien Naldi, Elena Alvarez-Buylla, David A. Rosenblueth and Luis Mendoza

The role of multiple feedback circuits in the regulation of the size and number of attractors in Boolean networks

SPEAKER: Eugenio Azpeitia

ABSTRACT. The study of gene regulation has demonstrated that genes and their products form intricate networks of regulatory interactions. Previous works reported the presence of statistically over-represented regulatory structures, or motifs, within gene regulatory networks. Such over-representation suggests that motifs have important functions in gene regulatory networks. In particular, it has been demonstrated that positive and negative feedback circuits are necessary for the appearance of multiple and cyclic attractors, respectively. Attractors represent important meaningful properties of biological systems. In gene regulatory networks, attractors represent the gene expression patterns observed in different cell types. Despite the fact that previous studies have analyzed the importance of feedback circuits on attractors, it is still not clear how multiple interconnected feedback circuits regulate the number and size of the attractors. Consequently, studying how the number and size of the attractors is determined in networks containing multiple feedback circuits is fundamental for a more general understanding of gene regulatory networks, which generally.

In this work, we study the effect of multiple feedback circuits over the size and number of attractors. In order to do this we build pathway-like networks. Pathways-like networks are networks that contain a lineal structure of regulatory interactions with some additional interactions that create feedback circuits. We use a Boolean formalism and computational tools to analyze the size and number of attractors of millions of pathway-like networks with 3 and 5 nodes. Then, we characterize each feedback circuit by its sign and functional cardinality (i.e., the network states where a feedback has an effect over the network dynamics), which is an extension of previous definitions of circuits' functionality (Thomas and Kauffman, Chaos, 2001). Later, we define the coupling between multiple feedback circuits as the set of signs and functional cardinality of all feedback circuits contained in a network. We find that the particular way in which feedback circuits couple largely determines both the number and size of the attractors. Importantly, we observe that networks with different structures that share the same feedback circuits coupling, in general produce the same number and size of attractors, while networks with the same structure, but different feedback circuits coupling can produce a different number and size of attractors. These findings suggest that inference of gene regulatory interactions by traditional methods, such as epistasis analysis, are limited, as they cannot distinguish between different networks that produce the same result, neither between different networks with the same structure that produce different results. Our study hence shows, that the characterization of feedback circuits in a regulatory network, combined with the network dynamics and structure, allows for a better characterization of regulatory structures.

Giovanni Petri, Francesco Vaccarino, Petra Ritter and Demian Battaglia

Conserved homological cores of structural and functional brain networks across age

SPEAKER: Giovanni Petri

ABSTRACT. We analyse the homological structure of the structural and functional connectivity of the human brain [1]. Persistent homology [2,3], a technique in topological data analysis, captures multiscale high-order patterns (in the form of simplicial complexes, panel (a)) in structural and functional con- nectomes [4,5]. In this contribution, we show evidence that the brain's algebraic topological struc- ture is in large part conserved over time at the expenses of its geometry. To do this, we analyse the persistent homology properties of brain structural and functional networks and their evolution in a cohort of 50 healthy patient across the age range 18-80. We find that structural connectomes display mild global topological changes with age (panel (b)): against a general reduction in overall connectivity, the brain regions of structural disconnection tend to reinforce their boundaries, intuitively akin to a sponge drying over time. On the contrary, functional connectomes do not show any large-scale homological change with age (panel (c)). We find that this overall topological conservation is obtained by a reorganization of the localization of homological features (geometry): the connectomes' homological scaffolds [7], surrogate networks that summarise the connectomes' homological information, show a backbone of links that are shared across age groups with distinct weight modulations related to ageing (panels (d) and (e)). While the ob- served changes in the structural connectomes are well reproduced by simple data-driven model, pointing to a natural decay based on independent fiber cell death, the same model erroneously predicts strong global changes in the functional topology, suggesting the existence of an adaptive meso-scale mechanism modulating brain functional connectivity to preserve the healthy functional topology despite the underlying structural changes.

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Carla Ng

Linking Human Health to Planetary Boundaries for Chemical Pollution

SPEAKER: Carla Ng

ABSTRACT. In their seminal work on a Safe Operating Space for Humanity, Rökstrom et al. (2009) introduce the concept of planetary boundaries (PB). These scientifically based limits on human perturbation to nine essential earth system processes – climate; biodiversity; nitrogen and phosphorus cycles; stratospheric ozone; ocean acidification; global freshwater use; land use; chemical pollution; and atmospheric aerosol loading – are proposed to ensure the sustainability of a hospitable world for future human populations. Key to defining this safe operating space is identifying appropriate control variables and system boundaries. Examples of control variables are atmospheric CO2 concentration for climate change, and area of forested land as a percentage of original forest cover for land-use change, with corresponding values for associated PBs set at 350 ppm and 75%, respectively. Defining measurable control variables and boundaries, even in the face uncertainty, allows for prioritization and development of concrete policy proposals. For chemical pollution, however, control variables and boundaries remain undefined.

Other groups have offered responses to the PB framework from the perspective of environmental chemistry. Diamond et al. (2015) submit that defining a PB for chemical pollution requires describing and quantifying the impact of an anthropogenic stressor on all ecosystems as a function of a measurable control variable related to a measurable response variable. Yet challenges persist, due to the high number and poorly identified mixtures of chemicals to which all organisms are currently exposed, our lack of knowledge regarding the toxic effect of complex mixtures, especially in the long term, and the difficulty of controlling exposure given the multitude of fate and transformation processes that occur between emissions and exposure. Persson and colleagues (2013) suggest a hazard-based approach, which takes into account the inherent properties of a chemical and is therefore independent of exposure, can facilitate action in the face of uncertainty. However this fails to address complex mixtures, and the authors acknowledge the difficulty of foreseeing potential unwanted earth system effects about which we are ignorant.

Here I propose a focus on two human health endpoints as directly observable and measurable effect variables for this particularly wicked PB, through which we might identify useful control variables: human fertility rates and the incidence of childhood disease. Recent work has revealed a dramatic decline in male fertility and increasing incidence of childhood disease, both linked to environmental pollution. Based on these response variables, I explore evidence that such a boundary for chemical pollution exists, and how control variables to limit the impact of environmental pollution could be defined. Based on concepts from resilience and the study of tipping points in ecological and social systems, can we identify thresholds for chemical burdens in populations? Must these thresholds be defined independently for each chemical considered, or are there ways to define broader (and perhaps less uncertain) classes of chemical pollution? Finally, how can these thresholds help us to motivate the most impactful and attainable policy or behavioral interventions to reduce exposures in the most impactful way?

Leila Niamir, Tatiana Filatova, Alexey Voinov and Hans Bressers

Household Energy Use and Behavior Change Tracking Framework: From Data to Simulation

SPEAKER: Leila Niamir

ABSTRACT. Climate is changing and its adverse impacts are felt worldwide. The greenhouse gas emissions from human activities are driving climate change and continue to rise. Consumers are one of the main drivers of energy transition. The distributed nature of renewables, the increasingly competitive costs of renewable technologies, and new developments in smart grids and smart homes make it possible for energy consumers to become active players on this market (EU, 2017). However, quantifying aggregated impacts on behavioral changes is a challenging task. Often behavioral shifts among households are modelled very rudimentary assuming a representative consumer (group), rational optimization choices and instantly equilibrating markets. The growing body of empirical literature in social sciences indicates complex behavioral processes among household who consider changes in their energy consumption and related investments. There is a number of barriers and drivers, which could trigger households to make a decision and change their behavior, for example regarding their energy use. In particular, a large body of empirical studies in psychology and behavioral economics shows that consumer choices and actions often deviate from these assumptions of rationality, and there are certain persistence biases in human decision making, which lead them to have different behavior. We did an extensive literature review of relevant theories in psychology (environmental psychology specifically) to identify theoretical basis for these barriers and drivers as well as existing empirical evidence. In this paper we aim to quantify and assess impacts that behavioral changes of households may have on the cumulative energy use and emission reduction. Towards this end, we run a comprehensive survey among households and combine it with agent-based modeling techniques. Our survey carried out in the Netherlands and Spain in 2016 is rooted in psychology theories that allow us to elicit behavioral and cognitive factors in households' decision making in addition to traditional economic factors. The survey is designed to elicit the factors and stages of a behavioral process with respect to the three types of energy-related actions households typically make: (1) invest in an energy saving equipment, (2) energy conservation due to a change in energy consumption habits, and (3) switching to another energy source. To reach to any of these decisions a household is assumed to follow the three main steps: knowledge activation, motivation, and consideration. At each step, several psychological factors, economical, socio-demographic, social, and structural and physical drivers and barriers are considered and estimated. In parallel, we develop an agent-based BENCH model grounded in the Norm Activation Theory and the survey data. BENCH was designed to integrate behavioral aspects into a standard economic decision of an individual regarding household energy use and to study the cumulative impacts of these behavioral changes at a regional level as well as dynamics of these changes over time and space. BENCH is parameterized based on the survey run in the Netherlands (N=1000 households). We run the empirical BENCH model for a period of 2016-2050 under different behavioral assumptions and two shared socioeconomic pathway (SSP) scenarios (business as usual and high technology cost).

Asim Zia, Andrew Schroth, Patrick J. Clemins, Christopher Koliba, Arne Bomblies and Brian Beckage

Understanding Lags, Thresholds and Cross Scale Dynamics in Social Ecological Systems: Cascading Impacts of Climate and Land Use Adaptation on Missisiquoi Bay

SPEAKER: Asim Zia

ABSTRACT. While a growing amount of modeling and experimental research in sustainability science and environmental sciences has identified the importance of understanding cross-scale dynamics, many issues about modeling cascades of lags, inertia and thresholds (phase transitions) in coupled natural and human systems remain unresolved. Situated in Social Ecological Systems (SES) theoretical and empirical framework, this paper addresses the following question: How do lags, inertia and thresholds (phase transitions) affect the evolution of state variables in SES that interact across multiple scales of space and time? We investigate this question in the context of modeling the cascading impacts of global climate change and land use land cover change (LULCC) on coupled riverine and lake system of the Missisquoi Watershed and its bay for 2000-2100 timeframe. The Missisquoi River at Swanton is a 2,200 km2 watershed within the Vermont and Québec portions of the Lake Champlain basin. A monitoring stream flow data record (1990-present) is available for the watershed outlet and long term monitoring record of water quality in the bay is available since 1992. We developed a novel Integrated Assessment Model (IAM) framework to explore cross-scale interactions in a coupled natural human system to uncover quantitative thresholds (phase transitions) of the interacting climate and land-use system which drive water quality in Missisquoi Bay over the 2000-2100 timeframe. To construct the IAM, first statistical downscaling, bias correction, and topographic downscaling of 4 GCMs for three representative concentration pathways (RCPs) was used to generate an ensemble of 12 future climate simulations of daily temperature and precipitation at 30 arc second (approximately 0.8km x 0.8km) resolution for the study site. In parallel, an LULCC agent based model (ABM) operating at the landowner parcel scale was developed to generate four extreme 30m x 30m land-use change scenarios for the Missisquoi watershed representing outcomes of different land-use adaptation policies; these scenarios are called business as usual, pro-forest, pro-agriculture and pro-urbanization. Both the 12 downscaled climate change scenarios and 4 LULCC forecast scenarios (total 48 scenarios) were used to drive a distributed hydrological model (RHESSys) to generate daily time-scale forecasts of hydrological discharges and nutrient flows from the Missisquoi River into Missiquoi Bay of the Lake Champlain. The bay is simulated by a 3D coupled system of biogeochemical and hydrodynamic lake models. The model interactions in IAM are transformed into an abstract computational workflow using the Pegasus Workflow Management System. We find that the best-case land use adaptation scenario through maximum amount of forest conservation in the watershed may not be able to avoid a phase transition of Missisquoi bay from currently eutrophic to hyper-eutrophic state under the worst-case global climate change scenario. We also find that under worst-case greenhouse gas emissions scenario [RCP85], the likelihood of algal blooms in the shallow bay will slowly expand to early summer and late fall months irrespective of the land use adaptation scenario. This study highlights the sustainability challenges that arise due to lags, inertia and phase transitions in smaller scale SES due to cascading effects from large scale SES.

Neo Martinez and Fernanda Valdovinos

Sustaining Economic Exploitation of Complex Ecosystems in Computational Models of Coupled Human-Natural Networks

SPEAKER: Neo Martinez

ABSTRACT. Sustaining socio-ecosystems requires balancing ecological and economic mechanisms that structure and drive the dynamics of these complex systems. This is particularly true of fisheries, the global collapse of which attests to profound imbalance among these mechanisms. Such lack of sustainability is at least partly due to insufficient understanding of the complexity and nonlinear dynamics of these socio-ecological systems. We have developed a multilayer network approach to mechanistically model the consumer-resource and supply-demand interactions amongst many ecological species and economic activities within fisheries. This approach integrates “allometric trophic network” models of ecological interactions and “resource economic” models of yield, profit and loss. Both models have successfully predicted the dynamics of particular systems. For example, resource economic models greatly aid the successful management of ecologically simple “donor-controlled” systems (e.g., forests and crab fisheries) whose target species critically depend on supply rates of resources (e.g., rain or detritus) that are largely determined by factors other than the target species themselves. In contrast, these models have failed, often spectacularly, in more complex ecosystems such as fisheries based on exploiting species at higher on the food chain that greatly affect the supply of their prey below them. Our socio-ecological models of the exploitation of fish higher in food chains express a spectrum of dynamics from low profit regimes of collapsed fisheries with few fish to high profit regimes of thriving fisheries with many fishes. Compared to classic socio-ecological models of “maximum sustainable yield” from vigorous exploitation of moderately abundant fish, our findings show higher profit at lower exploitation rates of more abundant fish. More dramatically, target fish go extinct at the vigorous exploitation that the classic models suggest yield maximum profit. The parameters, such as cost of fishing effort, that determine a system’s dynamic regime are relatively easy for policies to influence in order to sustain productive fishery dynamics. Such policies can subsequently leverage other, less controllable market mechanisms (e.g., supply and demand) to achieve sustainability. Additionally, highly counterintuitive dynamics known as the “hydra-effect” (where increasing exploitation increases, rather than decreases, fish stock) are observed. Key to the significance of these findings is that they occur within empirically realistic parameter spaces including growth, feeding and fishing rates as well as the structure of and dynamics of ecological networks and the role of humans within these networks. More broadly, our findings help increase our understanding of critically important socioecosystems while informing management strategies that help sustain and optimize of fisheries and other complex ecological networks exploited for economic gain.

Christopher Koliba, *Asim Zia* and *Scott Merrill*

Utilization of Computer Simulation and Serious Games to Inform Livestock Biosecurity Policy and Governance

SPEAKER: *Christopher Koliba*

ABSTRACT. This work presents novel approaches to integrating experimental gaming data into agent-based models of spatially explicit social ecological systems. The integration of behavioral science and computer science into the strategic, tactical and operational decision making of public, private and nonprofit managers has taken on increased attention in recent years. The uses of experimental, “serious” games and computer simulation models to describe, evaluate and inform changes in complex governance systems remain in their nascent stages, despite the long standing use of simulations to generate scenarios in business and military settings, and more recent interests in applying behavioral science approaches to “nudge” citizen utilization of government services. Drawing on an example of the computer simulation and gamification of portions of the United States’ pork industry, the authors in this paper ask and answer: How are simulations and games being used to identify vulnerabilities in the nation’s pork supply and what incentives can be pursued to bring greater biosecurity? How are stakeholders being partnered with in the design and use of simulation and gaming results to inform policy making and governance design?

This paper provides an overview of the empirically calibrated, spatially explicit agent based model of the pork industry within three regions of the United States. Details of a serious game developed to study how the use of information about biosecurity threat and biosecurity best management practice adoption of members of a network informs the propensity to adopt best management practice are provided, as well as details of a second game designed to study the use of messaging and incentives to ensure compliance of biosecurity measures at the farm level. Details of the integration of game results into the ABM are provided. This paper also explores how cutting edge applications of computer simulation and gamification have been processed in a series of stakeholder workshops of service providers, industry regulators, and street level producers. Tuning, strategic and operation implications, and new scenario and treatment protocols designed to link model and gaming outputs to policy and governance initiative for the livestock production chains are shared.

Laura Schmitt Olabisi and Saweda Liverpool-Tasie

Participatory Modeling of the Systemic Impacts of Climate Change on Grain Production in Nigeria

SPEAKER: Laura Schmitt Olabisi

ABSTRACT. The impacts of climate change on the agricultural sector in Nigeria going forward are expected to be severe, but so far there is a dearth of systemic analysis of how these impacts would develop over time, or how they would interact with other drivers impacting Nigerian agriculture. Moreover, there is a gap between the experience of farmers and policy-makers on the ground who are witnessing multiple aspects of climate change impacts in a highly localized context, and scientific reports which tend to be highly technical and general. Participatory modeling efforts could contribute to adaptation efforts by identifying policy mechanisms that serve as system 'levers' to effect change given the considerable uncertainty associated with both the socio-economic and ecological aspects of climate change. They could also bring together scientific information with locally contextual information on the direct and indirect impacts of climate change on complex agricultural systems. This study provides a systemic analysis of the impact of climate change on agricultural production in Nigeria using a participatory research method. We convened a workshop of key stakeholders with diverse and in-depth knowledge of Nigerian agriculture in Ibadan, Nigeria, in June, 2016. Using a causal loop diagramming (CLD) technique, we grouped these stakeholders by region and led them through an exercise in which they drew diagrams depicting impacts of climate change on Nigerian agricultural development. CLD is a method used in system dynamics modeling, and it is effective for identifying causal relationships between variables as well as feedback mechanisms. As expected, there were interesting differences across the 6 geopolitical zones of Nigeria reflecting their agro ecological differences. However, all groups identified both direct and indirect impacts of climate change on agricultural productivity, including heat, drought, flooding, pest and disease outbreaks, and climate-induced migration leading to conflict between pastoralists and farmers. Initial quantitative modeling results based on the CLDs demonstrate an impact of climate change on maize production in Nigeria that is consistent with other regional forecasts. We argue that this type of model, because it was constructed in a manner that is relevant and accessible to decision-makers, is highly useful for policy-making under complexity and uncertainty.

David Wolpert and Artemy Kolchinsky

Novel thermodynamic properties of computational processes

SPEAKER: David Wolpert

ABSTRACT. Recent breakthroughs in nonequilibrium statistical physics provide powerful tools for analyzing far-from-equilibrium processes. These tools have done much to clarify the relationship between thermodynamics and information processing. In particular, they have been used to formalize and then extend Landauer's pioneering work on the thermodynamics of the simplest kind of computation, bit erasure.

However despite our understanding of the thermodynamics of computation in the full sense, extending beyond simple bit erasure, is its infancy, and a great number of foundational open question remain. Here we present our preliminary investigations of three such questions, using the recently developed tools of nonequilibrium statistical physics.

First, for a physical process to be thermodynamically reversible it must be in thermal equilibrium at all but a countable number of instants. We show that this means that there are some computations that cannot be implemented in a thermodynamically reversible process, unless some additional "auxiliary" states are available to the process, in addition to the ones specifying the input/output map of the computation. For example, we show that no physical process over only N states can permute those states without dissipating work – however if the process has access to just a single extra, buffer state, then there is no such difficulty. We also investigate the broader issue of how many such additional auxiliary states are required to implement a given computation thermodynamically reversibly, both for deterministic and stochastic computations. We then use this analysis to motivate a physically-inspired measure of the complexity of a computation.

Second, we consider implementing computations with logic circuits, i.e., by networks of gates, each with a limited fan-in. In general, many different circuits can be used to implement the same computation. We show that the precise circuit used to implement a given computation affects the minimal work required to run the computation, and also affects the amount of work that is dissipated by running the computation. We also relate these minimal work requirements to information-theoretic measures of the complexity of the computation's input and output distributions.

Finally, we analyze the thermodynamic properties of any physical process that implements a Turing machine. The shortest input program p to a given Turing machine that causes the machine to compute a desired output string v – the Kolmogorov complexity of v – can be arbitrarily large. However we show that the smallest amount of thermodynamic work required to run the Turing machine on some input program that computes v has a finite upper bound, independent of the output. On the other hand, the average over all input programs (not just optimal ones) of the amount of thermodynamic work used by the Turing machine is infinite.

Daniel Maria Busiello, Jorge Hidalgo Aguilera and Amos Maritan

Entropy production for coarse-grained dynamics

SPEAKER: Daniel Maria Busiello

ABSTRACT. Countless works in the literature have investigated how coarse-graining influences our prediction of the physical properties of a system. In systems out of equilibrium, it is still unclear what is the role of the entropy production, and for systems described by a Master Equation, it can be estimated using Schnakenberg's formula. On the other hand, some years ago Seifert derived an analogous formula for dynamics described by a Fokker-Planck equation. In this work, we aim at connecting both formulations, and starting from a Master-Equation system we calculate how Schnackenberg's entropy production is influenced by coarse-graining. We show that such a value can be reduced to the Seifert's formula for some simple choices of the dynamics, but, surprisingly enough, we demonstrate that, in general, microscopic fluxes circulating in the system can give a macroscopic contribution to the entropy production. In consequence, neglecting information leads to an underestimation of the entropy production, and only a lower bound can be provided when the dynamics is coarse-grained.

Dániel Czégel and *Sámuel Balogh*

Asymptotic equivalence between generalized entropies' phase space volume scaling and anomalous diffusion scaling of the corresponding Fokker-Planck equation

SPEAKER: *Dániel Czégel*

ABSTRACT. A way to characterize non-ergodic and non-markovian stochastic processes is through generalized entropy functionals corresponding to their stationary distributions. These generalized entropies can be classified based on their asymptotic phase space volume scaling, which provides a classification of the processes themselves according to their stationary behavior. On the other hand, these processes can also be classified according to their anomalous diffusion scaling describing their non-stationary behavior. Here we show that if the dynamics is governed by a nonlinear Fokker-Planck equation consistent with the generalized entropy describing the stationary behavior of the process, the anomalous diffusion scaling exponent of the process and the entropy's phase space scaling exponent bijectively determine each other asymptotically at large times/volumes. This implies that these basic measures characterizing the stationary and the non-stationary behavior of the process provide the same information in the asymptotic regime.

Alec Boyd, *Dibyendu Mandal* and *James Crutchfield*

Leveraging Environmental Correlations: The Thermodynamics of Requisite Variety

SPEAKER: Alec Boyd

ABSTRACT. Key to biological success, the requisite variety that confronts an adaptive organism is the set of detectable, accessible, and controllable states in its environment. We analyze its role in the thermodynamic functioning of information ratchets a form of autonomous Maxwellian Demon capable of exploiting fluctuations in an external information reservoir to harvest useful work from a thermal bath. This establishes a quantitative paradigm for understanding how adaptive agents leverage structured thermal environments for their own thermodynamic benefit. General ratchets behave as memoryful communication channels, interacting with their environment sequentially and storing results to an output. The bulk of thermal ratchets analyzed to date, however, assume simple memoryless environments that generate input signals without temporal correlations. Employing computational mechanics and a new information-processing Second Law of Thermodynamics (IPSL) we remove these restrictions, analyzing general finite-state ratchets interacting with statistically complex structured environments that generate correlated input signals. On the one hand, we demonstrate that a ratchet need not have memory to exploit a temporally uncorrelated environment. On the other, and more appropriate to biological adaptation, we show that a ratchet must have memory to most effectively leverage complex structure in its environment. The lesson is that to optimally harvest work a ratchet¹s memory must reflect the input generator's memory.

Esteban Guevara Hidalgo

Infinite-Time and -Size Limit of the Large Deviation Function Estimator

SPEAKER: *Esteban Guevara Hidalgo*

ABSTRACT. Population dynamics provide a numerical tool allowing the study of rare trajectories of stochastic systems, by means of simulating a large number of copies of the system, which are subjected to a selection rule that favors the rare trajectories of interest. Such algorithms are plagued by finite simulation time- and finite population size- effects that can render their use delicate. We present a numerical approach which uses the finite-time and finite-size scalings of estimators of the large deviation functions associated to the distribution of rare trajectories in order to extract its infinite-time and infinite-size limit.

Pablo Carlos López, *Andrés Garcia* and *Gilberto Sanchez*

Non equilibrium stationary states of a dissipative kicked linear chain of spins

SPEAKER: *Pablo Carlos López*

ABSTRACT. We consider a linear chain made of spins of one half in contact with a dissipative environment for which periodic delta-kicks are applied to the qubits of the linear chain in two different configurations: kicks applied to a single qubit and simultaneous kicks applied to two qubits of the linear chain. In both cases the system reaches a non-equilibrium stationary condition in the long time limit. We study the transient to the quasi stationary states and their properties as function of the kick parameters in the single kicked qubit case and report the emergence of stationary entanglement between the kicked qubits when simultaneous kicks are applied. For doing our study we have derived an approximation to a master equation which serves us to analyze the effects of a finite temperature and the zero temperature environment.

Klaus Jaffe

The Roots of Synergy

SPEAKER: *Klaus Jaffe*

ABSTRACT. Synergy, emerges from synchronized reciprocal positive feedback loops between a network of diverse actors. For this process to proceed, compatible information from different sources synchronically coordinates the actions of the actors resulting in a nonlinear increase in the useful work or potential energy the system can manage. In contrast noise is produced when incompatible information is mixed. This synergy produced from the coordination of different agents achieves non-linear gains in energy and/or information that are greater than the sum of the parts. The final product of new synergies is an increase in individual autonomy of an organism that achieves increased emancipation from the environment with increases in productivity, efficiency, capacity for flexibility, self-regulation and self-control of behavior through a synchronized division of ever more specialized labor. Synergistic is the interdisciplinary science explaining the formation and self-organization of patterns and structures in partially open systems far from thermodynamic equilibrium. Understanding the mechanisms that produce synergy helps to increase success rates in everyday life, in business, in science, in economics and in increasing, yet to named areas. A mechanism discovered by biological evolution favoring the achievement of synergy in addition to division of labor is assortation: the combination of similar or compatible agents or information, to reduce the chances of noisy mismatches. Empirical evidence in many domains show that assortative information matching increases the probability of achieving synergy. This mechanism is so fundamental and unique that it has emerged as a product of ongoing biological evolution of sexual reproduction among living organisms. The roots of synergy are the features of that promote an increase the information content or negentropy of the system, and its power to produce useful work.

Conor Finn, Mikhail Prokopenko and Joseph Lizier

Local Information Decomposition Using the Specificity and Ambiguity Lattices

SPEAKER: Conor Finn

ABSTRACT. The recently proposed Partial Information Decomposition (PID) of Williams and Beers provides a general framework for decomposing the information provided by a set of source variables about a target variable. For example, the information provided by a pair of sources decomposes into the following Partial Information (PI) terms: the unique information provided each source; the shared or redundant information provided by either of the sources; and the complementary or synergistic information only attainable through simultaneous knowledge of both sources. In general, PID induces a lattice over sets of sources, providing a structured decomposition of multivariate information. Although PID fixes the structure of the decomposition, it does not uniquely specify the value of each PI term: for this one must separately define a measure of one of the PI terms in the decomposition.

To date, no satisfactory definition exists for the general case of an arbitrary number of variables. All currently proposed approaches suffer from at least one of the following crippling problems: (a) the resulting measure of shared information does not capture the “same information” about specific target realisations (events) but rather only the “same amount of information” about the target variable; (b) the measure is only consistent for the bivariate case (two source variables); or (c) the measure does not provide local or pointwise measures of the PI terms for specific realisations of the target and source variables.

We propose a new approach to multivariate information decomposition based upon PID, but which is distinct in several ways. In our approach the local information is the primary citizen—we seek to decompose local information into local PI terms. We also reveal the two orthogonal types of information that individual local source realisations can provide about a local target realisation, i.e. being either positive or negative information (or indeed both at the same time). This perspective enables us to rigorously define when sources carry the “same information” as opposed to merely the “same amount of information”. The framework of PID can then be applied separately to each of these two types of information, providing a lattice over each—namely the specificity and ambiguity lattices. Just as in PID, this fixes the structure of the information decomposition (on each lattice) but does not uniquely define the value of the PI terms.

To achieve uniqueness, we define a local measure of redundancy (on both lattices), and justify how it captures the “same information” by respecting both the locality and the type of information. This local redundancy measure is then used to uniquely define all local PI terms on both the specificity and ambiguity lattices. Crucially, this information decomposition can be applied to arbitrarily large sets of sources, addressing a major stumbling block in this domain. We apply the decomposition to a variety of examples which provides new insights into classic examples, and demonstrate the unique ability to provide a local decomposition. Finally, interpreting these results sheds light on why defining a redundancy measure for PID has proven to be so difficult—one lattice is not enough.

Ryan James and James Crutchfield

Multivariate Dependence Beyond Shannon Information

SPEAKER: Ryan James

ABSTRACT. Accurately determining dependency structure is critical to discovering a system's causal organization. We recently showed that the transfer entropy fails in a key aspect of this---measuring information flow---due to its conflation of dyadic and polyadic relationships. We extend this observation to demonstrate that this is true of all such Shannon information measures when used to analyze multivariate dependencies. This has broad implications, particularly when employing information to express the organization and mechanisms embedded in complex systems, including the burgeoning efforts to combine complex network theory with information theory. Here, we do not suggest that any aspect of information theory is wrong. Rather, the vast majority of its informational measures are simply inadequate for determining the meaningful dependency structure within joint probability distributions. Therefore, such information measures are inadequate for discovering intrinsic causal relations. We close by discussing more nuanced methods of determining the dependency structure within a system of random variables.

Abel Camacho Guardian, Claudio J. Tessone and Rene Algesheimer

Idiosyncratic correlations and non-Gaussian distributions in network data

SPEAKER: Abel Camacho Guardian

ABSTRACT. During the last decades, complex social, economical and biological systems have been studied using agent-based models (ABM). ABM are a powerful tool to discover analytic truths at the macroscopic-level when simple rules at the agent-agent interaction level are assumed. Despite great achievements in discovering analytic truths in complex systems and a large number of large datasets. Statistical models aimed to discover factual truths in complex systems have not reached the rigorous approach of econometrics models. In this paper, we introduce a network model, power law random graph model (PRGM) formulated at the agent-agent interaction level via the concept of q-conditional independence where q can be interpreted as idiosyncratic correlations or an interaction term between well-defined social mechanisms. We show that the exponential random graph models (ERGM) are the subclass of PRGM with q = 1. Motivated by the derivation of ERGM via the Boltzmann-Shannon entropy by Park and Newman, we present a second formulation of the PRGM via Tsallis entropy. Next, we construct a subclass of PRGM, called q-Markov graph models, defined by simple dependency assumptions and that violates Gaussian approximation of the network statistics. The violation of Gaussian approximation is caused by competitive social mechanisms, and it enriches PRGM with distributions ranging from bimodal, skewed and flat. Our findings open the question What warrants Gaussian approximations used to justify factual evidence in complex systems? Finally, with the help of the subclass q-Bernoulli random graph models and using two networks datasets of friendships between students in classrooms in Switzerland and the US, we show how the idiosyncratic correlation q helps to address the problem of models placing too much probability mass around a few type of networks. Although the problem of placing too much probability is well documented in poor-fitting network models, we show that this problem is inherited from the exponential decay of rare events in ERGM, and it occurs in poor-fitting- as well as overfitting models.

Fabio Saracco, Riccardo Di Clemente, Tiziano Squartini, Mika Straka, Guido Caldarelli and Andrea Gabrielli

Entropy-based approach to the analysis of bipartite networks

SPEAKER: Fabio Saracco

ABSTRACT. Bipartite networks are ubiquitous in many different disciplines: they appear in the study of the world trade web, in social networks, in on-line retailer platform recommendation systems, in sociology and in many other fields. Nevertheless, in front of their spread presence in research, there is a general lack of proper tools for their analysis. The aim of this talk is to provide a general overview of the entropy-based approaches to the analysis. Recently the Bipartite Configuration Model (BiCM), an entropy-based null-model, provided the proper tool to reveal the non trivial information in bipartite systems. Constraining the entropy of bipartite graphs, it is possible to discount the information of the degree sequence; thus the BiCM is, at the same time, general (no hypothesis is tailored on the network analysed), unbiased (since it is entropy based) and analytical. Comparing the presence of bipartite cliques with its expectation provides major insights about the network structure: when applied to the network of trade, the BiCM reveals the presence of drastic structural changes few years before the system contagion from the world financial crisis, taking the whole system to a more random configuration. The BiCM also provides the most natural benchmark in order to avoid information losses whenever projecting a bipartite network on the layer of interest. The application of this method to a social data set of Users and Movies permits to reveal films clusters based on the audience composition (“family movies”, “underground films”, “cult movies”, and so on); in the same way, the application of our method to the network of trade, permits to uncover non trivial communities of countries, based on their technological level and cluster of wares, according to the development of their exporters. In our presentation we exhaustively review all applications of entropy-based approaches to the analysis of bipartite networks.

Fabio Saracco, Carolina Becatti, Giuseppe Trapani, Guido Caldareli, Rossana Mastrandrea and Tiziano Squartini

Beyond the limits of modularity: the pseudo-modularity bipartite community detection

SPEAKER: Fabio Saracco

ABSTRACT. Bipartite networks are ubiquitous in many disciplines [1], but despite their presence the amount of statistical tools for the analysis is really poor. To the best of our knowledge, actually just two sound community detection algorithms are present for bipartite systems [2, 3], both based on the extension of modularity [4] to bipartite networks. The approaches and the outputs of the two differ substantially. In [2] the author applies by brute force the standard modularity to bipartite networks, thus obtain- ing communities composed by nodes belonging to both layers. On the other hand, the approach of [3] is to ex- tend the null-model implemented in standard modularity [5] to bipartite networks and then discounts this information to reveal non random co-occurrences of links in the projected network on one of the two layers. In the present paper we extend the concept of modularity, substituting the (bipartite) null-model with the recently proposal extension of Exponential Random Graphs to bi- partite systems [6]. Actually, our proposal catch the main philosophy of claiming for the existence of a community once the number of intra-community link is more than the expectation, but also overcome some limits of the previous proposals. As in [3], our method returns communities of nodes belonging to the same layer by comparing the expected co-occurrences of links with the expectation from a bipartite null-model. Differently from [2, 3], our method does not have evident limit of resolution [7]. We explicitly prove that our definition satisfies almost all the properties of standard modularity [8] and we discuss the missing ones; following an approach similar to standard Louvain algorithm [9], we test our algorithm on the network of Southern Women [10], finding results that agree with the original social analysis. We face other bigger datasets, like the bipartite version of World Trade Web and Movielens data sets, finding countries partitioned according to their technological development, exported ware clusters based on their exporters and films communities based on the audience; the results are compared with results from the other methods [2, 3] and deeply discussed.

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Georgi Georgiev, Germano Iannacchione, Atanu Chatterjee and Thanh Vu

Benard Cells as a model for Entropy Production, Entropy Decrease and Action Minimization in Self-Organization

SPEAKER: Georgi Georgiev

ABSTRACT. In self-organization, complex systems increase the entropy in their surroundings and decrease their internal entropy, but the mechanisms, the reasons and the physical laws leading to this processes are still a question of debate. Energy gradients across complex systems lead to change in the structure of systems, decreasing their internal entropy to ensure the most efficient energy transport and therefore maximum entropy production in the surroundings. This approach stems from fundamental variational principles in physics, such as the principle of least action. It is coupled to the total energy flowing through a system, which leads to increase the action efficiency. In the simplest physical system of Benard Cells, we compare energy transport through a fluid cell which has random motion of its molecules, and a cell which can form convection cells. We examine the signs of change of entropy, and the action needed for the motion inside those systems. The system in which convective motion occurs, reduces the time for energy transmission, compared to random motion. For more complex systems, those convection cells form a network of transport channels, for the purpose of obeying the equations of motion in this geometry. This leads to decreased average action per one event in the system. Those transport networks are an essential feature of complex systems in biology, ecology, economy and society.

Ciro Cattuto

High-resolution social networks: state of the art and perspectives

SPEAKER: Ciro Cattuto

ABSTRACT. Digital technologies provide the opportunity to quantify specific human behaviors with unprecedented levels of detail and scale. Personal electronic devices and wearable sensors, in particular, can be used to measure the structure and dynamics of human close-range interactions in a variety of settings relevant for research in complex systems. This talk will review the experience of the SocioPatterns collaboration, an international effort aimed at measuring and studying high-resolution social networks using wearable sensors. We will discuss technology requirements and measurement experiences in diverse environments such as schools, hospitals, households and low-resource rural settings in developing countries. We will discuss salient features of empirical data, reflect on challenges such as generalization and data incompleteness, and review modeling approaches based on ideas from network science, epidemiology and computer science.

Hiroki Sayama, Farnaz Zamani Esfahlani and Ali Jazayeri

Robust Tracking and Behavioral Modeling of Pedestrian Movement in Ordinary Video Recordings

SPEAKER: Hiroki Sayama

ABSTRACT. Collective behaviors of animals, such as bird flocks, fish schools, and pedestrian crowds, have been the subject of active research in complex systems science and behavioral ecology in particular. Previous literature on this topic mostly focused on studying individual behaviors in isolation, or in response to other individuals in the vicinity through simple kinetic interaction rules. A commonly adopted assumption is that the same set of behavioral rules applies to all individuals homogeneously, while not much attention was paid to modeling and analyzing heterogeneous behavioral states and their interactions in the collective. To address this theoretical/methodological gap, we previously proposed a generalizable computational method to detect heterogeneous discrete behavioral states and their interactions among individuals from externally observable spatio-temporal trajectories of those individuals [1,2]. Our method assumes that individuals are acting as finite state machines, and constructs a stochastic model of their state transitions that depend on both the internal state of the individual and the external environmental context (including presence and states of other individuals nearby). However, the method was tested only with a small-sized population of termites in a well-controlled experimental setting in a laboratory, while its applicability to more complex, noisy, dynamically changing collectives “in the wild” remained unclear. In this study, we have developed a robust object tracking system that can track the movements of pedestrians from an ordinary low-resolution video recording taken from an elevated location, and have applied our behavioral modeling method to the trajectories of pedestrians obtained with this tracking system. As the input data, we recorded pedestrians walking in a university campus during a lunch break (recording was conducted with the Binghamton University IRB approval). To enhance the robustness of pedestrian tracking, our system used a hybrid approach that combined image processing (for motion detection and perspective transformation; implemented with OpenCV) and real-time, online agent-based simulation (for motion prediction in a noisy, dynamic environment; implemented with Python). From the resulting trajectories, a total of 17 distinct behavioral states were identified, based on the speed and the direction of movement. The trajectories labeled with these behavioral states were then fed into the proposed behavioral modeling method. Figure 1 shows the overview of the whole process. The resulting behavioral transition model was given as a 17×17×18 tensor (Fig. 1D). The majority of transitions were detected in the main-diagonal (= maintenance or minor change of direction) and sub-diagonal (= change of speed) parts of the tensor. A few notable interactions were detected between different states (e.g., having neighbors moving in other directions slows down fast-moving individuals, etc.), but state interactions were generally much less among pedestrians than among termites in previously reported results. This work demonstrated that the developed tracking system and the modeling method can handle noisy real-world collective behaviors. Future directions of research include further improvement of robustness and accuracy of the object tracking system and detection of behavioral anomalies using models generated by this method. This material is based upon work supported by the US National Science Foundation under Grant No. 1319152.

Alfredo Morales, *Vaibhav Vavilala*, *Rosa M. Benito* and *Yaneer Bar-Yam*

Global Patterns of Human Communication

SPEAKER: *Alfredo Morales*

ABSTRACT. Social media are transforming global communication and coordination. The data derived from social media can reveal patterns of human behavior at all levels and scales of society. Using geolocated Twitter data, we have quantified collective behaviors across multiple scales, ranging from the commutes of individuals, to the daily pulse of 50 major urban areas and global patterns of human coordination. Human activity and mobility patterns manifest the synchrony required for contingency of actions between individuals. Urban areas show regular cycles of contraction and expansion that resembles heartbeats linked primarily to social rather than natural cycles. Business hours and circadian rhythms influence daily cycles of work, recreation, and sleep. Different urban areas have characteristic signatures of daily collective activities. The differences are consistent with a new emergent global synchrony that couples behavior in distant regions across the world. A globally synchronized peak that includes exchange of ideas and information across Europe, Africa, Asia and Australasia. We propose a dynamical model to explain the emergence of global synchrony in the context of increasing global communication and reproduce the observed behavior. The collective patterns we observe show how social interactions lead to interdependence of behavior manifest in the synchronization of communication. The creation and maintenance of temporally sensitive social relationships results in the emergence of complexity of the larger scale behavior of the social system.

Alfredo J. Morales, Vaibhav Vavilala, Rosa M. Benito, Yaneer Bar-Yam, Global patterns of synchronization in human communications, Journal of the Royal Society Interface (March 1, 2017), doi: 10.1098/rsif.2016.1048.

Maxime Lenormand, *Patrizia Tenerelli* and *Sandra Luque*

Measuring cultural value of Ecosystem Services using geotagged photos

SPEAKER: *Maxime Lenormand*

ABSTRACT. There is an increasing interest in the ecosystem-based approach to land management that calls for operational cost-effective methods for assessing ecosystem services (ES) at different spatial scales. When focusing on intangible ES, such as cultural ecosystem services (CES), it is particularly challenging to assess both the capacity of ecosystems to provide them and the extent of their use by people. While it is at the centre of human dimension, cultural value of ecosystem services such as forests, rivers or green urban areas are not straight forward. Interactions between people and natural spaces, through leisure or tourism activities, form a complex socio-ecological network changing over time and space in response to economic, technological, social, political, spatial and cultural drivers. Unthinkable until recently, the increasing availability of large databases generated by the use of geolocated information and communication technologies (ICT) devices allow us to gain a better understanding of complex socio-ecological interactions. Within this context we propose to identify emergent patterns of spatial distribution of CES based on the presence of visitors inferred from geolocalized Flickr photos collected in 16 sites in Europe. These spatial patterns will be used to assess and understand preferences and factors that determine their provision from local to broader scales. In particular, explanatory variables related to landscape settings but also to the Flickr users' timeline will be extracted to investigate how CES beneficiaries interact with their environment and natural settings according to its complexity and their mobility behaviours in space and time. This will allow us to gain a better insight into CES and the complex interrelation perceived across time and space by people.

Giacomo Livan and Orowa Sikder

How networks shape fake narratives

SPEAKER: Giacomo Livan

ABSTRACT. The rise of “fake news” has been a defining feature of the latest year of political events. While the spreading of misinformation has been a recurring phenomenon in human societies, the proliferation of social media has accelerated it by increasing the ability of individuals to transmit and consume information. This work aims at providing a sound theoretical framework to this phenomenon by incorporating inputs from the behavioral literature into a network model. In particular, we seek to examine how the psychological phenomenon of motivated reasoning contributes to the aggregation and propagation of misinformation through social networks. Motivated reasoning refers to the tendency of individuals to radicalize and strengthen pre-established convictions when presented with confuting information, which ultimately leads to selectively recruit, process, and recall information in order to cohere with such convictions. Our model relies on an artificial society of agents connected by a social network who communicate and exchange the scattered information available to them about a binary world event (e.g., whether climate change is real or not) for which a ground truth exists. The crux of the model is that while the majority of agents are rational, i.e. update their opinions based on new information according to Bayes’ rule, a small minority of the agents are motivated reasoners (MRs). Such agents behave rationally until their conviction on a possible outcome of the issue at stake exceeds a threshold (i.e. until they “make up their minds”). When this happens, MRs begin to replace the incongruent information (i.e. the information contradicting their beliefs) with congruent signals which they later communicate to their neighbors. We provide a fully analytic solution of the model’s dynamics on a regular network, which we validate with extensive numerical simulations, and we numerically investigate more complicated network topologies. We show that the network’s dynamics neatly separates into two regimes: after an initial rational phase characterized by the seamless transmission of unfiltered information, at a critical time the MRs’ convictions begin to consolidate and give rise to a post-rational phase where MRs actively propagate distorted information. Within this framework we are able to predict under what conditions a society will either reach consensus or stabilize around a polarized state. We show that the long run outcome of the information diffusion process is entirely determined by the fraction of MRs that are for or against the ground truth when the transition time is hit. Furthermore, we are able to characterize analytically the distribution of agents’ belief at any point in time. This allows to fully track the evolution of antagonistic communities, a result which provides a quantitative description of the widely debated “echo chamber” phenomenon.

Our model offers no more than a caricature of the complexity of real world information sharing. Yet, our relatively simple picture of motivated reasoning allows us to examine quantitatively how social networks can effectively aggregate individual biases and distort the collective interpretation of facts and news.

Jelena Grujic and *Miljana Radivojevic*

Complex networks in archaeology: Community structure of copper supply networks

SPEAKER: *Jelena Grujic*

ABSTRACT. Complex networks analyses of many physical, biological and social phenomena show remarkable structural regularities, yet, their application in studying human past interaction remains underdeveloped. Here, we present an innovative method for identifying community structures in the archaeological record that allow for independent evaluation of the copper using societies in the Balkans, from c. 6200 to c. 3200 BC. We achieve this by exploring modularity of networked systems of these societies across an estimated 3000 years. We employ chemical data of copper-based objects from 79 archaeological sites as the independent variable for detecting most densely interconnected sets of nodes with a modularity maximization method.

We designed two distinctive networks: one, that had artefacts for nodes, and the other, where archaeological sites acted as nodes. Our Artefacts and Sites networks were defined exclusively on data (selected trace elements for 410 copper artefacts) isolated from any geographical, cultural or chronological information, in order to secure an independent estimate of economic and social ties amongst copper-using societies in the Balkans within the observed time. Our network was built in two discrete steps: 1) we grouped the data in ten distinctive chemical clusters (Network 1: Artefacts); 2) placed a connector between the sites that contain pairs of artefacts from the same cluster and analysed the modularity of the final network (Network 2: Sites). In both steps we used the Louvain algorithm to obtain community structures (modules), and bootstrapping to test the significance of acquired results. Our results reveal three dominant modular structures across the entire period, which exhibit strong spatial and temporal significance (Figure 1). The three community structures, exhibit high correlation with the known spatial and chronological dynamics of various cultural phenomena – archaeological cultures in the Balkans between the 7th and the 4th millennium BC. The earliest known copper-based artefacts are included in the Module 0 assemblage, identified as copper minerals from the Early Neolithic Starčevo culture horizons at Lepenski Vir, Vlasac and Kolubara-Jaričište, dated from c. 6200 to c. 5500 BC. These fall within the same module as copper minerals and beads from the early Vinča culture occupation at the sites of Pločnik (Period 2, 5500 – 5000 BC), but also Gomolava and Medvednjak (Period 3, 5000-4600 BC).

We select two key arguments to highlight the novelty of our model for studying community structures in the human past record. One is that it is based on a variable independent of any archaeological and spatiotemporal information, yet provides archaeologically and spatiotemporally significant results. The second is that a study of community structure property of networked systems in the past produces coherent models of human interaction and cooperation that can be evaluated independently of established archaeological systematics. Despite the imperfect social signal extracted from the archaeological record, our method provides important new insights into the evolution of the world's earliest copper supply network and establishes a widely applicable model for exploring technological, economic and social phenomena in human past, anywhere.

Noé Gaumont, Maziyar Panahi and David Chavalarias

Evolution of communities on twitter during the 2017 French presidential election

SPEAKER: Noé Gaumont

ABSTRACT. Twitter acquired a central place as a mean of communication for political parties in the last year. For example, Donald Trump has 16.1 million follower on twitter while on a smaller scale François Hollande has 1.9 million follower on the 17th march 2017. This allow them to reach a very large audience. Not only is Twitter a large scale broadcasting platform, it also allows people to react easily with replies, mentions, quotes and retweets. Thus, the impact of each tweet can be measured by the analysis of all the reactions it generated.

In this study, we are focusing on the French presidential election and the evolution of the supporters of each candidates during the campaign. Through the Twitter streaming API, we are collecting all the activity surrounding a list of 3 500 accounts, from august 2016. These accounts correspond to deputies, mayors, senators and all the candidates in the French presidential election. This collect includes all the tweets from these 3 500 accounts but also the reactions\footnote{Because of Twitter API limitation, only a fraction of the reaction are available.} (replies, quotes and retweets) generated by these tweets. Thus on 1st of March 2017, we already collected more than 21 million tweets from more than 1.2 million unique user. Parts of the data are available: \url{multivac.iscpif.fr}.

Most of the studies on Twitter uses the information of followers/followees to deduce political support, this is a powerful approach and led to meaningful insights on the structure of the Twitter network such as the existence of community structure. However, follow information is binary and not very dynamic. We use the notion of retweet, instead. A single retweet may not be a sign of agreement, however multiple retweets in a short time period are evidences of a strong relations between two persons. Like previous study, we find evidence of community structure inside the weighted graph of retweets because people close to a candidate hardly ever retweet people from other communities. As retweets are highly dynamic, we are able to have a more fined-grained description of the structure by analyzing the temporal network as a series of graphs on overlapping time windows. By applying community detection algorithm on each graph, we follow how the communities grow, split, merge or decline over time, see Figure~\ref{fig:alluvialcouleurlienetnoeud}. The novelty of our approach is being able to track these evolutions to existing events. This reflects how much the twitter medium reacts to event in the real life (official annoucement, debate, presidential primary). For example, Figure~\ref{fig:alluvialcouleurlienetnoeud} focus presidential primary of the right involving mainly Fillon, Juppé and Sarkozy. After the first round won by Fillon and Juppé, Sarkozy lost a lot supporters in favors of Fillon. After the second round won by Fillon, the main process occurred and Juppe lost a lot of supporter. Another interesting evolution is the fusion of the community of Sarkozy and Fillon which could be explained by Sarkozy's choice to support Fillon between the first and second round of the primary.

Albert Diaz-Guilera

Synchronization in populations of moving oscillators

SPEAKER: Albert Diaz-Guilera

ABSTRACT. Here we will show results obtained in our group concerning synchronization of populations of moving oscillators. On the one hand, populations of identical Kuramoto oscillators that move randomly on a plane, without considering excluded volume effects, enables to obtain analytical results for the time needed to synchronize [1]; later on, we hace extended this framework to locally interacting self-propelled particles for which synchronization generically proceeds through coarsening verifying the dynamic scaling hypothesis, with the same scaling laws as the the 2d XY model following a quench [2]. Our results shed light into the generic nature of synchronization in time- dependent networks, providing an efficient way to understand more specific situations involving interacting mobile agents. Alternatively, we have also investigated synchronization in populations of integrate and fire oscillators, showing that under restrictive conditions of connectivity, the time needed for the population to synchronize is not a monotonous function of velocity [3] [1] Naoya Fujiwara, Jürgen Kurths, and Albert Díaz-Guilera. Synchronization in networks of mobile oscillators. Phys. Rev. E 83, 025101(R) (2011). [2] D. Levis, I. Pagonabarraga, A. Diaz-Guilera. Synchronization in dynamical networks of locally coupled self-propelled oscillators. Phys. Rev X (in press). [3] L. Prignano, O. Sagarra, and A. Díaz-Guilera. Tuning Synchronization of Integrate-and-Fire Oscillators through Mobility. Phys. Rev. Lett. 110, 114101 (2013).

Martin Rohden, Jeffrey Emenheiser, Anastasiya Salova, Jim Crutchfield and Raissa D'Souza

Attractor switching patterns of nanoelectromechanical oscillators

SPEAKER: Martin Rohden

ABSTRACT. Networks of nanoelectromechanical oscillators have been realized experimentally and are therefore a complex system which can be studied both experimentally and analytically [1]. However, the architecture of their attractors and basins are not well understood. Here, we study a system consisting of eight nonlinear amplitude-phase nanoelectromechanical oscillators arranged in a ring topology with reactive nearest-neighbor coupling which is simple and connects directly to experimental realizations. The system possesses multiple stable fixed points and we determine escape times from different fixed points under the influence of Gaussian white noise applied to each of the oscillator's amplitudes. Furthermore, we study switching patterns between different stable states by applying Gaussian white noise. We compare our findings with analytical results based on the Freidlin-Wentzell potential and determine which states are most stable for which parameter setting. This work serves as a step towards a controlled switching mechanism.

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Darka Labavic and Hildegard Meyer-Ortmanns

Physical Aging, Emerging Long-Period Orbits and Self-similar Temporal Patterns in Deterministic Classical Oscillators

SPEAKER: Hildegard Meyer-Ortmanns

ABSTRACT. Physical aging is understood as the breaking of time translation invariance in the measurement of autocorrelation functions and long intrinsic time scales. In previous work [1] we had shown physical aging of repulsively coupled classical oscillators under the action of noise. Noise led to the migration of oscillator phases through a rich attractor space. To explore the role of stochastic fluctuations in physical aging, we here [2] replace noise by a quenched disorder in the natural frequencies. Again we identify physical aging, now in a deterministic rather than stochastic system of repulsively coupled Kuramoto oscillators, where the attractor space is explored quite differently. Tracing back the origin of aging, we identify the long transients that it takes the deterministic trajectories to find their stationary orbits in the rich attractor space. The stationary orbits show a variety of different periods, which can be orders of magnitude longer than the periods of individual oscillators. Most interestingly, among the long-period orbits we find self-similar temporal sequences of temporary patterns of phase-locked motion on time scales, which differ by orders of magnitude. So the self-similarity refers to patterns in time rather than static fractals in space. The ratio of time scales is determined by the ratio of widths of the distributions about the common natural frequency, as long as the width is not too large. The effects are particularly pronounced if we perturb about a situation in which a self-organized Watanabe-Strogatz phenomenon is known to happen, going along with a continuum of attractors and a conserved quantity. We expect similar phenomena in coupled FitzHugh-Nagumo elements with a certain disorder in the model parameters and antagonistic couplings as guarantee for a rich attractor space.

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Luis M. Rocha, Alexander Gates, Santosh Manicka, Manuel Marques Pita and Rion Correia

The effective structure of complex networks: Canalization in the dynamics of complex networks drives dynamics, criticality and control

SPEAKER: Luis M. Rocha

ABSTRACT. Network Science has provided predictive models of many complex systems from molecular biology to social interactions. Most of this success is achieved by reducing multivariate dynamics to a graph of static interactions. Such network structure approach has provided many insights about the organization of complex systems. However, there is also a need to understand how to control them; for example, to revert a diseased cell to a healthy state in systems biology models of biochemical regulation. Based on recent work [1,2] we show that the control of complex networks crucially depends on redundancy that exists at the level of variable dynamics. To understand the effect of such redundancy, we study automata networks−both systems biology models and large random ensembles of Boolean networks (BN). In these discrete dynamical systems, redundancy is conceptualized as canalization: when a subset of inputs is sufficient to determine the output of an automaton. We discuss two types of canalization: effective connectivity and input symmetry [2].

First, we show that effective connectivity strongly influences the controllability of multivariate dynamics. Indeed, predictions made by structure-only methods can both undershoot and overshoot the number and which sets of variables actually control BN. Specifically, we discuss the effect of effective connectivity on several structure-only controllability theories: structural controllability, minimum dominating sets, and feedback vertex sets [1,3].

To understand how control and information effectively propagate in such complex systems, we uncover the effective graph that results after computation of effective connectivity. To study the effect of input symmetry, we further develop our dynamics canalization map, a parsimonious dynamical system representation of the original BN obtained after removal of all redundancy [2]. Mapping canalization in BN via these representations allows us to understand how control pathways operate, aiding the discovery of dynamical modularity [4] and robustness present in such systems [2].

We also demonstrate that effective connectivity is a tuning parameter of BN dynamics [5], leading to a new theory for criticality, which significantly outperforms the existing theory in predicting the dynamical regime of BN (chaos or order). Input symmetry is also shown to affect criticality, especially in networks with large in-degree. Moreover, we argue that the two forms of canalization characterize qualitatively distinct phenomena, since Boolean functions cover the space of both measures and prediction performance of criticality is optimized for models which parameterize the two forms separately [6].

Finally, we will showcase a new Python toolbox that allows the computation of all canalization measures, as well as the effective graph and the dynamics canalization map. We will demonstrate it by computing the canalization of a battery 50+ systems biology automata networks.

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Mikko Kivelä, Márton Karsai, Jordan Cambe and Jari Saramäki

All at once: a global representation of δt-connected time-respecting paths in temporal networks

SPEAKER: Márton Karsai

ABSTRACT. Temporal networks code the interaction dynamics of large number of entities, which lead to the emergence of complex structures observed in physics, biology, or social systems. Such time-varying structures largely determines the speed and final outcome of ongoing dynamical processes, including contagion, synchronisation dynamics, or evolutionary games. It has been particularly shown that the timings of contacts between nodes have major role in this sense (a) because any diffusion process has to follow causal, time-respecting paths spanned by sequences of contacts; and (b) because the speed of spreading is heavily influenced by temporal inhomogeneities, as well as timing correlations between contacts of nodes. Despite the recognised importance of time-varying interactions, our understanding about temporal networks is yet limited as neither a computationally effective representation nor methodologies to capture simultaneously temporal and structural correlations has been provided. Correlations that frequently result in short waiting-times between the contacts of individual nodes are of special importance to a subclass of spreading processes. These processes are characterised by a waiting-time constraint, where the spreading quantity has to be transmitted within some given time δt. Examples of such spreading processes include variants of common disease spreading models such as the Susceptible-Infectious-Recovered and Susceptible-Infectious-Susceptible, social contagion processes, ad-hoc routing protocols for mobile agents, or passenger routing in transport networks. The waiting-time constraint of a dynamical process can be incorporated into time-respecting paths, which consist of successive contact events that share at least one common node and are separated by no more than δt units of time. The connectedness of such paths is key to understanding the possible outcomes of a dynamical process: \emph{e.g.}, for very low values of δt, network-wide connectivity is unlikely to exist and spreading processes may not percolate the temporal network, while for large δt the temporal structure may be connected allowing for the emergence of a global phenomena. However, the detection and analysis of time-respecting paths is computationally expensive especially in large temporal networks, where they really matter.

Here we introduce a new representation of temporal networks by mapping them to static weighted directed acyclic graphs, called event graphs. We show that event graphs can be related to directed percolation with the characteristic quantities showing some expected scaling behaviour. Event graphs provide a powerful tool that encapsulate the complete set of time respecting paths at once, even for very large temporal networks; can be used easily to study unlimited and limited-waiting-time processes on networks; they can capture the complete set of potentially affected nodes for spreading initiated from a given node and time, without requiring the expensive computation of average outcomes of stochastic simulations. They are easy to use to compute centrality scores for events, links, and nodes and to identify the complete set of δt-connected temporal components in a computationally economic way. We illustrate these benefits of event graphs by performing extensive simulation studies and analysing large-scale data sets using them. This representation opens new directions to study system level higher-order correlations in temporal networks.

Mengsen Zhang, J. A. Scott Kelso and Emmanuelle Tognoli

Multiagent Coordination Dynamics: The Human Firefly Experiment

SPEAKER: Mengsen Zhang

ABSTRACT. Living systems often contain oscillatory activities on multiple spatiotemporal scales. Studying the coordination among diverse oscillatory processes is essential for understanding the organization of complex structures and their behavior. Theoretical modeling has tended to focus on systems at either end of the spectrum: large-scale networks for their propensity to globally synchronize (with less attention given toward segregation into local structures) or systems with very few coupled oscillators (N≤3) that often exhibit a rich mix of integrative and segregative tendencies, but lack the necessary number of components to uncover organization at multiple spatiotemporal scales. In real-life human interactions, much happens in between. We have developed an experimental paradigm, dubbed the “human fireflies” to study the formation and evolution of coordinative structures in small groups (N=8 people). We aim to (1) examine the effect of symmetry breaking on collective dynamics; (2) characterize the forms of coordination that emerge at a micro level; and (3) provide benchmark experimental observations against which the relevance of theoretical models may be tested. Participants (8 people ×15 groups) were seated around an octagonal table and performed a rhythmic tapping task. Each participant was equipped with a touchpad that broadcast his/her tapping behavior to others, and an array of eight LEDs that displayed tapping behavior of self and others as brief flashes. Before each 50s period of interaction, participants were paced with a metronome (10s), and instructed to continue tapping at its frequency throughout the interaction while being attentive to others’ behavior. We manipulated the spatiotemporal symmetry of this eight-component system through metronome assignments, effectively splitting people into two groups of four such that frequencies were identical within groups, but different between groups. Symmetry breaking in the system was parametrically controlled by the frequency difference between the two groups (δf = 0, 0.3 or 0.6Hz). We examined under which conditions the groups remained segregated as two coordinative structures behaving at distinct frequencies, or integrated into a single superstructure in which the initial division into two groups was lost. Inferring from the relation between within- and between-group phase coordination, we identified the critical frequency difference that borders the regimes of integration and segregation. Close examination of the dynamics revealed that integration did not take the canonical form of stable phase relations (i.e. phase-locked synchronization). Rather a form of metastable relations emerged (i.e. recurrent dwells approaching stable phase relations, interleaved with escapes from said relations). In multiagent systems, such metastable coordination dynamics enables a component to switch between multiple coordinative structures in a recurrent fashion. Our results supply future theoretical studies of the dynamics of multiagent coordination with an empirical reference: plausible models ought to exhibit metastable coordination dynamics and contain a critical level of symmetry breaking that demarcates the boundary between segregation and integration. Such models will be useful to explore the consequences of different forms of coordination in terms of, inter alia, the complexity and stability of large-scale social networks, and more generally to aid discovery of laws of human behavior and their interaction.

Dijana Tolic and Nino Antulov-Fantulin

Time augmented bond percolation for statistical inference in complex networks

SPEAKER: Dijana Tolic

ABSTRACT. We propose a novel method for solving source and model inference problems on arbitrary graphs and for a bigger class of contagion network processes, such as time homogeneous compartmental contagion models with non-recurrent states. Different source detection estimators vary in their assumptions on the network structure or on the spreading process models. Furthermore, the problem of source inference on arbitrary graphs is computationally hard (\# P-complete class), which is why most state-of-the-art methods, such as belief propagation and message passing consider only network structures that are locally tree-like.

Given a contact network and a snapshot of a dynamical process at a certain time, we propose a mapping of spreading dynamics to weighted networks, where edge weights represent interaction time delays. This mapping is constructed in such a way that the time respecting paths (shortest paths) in the weighted network preserve the causality of spreading.

We overcome the limitations of current methods such as: message passing, mean-field like approximation and kinetic Monte Carlo methods and establish the connection of our mapping with bond percolation theory. Our method is relevant for broader class of inference problems, such as localizing the total set of source nodes which generate dynamical process on complex network. Multiple source inference is even more challenging problem with a sizable practical importance. We show that, under certain assumptions, the proposed methodology is able to locate the multiple sources using only single source solutions.

Chiranjit Mitra, Tim Kittel, Anshul Choudhary, Jürgen Kurths and Reik V. Donner

Recovery time after localized perturbations in complex dynamical networks

SPEAKER: Chiranjit Mitra

ABSTRACT. Maintaining the synchronous motion of dynamical systems interacting on complex networks is often critical to their functionality. However, real-world networked dynamical systems operating synchronously are prone to random perturbations driving the system to arbitrary states within the corresponding basin of attraction, thereby leading to periods of desynchronized dynamics with apriori unknown durations. Thus, it is highly relevant to have an estimate of the duration of such transient phases before the system returns to synchrony, following a random perturbation to the dynamical state of any particular node of the network. We address this issue here by proposing the framework of single-node recovery time (SNRT) which provides an estimate of the relative time scales underlying the transient dynamics of the nodes of a network during its restoration to synchrony. We utilize this in differentiating the particularly slow nodes of the network from the relatively fast nodes, thus identifying the critical nodes which when perturbed lead to significantly enlarged recovery time of the system before resuming synchronized operation. Further, we reveal explicit relationships between the SNRT values of a network, and its global relaxation time when starting all the nodes from random initial conditions. Earlier work on relaxation time generally focused on investigating its dependence on macroscopic topological properties of the respective network. However, we employ the proposed concept for deducing the microscopic relationships between topological network characteristics at node-level and the associated SNRT values. The framework of SNRT is further extended to a measure of resilience of the different nodes of a networked dynamical system. We demonstrate the potential of SNRT in networks of Rössler oscillators on paradigmatic topologies and a model of the power grid of the United Kingdom with second-order Kuramoto-type nodal dynamics, illustrating the potential practical applicability of the proposed concept.

Nino Antulov-Fantulin and Dijana Tolic

Signatures of dynamical regimes in the temporal Bitcoin transaction networks

SPEAKER: Nino Antulov-Fantulin

ABSTRACT. Half a decade after Bitcoin became the first widely used cryptocurrency, blockchains are receiving considerable interest from both industry and the research community. We study the dynamical and structural properties of the temporal Bitcoin network, which can be reconstructed from the historical Bitcoin transactions between the users. Applying the widely used method of Non-negative Matrix Factorization, we obtain a low-rank approximation of the temporal Bitcoin network in the unsupervised clustering framework. We are able to quantify the change of dynamical regimes and characterize the situations when the cluster assignment probability distribution is concentrated or dispersed introducing the Shannon entropy measure. Each of the basis vectors, or networks, has a clear physical interpretation due to the non-negativity constraint introduced in the structural decomposition. The regime is formally defined as a cluster or group of similar BTC transaction snapshots. The total number of regimes is set to be equal to the number of clusters, which are estimated from the spectrum of the matrix which describes the BTC transaction dynamics. With the proposed information theoretic and spectral measure, we quantify points in time where the systems demonstrates the regime switching dynamics. We compare and analyze the Bitcoin exchange prices towards the USD, CNY and EUR with the changes of dynamical regimes.

Olga Briukhova, Marco D'Errico and Stefano Battiston

Reshaping Financial Network: Central Clearing Counterparties and Systemic Risk

SPEAKER: Olga Briukhova

ABSTRACT. Over-the-counter (OTC) derivatives constitute a complex network of risk transfers. Due to their opacity and lack of regulation, these markets played a significant role in the global financial crisis of 2007-2009 (Haldane, 2009). As a response, the G20 leaders committed to make derivatives safer by increasing their transparency and mandating clearing for certain classes of OTC derivatives through central clearing counterparties (CCPs). Interposing themselves between existing nodes in the network, central clearing is expected to reduce systemic risk by acting as a buffer between different nodes, decreasing exposures via multilateral netting, and ensuring loss-mutualisation. However, the introduction of CCPs drastically modifies the underlying network structure, creating a more star-like architecture. This paper investigates whether and under which conditions mandatory central clearing improves financial stability. In particular, we show that when a shock is sufficiently large, a highly diversified and insufficiently capitalized CCP connects all its members rather than insulates them. We analyse how central clearing redistributes wealth among OTC market. We show how the participation of each member in a CCP creates externalities to all other members on three different levels: risk, netting benefits, and capital costs. First, we show that central clearing transfers losses from riskier to safer members. The size of exposure between members cannot be fully controlled and managed by any single member, since it is not determined by bilateral transactions between them but by positions and credit quality of all the other CCP members. Second, we analyse the redistribution effects arising from multilateral netting. Bilateral netting is beneficial for those agents whose credit quality is high relative to the average quality of their counterparties, however one party gains the exact amount another party loses. In a CCP, netting effect comes along with the counterparty effect, i.e. the change of the average quality of the CCP. The combination of these two effects makes it possible for both counterparties to increase expected payoffs by transferring part of the negative counterparty effect to other members. We show that members with relatively high quality tend to make their position towards the CCP flatter, while riskier members keep their positions more directional. This makes the CCP more dependent on the payments from risky members and might increase systemic risk. Third, we show that since default fund requirements associated with an additional unit cleared by the big member are shared among all members, the small members pay relatively more per one unit of cleared notional. These negative externalities can be avoided by setting individual requirements in accordance with the member's contribution to the total capital requirement. Last, we provide an empirical EU-wide multi-layer network of CCPs and their members focusing on common memberships. In general, our work points towards the need to further understand the impact of policies on the network structure and in particular, the redistributional effects of mandatory central clearing, how they change banks' strategies and influence systemic risk.

Andrea Zaccaria, Francesco Corradi and Luciano Pietronero
Liquidity crises in the limit order book: a tale of two time scales
SPEAKER: Andrea Zaccaria
ABSTRACT. We present an empirical analysis of the microstructure of financial markets and, in particular, of the static and dynamic properties of liquidity. We find that on relatively large time scales (15 min) large price fluctuations are connected with the failure of the subtle mechanism of compensation between the flows of market and limit orders: in other words, the missed revelation of the latent order book breaks the dynamical equilibrium between the flows, triggering the large price jumps. This behavior naturally leads to a dynamical definition of liquidity. On smaller time scales (30 s), instead, the static depletion of the limit order book is an indicator of an intrinsic fragility of the system, which leads to a strongly nonlinear enhancement of the response, in terms of price impact, to incoming orders, even if their volume is small. In order to quantify this phenomenon, we introduce a static measure of the liquidity imbalance present in the book and we show that this quantity is correlated to both the sign and the magnitude of the next price movement. These empirical findings prove that large price fluctuations are due to different mechanisms that act at different time scales. In both cases, the volumes of the incoming orders play a minor role with respect to the fragility of the system and, in particular, to the possible typologies of liquidity crises we discuss. In conclusion, the effective liquidity should be defined in relation to the time interval one wants to consider.

Stanislao Gualdi, Giulio Cimini, Kevin Primicerio, Riccardo Di Clemente and Damien Challet
Statistically validated network of portfolio overlaps and systemic risk
SPEAKER: Giulio Cimini
ABSTRACT. Common asset holding by financial institutions, namely portfolio overlap, is nowadays regarded as an important channel for financial contagion with the potential to trigger fire sales and thus severe losses at the systemic level. In this paper we propose a method to assess the statistical significance of the overlap between pairs of heterogeneously diversified portfolios, which then allows us to build a validated network of financial institutions where links indicate potential contagion channels due to realized portfolio overlaps. The method is implemented on a historical database of institutional holdings ranging from 1999 to the end of 2013, but can be in general applied to any bipartite network where the presence of similar sets of neighbors is of interest. We find that the proportion of validated network links (i.e., of statistically significant overlaps) increased steadily before the 2007-2008 global financial crisis and reached a maximum when the crisis occurred. We argue that the nature of this measure implies that systemic risk from fire sales liquidation was maximal at that time. After a sharp drop in 2008, systemic risk resumed its growth in 2009, with a notable acceleration in 2013, reaching levels not seen since 2007. We finally show that market trends tend to be amplified in the portfolios identified by the algorithm, such that it is possible to have an informative signal about financial institutions that are about to suffer (enjoy) the most significant losses (gains).

Sebastian Poledna, Serafin Martinez Jaramillo, Fabio Caccioli and Stefan Thurner
Quantification of systemic risk from overlapping portfolios in Mexico
SPEAKER: Sebastian Poledna
ABSTRACT. Financial markets are exposed to systemic risk, the risk that a substantial fraction of the system ceases to function, and collapses. Systemic risk can propagate through different mechanisms and channels of contagion. One important form of financial contagion arises from indirect interconnections between financial institutions mediated by financial markets. This indirect interconnection occurs when financial institutions invest in common assets and is referred to as overlapping portfolios. In this work we quantify systemic risk from overlapping portfolios. Having complete information of security holdings of major Mexican financial intermediaries and the ability to uniquely identify securities in their portfolios allows us to represent the Mexican financial system as a bipartite network of securities and financial institutions. This makes it possible to quantify systemic risk arising from overlapping portfolios. We show that focusing only on direct exposures underestimates total systemic risk levels by up to 50%. By representing the financial system as a multi-layer network of direct exposures (default contagion) and indirect exposures (overlapping portfolios) we estimate the mutual influence of different channels of contagion. The method presented here is the first objective data-driven quantification of systemic risk on national scales that includes overlapping portfolios.

Michael Harre

Repeated Games, Decisions, and Universal Turing Machines

SPEAKER: *Michael Harre*

ABSTRACT. Turing machines have been used by Ken Binmore, Vela Velupillai and many others as a tool for understanding the interactions between economic agents with idealised computational abilities. This has lead to a better understanding of the limits of the computability of equilibria as well as to help define "complexity economics" using concepts from Turing, Shannon, Kolmogorov and Simon. This talk takes a similar approach to that of earlier work on repeated games and establishes some formal results regarding Turing Machines and economic theory. The starting point is agents playing repeated games in which the agents use past choices and outcomes as the information set for their next choice. These repeated games are separated into two distinct but coupled computational steps: the interaction step in which the agents' joint actions are used to derive payoffs and the decision step where agents use past interactions to decide what action to choose next. The decisions in the second step are easily thought of as an agent performing computations where we will assume only that the agents are only finite automata, not Turing Machines. On the other hand it is less common for the underlying game that defines the economic interactions (the first step) to be thought of as a form of computation per se. It is shown that after a suitable relabeling of the system elements the combination of interactions and decisions is isomorphic to classical logic gates for a large class of games. This provides a common formal language in which to analyse the relationship between strategies (an agent's 'internal' cognitive process) and the economic interaction (the logical structure of the game). Classical strategies such as 'tit-for-tat' and 'win-stay, lose-shift' will be used as examples. With this approach a number of interesting properties emerge and the consequences for economic theory are discussed, with a focus on showing that for a certain idealised model of the economy it can be readily shown that such an economy is a Universal Turing Machine.

Ricardo Mansilla and *Rodrigo Rodriguez*

Study of the opening and closing price dynamics in the NYSE using the Takens Embedding Theorem

SPEAKER: *Ricardo Mansilla*

ABSTRACT. For a long time there has been a controversy about whether the opening and closing prices in the markets have different dynamics. In effect, the incentives of economic agents are different in each case: at the close of the market, economic agents are pressured by not leaving open positions, while in the opening they are pressured by the uncertainty created by the news during the previous night in the markets. For a long time the following question has been debated: the dynamics of opening and closing prices are different? In this work we use of the Embedding Theorem to study the dynamical properties of the associated time series. The fundamental conclusion is that there are no perceptible differences between the two phenomena

Jose J. Ramasco

Immigrant community integration in world cities

SPEAKER: *Jose J. Ramasco*

ABSTRACT. Immigrant integration is a complex process comprehending many different factors such as employment, housing, education, health, language, legal recognition as well as the built of a new social fabric. In the last years, there have been advances in the definition of a common framework concerning immigration studies and policies, although the approach to this issue remains strongly country-based. The outcome of the process actually depends on the culture of origin, the one of integration and the policies of the hosting country government. Traditionally, spatial segregation in the residential patterns of a certain community has been taken as an indication of ghettoization or lack of integration. While this applies to immigrant communities, it can also affect minorities within a single country. The spatial isolation reflects in the economic status of the segregated community and in social relationships of its members. Immigrant integration has been the focus of many research studies using traditionally national census data and similar surveys. In parallel, in the last few years we have witnessed a paradigm shift in the context of socio-technical data. Human interactions are being digitally traced, recorded and analyzed in large scale. Sources are as varied and different as mobile phone data, credit card transactions, or Twitter data. Going beyond the urban scale, Twitter data have been used to detect the diffusion of human mobility and the languages spoken. Language identification related to the spatial location of Twitter users has been investigated, towards a more complete characterization of spatial local dialects. Finally, Twitter has been used as a statistical database for representations of demographical characteristics of users and language identification patterns. Several attempts have been made in order to identify, characterize and group international communities in cities based on Information and Communication Technologies (ICT) data and to perform social segregation analyses.

Here we present a novel approach to quantify the spatial integration of immigrant communities in urban areas worldwide by using social media information collected through the Twitter microblogging platform; first, we characterize immigrants through their digital spatio-temporal communication patterns, defining their residence place and most probable native language. The distribution of residence detected by Twitter has been validated with census data for three major cities: Barcelona, London and Madrid. Then we perform a spatial distribution analysis through a modified entropy metric, as a quantitative measure of the spatial integration of each community in cities and the corresponding relevance within countries. These results have been recently posted in a paper in arXiv (F. Lamanna, M. Lenormand, M. Henar Salas-Olmedo, G. Romanillos, B. Goncalves, Jose J. Ramasco, Immigrant community integration in world cities, arXiv: 1611.01056 (2016)). The lower the spatial entropy becomes, the more isolated the communities are. The cities can be classified in three major groups depending on the number of immigrant communities hosted and how well they spatially assimilate them. Along the same lines, one can also study which cultures integrate better in which hosting countries.

Riccardo Gallotti and Jose Ramasco

Estimating aviation passengers flows and airports catchment areas from geo-located tweets

SPEAKER: Riccardo Gallotti

ABSTRACT. The current practices in Air Transportation Analytics and Management substantially disregard the passengers' movements outside of the airport. This historical lack of perspective is a consequence of the intrinsic limitations in both accuracy and validity of the traditional methods used to obtain data on passengers' activities. As a consequence, managers and policy makers policy are often not provided with sufficient information to correctly weight their decisions on the basis of the of the consequences that are ultimately expected for the passengers.

The recent development and popularised use Information and Communication Technologies offer new alternative sources of information allowing for the precise derivation of individual mobility at different spatial scales, overcoming many of the limitations of traditional methods. Here, we investigate how one can extract precise information on the passengers' trajectories from a large database of geolocated tweets including over 14M users tracked for two years in the european continent.

We first extract statistics on the international movements. About 15% of the users tweet from more than a single country and we associate consecutive tweets in different countries to an international trip. Our estimate is validated by comparing the observed flows for the first quarter of 2015 with those two independent datasets: the tickets sales provided by Sabre Airline Solutions and the passengers between airports provided by Eurostat. The observed deviations are associated to the use of other modes of transport, as can be observed for neighbouring countries such as Austria and Slovakia. The match is instead closer where flying is the only viable option like between Spain and the United Kingdom.

We then perform an analysis at a smaller scale by associating observed long range displacements to the closest pair of airports (departure and arrival) between which domestic or international commercial flights are regularly available. This rationale allows us to estimate the airports' catchment area as long as airports do not compete for the same region. This is not the case large metropolitan areas served by more than one airport. To analyse this more complex scenario we integrate information on ticket prices and the travel-times between the user's home and the alternative airports (provided by Google's API) and describe the passenger decision behavior using a discrete choice (multinomial) logit model to estimate the value of time in the urban segments in aviation mobility.

This study shows how the availability of ICT data allows for a new comprehensive perspective on the door-to-door characteristic of aviation mobility. The air transport system interacts with other transport modes, both competing for same users or being integrated in a complex multi-layer mobility network. While passengers can still be described within the classical rational choice paradigm, new models must be developed to including the influence of those aspects in the passenger's travel decisions.

Gustavo Carreón-Vázquez, Carlos Gershenson and Luis A. Pineda

Efficient boarding and alighting in public transportation systems

SPEAKER: Gustavo Carreón-Vázquez

ABSTRACT. Millions of people use public transportation systems (PTS) every day. An efficient regulation of passengers and the correct use of the infrastructure can lead to an improved performance. Crowded PTS without a suitable regulatory strategy for the boarding and alighting process can be a source of significant delay. In this research we present two main results: a computational simulation to test passenger regulatory strategies for boarding and the implementation of the best strategy in a station of the Mexico City Metro. Computer simulations of the Social Force Model (SFM) have been used to describe collective patterns that appear in real pedestrian motion. We use the SFM to implement a realistic simulation of passenger flow considering specifically the boarding and alighting processes. To calibrate the model variables, we performed a study of the dynamics in a Mexico City Metro line, where we obtained the boarding and alighting time, the train station time, and estimated delay time. We implemented a “default strategy” for boarding, which models current passenger dynamics. We compare this with an alternative regulatory strategy using exclusive doors for entry and exit, called “dedicated doors” for boarding and alighting; and the strategy “guide lines” to organize the passengers on the platform to create two flows for entry and one flow for exit. Using the computer simulation results, we implemented the strategy “guide lines” in a station of the Mexico City Metro. Our results show a reduction of boarding and alighting time in 10% to 15%, and a reduction of station delay in 15% to 25%. This new scheme has been accepted favorably by passengers. Our work evaluates an efficient boarding strategy, reducing passenger waiting times at stations and also travel times of all trains. The potential adoption of this strategy opens the opportunity to a low cost and high impact improvement in public transportation systems.

Riccardo Gallotti, *Rémi Louf*, *Jean-Marc Luck* and *Marc Barthelemy*

Biases and errors in the temporal sampling of random movements

SPEAKER: *Riccardo Gallotti*

ABSTRACT. New sources of ICT data allow to track individual trajectories at an unprecedented scale. However, as it is the case for any dataset, these new sources of information have limits and biases that need to be assessed.

Here, we study trajectories alternating rests and moves of random durations. Isolate and identifying these intertwined static and dynamic behaviours is an important statistical challenge and a growing array of segmentation methods based on spatio-temporal characteristics of the trajectories have been tailored for the specific dataset in question. These procedures are however limited from technological constraints that impose a temporal sampling of the trajectory, as one needs a time Δ between sampled points significantly smaller than the characteristic duration of rests and moves in analysis to reconstruct the trajectory.

This issue is particularly evident in human mobility data. Currently, the most common sources used are Call Detail Records (CDR) of mobile phone data and geo-located social media accesses, where the flaws described above are amplified by the random and bursty nature of human communications.

In this paper, we discuss the effect of periodical and bursty sampling on the measured properties of random movements. We consider trajectories as an alternating renewal process, a generalisation of Poisson processes to arbitrary holding times and to two alternating kinds of events, moves and rests, whose durations t and τ are regarded as independent random variables. The sampling time interval Δ depends on the particular experiment and can be either constant or randomly distributed.

We analytically solve the ideal case of constant sampling and short-tailed distributions of rest and move durations with the naive assumption that every observed displacement is to be associated to a movement. We obtain explicitly the distribution $P(\ell^\ast)$ of sampled displacements and its first two moments, that also allow us to quantify difference between the real $\ell=vt$ and sampled $\ell^\ast$ displacement lengths. Moreover, we are able to provide an optimal sampling time $ \hat\Delta=1.96\sqrt{\tbar\taubar}$ maximizing the fraction of correctly sampled movements. We then extend these results numerically, and show that sampling human trajectories in more realistic settings is necessarily worse. Finally, we use high-resolution (spatially and temporally) GPS trajectories to verify our predictions on real data. We find that for real cases, characterized by long-tailed rest durations, the fraction of correctly sampled movements is dramatically reduced. We test our results with high-resolution GPS trajectories of human, where constant sampling allows to recover at best 18% of movements, while even idealized methods cannot recover more than 16% of moves from sampling intervals extracted from real communication data.

These figures suggest that in the sampling of of human trajectories alternating rests and movements it is not possible to successfully reconstruct the real moves from the empirical sequence of displacement observed only through the lens of mobile phone communications. Further studies, taking advantage of the new analytical tools we provide here to evaluate the quality of a sampled individual trajectory, are certainly necessary to assess the bias induced by sampling on statistics aggregated at individual or collective level.

Christopher Monterola, Nan Hu, Erika Fille Legara, Lee Gary and Terence Hung

Quantifying the Relationship between Land-use and Transport Systems for Land Use Planning

SPEAKER: Christopher Monterola

ABSTRACT. Designing an efficient transport system for a city that can support the evolving activities of its people and its existing and planned infrastructures requires proper understanding of the interplay between land-use and transport or how land use utilization drives transport demand. Here, we quantify the spatiotemporal dependencies of ridership with land-use sector types and amenities using three machine learning methods: 1) decision tree, 2) support vector regression, and 3) item-based collaborative filtering method based on cosine similarity. We compare and contrast the methods based on accuracy, generalization, efficiency, and ``interpretability'' and discuss the implications of each method to strategic planning and urban design. While the accuracy and generalization of the three methods are comparable (<5% error), we note that decision tree methods are more intuitive and useful for policy makers as they provide immediate references to critical parameter values. In all cases, our results support the thesis that amenity-related features are better predictors than the more general ones suggesting that high-resolution geo-information data are essential for transport demand planning. We apply the framework to actual scenarios, specifically looking at Singapore's urban plan toward 2030, which includes the development of "regional centers" across the city-state. Our model reveals that there is an initial increase in transit ridership as the amount of amenities is increased which eventually reverses with continued strategic growth in amenities. The transition of these two trends for the Singapore example is the region when the increase in amenities is about 55% — a number that is potentially valuable for urban planners and policy makers.

Luis Arturo Rivas- Tovar

Complexity in Megacities Public transport system. The measure of efficiency by LART Model

SPEAKER: Luis Arturo Rivas- Tovar

ABSTRACT. The objective of this research is made a comparative analysis of the efficiency in the public transport system of Mexico City versus the transport systems of London and Madrid. Mexico City is comparable in terms of its demographic and territorial dimension, the complexity of its transportation systems in those two cities, and even its purchasing power parity, to the surprise of most Mexicans. The research method was the observational study and the documentary analysis using the case analysis method, evaluating three variables: Incentives to use public transport, disincentives to use private transport and public policies on transportation. As a result of the investigation it is concluded that there is a high efficiency in the case of Madrid and London and a low efficiency in the case of Mexico City whose system has had a sad involution in recent years. Three key actions are recommended to reverse the process: 1) Creation of a metropolitan consortium such as that exists in Madrid or London that integrates all models of transportation of the city, 2) To label the gas taxes to finance actions of improvement to the public transport. 3) The system of traffic restriction must reward the low emission of gases and the technologies that less pollute abandoned the populist drifts that have led to the involution of the transport system in Mexico City in recent years. The main public policy should be: Privilege and finance public transportation. The relevance of this work is that the control of efficiency is an issue in which there has not been work in Mexico and this is the first comparative inspection work published in Mexico. A model to measure and compere efficiency in Megacities is proposed as result of this research.

Alfonso Valiente-Banuet and Miguel Verdú

Human impacts on multiple ecological networks act synergistically to drive ecosystem collapse

SPEAKER: Alfonso Valiente-Banuet

ABSTRACT. Understanding the consequences of biodiversity loss is one of the most urgent tasks faced by ecologists and conservation biologists at present. Highly biodiverse ecosystems worldwide are rapidly losing species diversity as a result of human overexploitation of natural resources. However, it is not known whether there is a critical threshold of species loss at which a particular ecosystem fails to recover, leading to its collapse. This study was conducted in the Tehuacán-Cuicatlán Valley located in south-central Mexico, which is one of the most biologically rich, semi-arid regions of the Western Hemisphere. This area is characterized by a high degree of endemism among different taxonomic groups, such as columnar cacti and Agave species. In the vicinities of Los Reyes Metzontla town, human overexploitation of natural resources such as wood used for firing ceramics, as well as agave species for mezcal production has increased considerably. By combining multiple ecological networks (including plant facilitation by which most plant species recruit under field conditions, cacti and agave pollination, as well as cacti seed dispersal), we document how an ecosystem may collapse through synergistic disruptions to these networks. We simulated coextinction cascades across these ecological networks by removing from the facilitation network the plant species that were being overexploited by local inhabitants. To do this, a quantitative scenario was used in which nurse species extinction produces coextinction of their facilitated species, which concomitantly affect pollination and seed dispersal services. In addition, we tested simulation accuracy by comparing the species predicted to become extinct or to survive with the species present or absent in the disturbed areas where human overexploitation occurs. Finally, we experimentally tested whether the co-extinction cascades will lead to a shortage of bat dispersers, thereby inhibiting the arrival of new seeds to the ecosystem. We find that coextinction simulations triggered by the removal of only 16% of species show that extinctions are dramatically accelerated. In addition, we show that ecosystem collapses when the nurse species habitat availability is reduced to below 76% of its original extent. Although the interdependence of different ecological networks is indicative of ecosystem fragility and low resilience, our findings allow the design of remediation efforts, thereby helping to bridge the gap between ecology and conservation biology.

Cheryl Abundo, Ning Ning Chung, Lock Yue Chew and J. Stephen Lansing

Heterogeneous kinship practices generate an apparent cross-dressing in genetic diversity

SPEAKER: Cheryl Abundo

ABSTRACT. Migrations in traditional societies like Sumba and Timor are mostly motivated by marriage and the union of resources. Kinship practices, that define the post-marital residence rules of the villages, structure the way individuals move in the population. Individuals in endogamous villages prefer to marry within the existing clans of their village. Neolocality allows anyone regardless of gender to migrate out of their natal villages. Patrilocality and matrilocality have gender biased movements such that females frequently migrate out of patrilocal villages while males often choose to reside outside of their natal matrilocal village.

Uninformed hypothesis might lead us to expect individuals from matrilocal villages to be more related in the matriline since females stay after marriage, while individuals from patrilocal villages to have closer kins in the patriline since males reside in their natal village after marriage. However, genetic data from the Indonesian islands of Sumba and Timor tells us otherwise. And this is because villages cannot be considered in isolation. They exist within the context of a network of interacting villages, each possibly having a distinct kinship practice.

Using an n-deme model of kinship structured migrations, we observe the existence of the phenomena of trans-locality wherein the villages appear to cross-dress. That is, a village that in reality practices matrilocality shows a signal of ``patrilocality'' in that it appears to be more related in the patriline. Similarly, a patrilocal village may show a signal of ``matrilocality'' and appear more related in the matriline. This happens when (1) a mixture of different types of kinship practices exists in the population, (2) interaction of villages are limited such as when migration rates are low, or (3) kinship rules are not strictly followed.

Martin Zumaya and *Maximino Aldana*

Non-local interactions delay system's expansion and promote order in a collective motion model in open space

SPEAKER: *Martin Zumaya*

ABSTRACT. Collective motion is one of the more ubiquitous examples of coordinated behavior in nature and has been studied extensively in recent years both theoretically and empirically. Most of the current models of collective motion are defined within periodic boundary conditions or consider the system already in an ordered stationary state, so that when the particles' motion is unconfined and random initial conditions are taken into account, the system is not able to organize in a coherent moving group and all its components end up being spread out in space.

Addressing this issue, we propose a model of collective motion in open space based on local and non-local alignment interactions between particles, which is able to build up ordered states from random initial conditions and control the system expansion with very few non-local interactions per particle; the model also shows noise driven spontaneous collective changes of direction, an important feature observed in real systems.

We also show that the inclusion of non-local information in other models allows them to present the same behavior, suggesting that non-local information is an efficient mechanism to maintain the system's order and cohesion over time.

The need of non-local interactions results controversial with the general accepted idea of the competence of only local information to build up collective states and requires further study.

Alvarez-Martinez Roberto

Signatures of Criticality in Microbial Communities

SPEAKER: *Alvarez-Martinez Roberto*

ABSTRACT. Many of most interesting phenomena emerge from interactions among many elements. In particular, understanding the dynamics of complex ecosystems, such as microbiota, is one of the most challenging goals of our time. It has been argued that interactions between bacterial communities are dominated by two opposite regimes: a selection-dominated regime (the niche theory) and a stochasticity regime (neutral theory). In this work we use the rank-abundance distributions from stationary states in order to show that data are poised near to a critical point between these phases. Here we use distributions of OTUs' abundances and analogues to ensembles in thermodynamics (Renyi entropies and statistical ensembles) to find free energies. Remarkably, the distributions that emerge from the data are located at a very special point in their parameter space a critical point. This result suggests there may be some deeper principle behind the behavior of these interactions.

Omri Tal

Use of Information Theory in population structure analysis

SPEAKER: Omri Tal

ABSTRACT. There has recently been growing interest at borrowing both concepts and technical results from information theory for analysis in the biosciences. I will briefly review recent efforts at incorporating notions such as entropy and uncertainty, channel capacity, noise and distortion, and mutual information into biological settings. I highlight other manifestations of the notion of information, such as Kolmogorov complexity and Fisher information, of potential relevancy in a biological framework beyond merely as metaphorical tools. I then demonstrate novel conceptual and quantitative links between features of population genetic samples and a core information-theoretic property. In essence, long stretches of genetic variants may be captured as typical sequences of a nonstationary source modeled on the source population. This will provide motivation for constructing simple typicality-based population assignment schemes. I introduce the concepts of typical genotypes, population entropy rate and mutual typicality, and their relation to the asymptotic equipartition property. Finally, I propose a useful analogy between a communication channel and an inference channel, where channel noise results from fuzzy population boundaries and parameter estimation, and where the channel capacity closely corresponds to informativeness for population assignment.

Daniel Amor, Raul Montañez, Salvador Duran-Nebreda and Ricard Solé

Spatial dynamics of synthetic microbial hypercycles modulated by resource availability

SPEAKER: Daniel Amor

ABSTRACT. The hypercycle, the simplest model for autocatalytic cycles, early provided major theoretical insights on the evolution of mutualism. However, little is known about how natural environments could shape hypercycle dynamics. In order to explore this question, we used engineered bacteria as a model system for hypercycles. We recapitulate a variety of environmental scenarios identifying trends that transcend the specific model system, such an enhanced genetic diversity in environments requiring mutualistic interactions. Interestingly, we show that improved environments can slow down hypercycle range expansions as a result of genetic drift effects preceding local resource depletion. Moreover, we show that a parasitic strain is excluded from the population during range expansions (which acknowledges a classical prediction). Nevertheless, environmental deterioration can reshape population interactions, this same strain becoming part of a three-species hypercycle in scenarios in which the two-strain mutualism becomes non functional. Our results illustrate some evolutionary and ecological implications that will be relevant for the design of synthetic consortia for bioremediation purposes.

Linnéa Gyllingberg and David Sumpter

The evolution of reproductive helping through resource competition

SPEAKER: Linnéa Gyllingberg

ABSTRACT. Mathematical models have been widely and successfully applied in understanding the interplay of population structure and the evolution of social behavior. Here we ask whether helping and non-helping behaviour can co-exist in social groups, and importantly, what ecological factors affect this coexistence. We use two types of modelling techniques to examine this question. The first is an individual based model based on the lifecycle of social wasps and other colony founding species which compete for limited resource sites. The second is a mean field approximation derived from the individual based model. Both techniques use simple ecological parameters, such as number of offspring, effect of division of labour and dispersal distance. Using these two techniques, we find that the spatial structure of populations is critically important in allowing helping behaviour to evolve. Our broad approach to investigating helping behaviour highlights the importance of spatial effects in the evolution of social behaviours.

Aisling Daly, *Tim Depraetere*, *Jan Baetens* and *Bernard De Baets*

Bringing models of microbial systems closer to reality

SPEAKER: *Jan Baetens*

ABSTRACT. The functioning, dynamics and spatial structure of many microbial communities can be undoubtedly complex, and seemingly hard to describe mathematically. Still, mathematical biologists and modellers have succeeded in simulating their spatio-temporal dynamics in a convincing way using so-called individual-based models that track the features of every individual explicitly through space and time and account naturally for local interactions and spatial heterogeneities. Besides, it has been demonstrated that similar approaches are applicable to other organisms, such as mussels and nematodes, while it is generally acknowledged that individual-based models are well suited to formalize many types of complex systems. Typically, individual-based models of microbial communities merely incorporate the so-called mechanisms of life, being reproduction, competition and dispersal. At the same time, there is also a strong bias in literature towards communities consisting of only three species whose mutual interactions are governed by a deterministic competition structure, meaning that an individual of species A, for instance, will always outcompete one from species B. In reality, however, microbial communities consist of numerous species, the competitive strength of the species depends on its fitness, which, amongst other things, is governed by the substrate availability and prevailing environmental conditions, there is interaction between the microorganisms and their environment, and so on. Moreover, in microbiology it is now acknowledged that genetically identical bacterial cells in a well-mixed environment may have individually differing phenotypes.

In order to bring the existing individual-based models of microbial communities closer to reality, and hence to further our understanding of these complex systems, we explore in this work the effects of incorporating substrate uptake, varying community evenness and non-deterministic competition outcomes on the simulated community dynamics. In addition, we advance the existing models by accounting explicitly for the dimensions of the tracked individuals, another aspect that has been overlooked by most works in this direction. Our results indicate that long-term system behaviour is strongly dependent on initial evenness and the underlying competition structure. Generally speaking, a system with four species is unstable, but it appears that a higher initial evenness has a small stabilizing effect on the ecosystem dynamics by extending the time until the first extinction. Likewise, we observe a strong impact of introducing stochasticity with respect to the outcomes of competition events on the in silico dynamics in the sense that this stochasticity has a strong negative impact on the coexistence of species. Furthermore, we are able to show that there exists a trade-off between increasing biomass production and maintaining biodiversity, which is in agreement with experimental observations of a net negative biodiversity effect on biomass productivity.

Even though the above extensions make the individual-based models of microbial communities more realistic, they still neglect important mechanisms like adaptation, while also the interplay between the mechanisms of life and the environmental conditions remains veiled. Hence, we will pinpoint during our talk some promising avenues of further research in this exciting and rapidly evolving field.

Sabin Roman, Erika Palmer and Markus Brede

Dynamical system modelling of human-environment interactions: the case of the Classic Maya collapse

SPEAKER: Sabin Roman

ABSTRACT. Drought has often been invoked as a key reason for the collapse of the Classic Maya. However, socio-cultural processes must have played an integral part in the development of Maya society and subsequently its collapse. This study investigates the societal development of the Maya in the Southern Lowlands over a span of approximately 1400 years, which includes the Classic Period (300-900 CE). We propose a dynamical system model whose variables represent the major specialisations present within the society, the state of the land and the number of monuments built. Assuming a drastic rise in the practice of intensive agriculture, the model reproduces the time evolution of crude birth rates and population levels over 1400 years. Furthermore, the model also manages to reproduce the building rate of monuments throughout the Classic Period.

Parameter values were chosen to coincide with the literature values where available. We define a distance function by which we can measure the deviation of the model output from the empirical time series. We use this distance function to perform a thorough sensitivity analysis with respect to the key parameters in the model. What we find is that the model lies at a (local) minimum in the space of parameters and for changes in parameters values the deviation from the minimum is gradual and quasi-parabolic. Hence, no fine-tuning is present or needed and the sensitivity analysis shows that the model output is robust under parameter changes.

In addition, the model brings into question the role that drought played in the collapse. Our results indicate that a 50% reduction in rainfall does not significantly alter the outcome of the simulation with respect to the population levels. What the model is showing is that the land's production capacity might have already been severely exhausted and a reduction in crops unavoidable even in the absence of drought.

We have not tried to single out any one cause for the collapse of the Classic Maya but aimed at identifying a set of interlocking mechanisms that could spur a positive feedback in population growth and monument building. Also, we do not claim to have settled the long-standing problem of the Classic Maya collapse but rather hope to re-balance the discussion regarding the role of drought and socio-cultural factors.

Juan Manuel Torres-Rojo and Roberto Bahena

Scale invariant behavior of cropping area losses

SPEAKER: Juan Manuel Torres-Rojo

ABSTRACT. ABSTRACT This paper shows how agricultural disasters display Self-Organized critical behavior, which implies that under a wide range of circumstances, these disasters exhibit a power-law dependence on frequency in the affected area whose order of magnitude approximates those reported for extreme climate events. Self-Organized critical behavior has been observed in many extreme climate events as well as in the density and distribution of pests linked to crop production. Empirical proof is provided by showing that the frequency-size distribution of the cropland loss fits the Pareto and the Weibull models with scaling exponents statistically similar to the expected value. In addition, the test included comparisons of the expected value and the predicted value of the scaling exponents among different subsystems and among systems of the same universality class. Results show that the Pareto model fits the heavy tailed distribution of losses mostly caused by extreme climate events, while the Weibull model fits the whole distribution, including small events. The analyses show that crop losses adopt Self-Organized critical behavior regardless of the growing season and the water provision method (irrigated or rainfed). Irrigated systems show more stable behavior than rainfed systems, which display higher variability. The estimation is robust not only for calculating model parameters but also for testing the proximity to a power-law-like relationship. A long-term risk index by growing season and water provision method is derived as an application of this power-law behavior. The index is flexible, comparable among geographical units regardless its size and provides a direct measure of the probability to loss a cropping area.

Carolin Antoni, Elisabeth Huber-Sannwald, Anuschka Van't Hooft and Humberto Reyes-Hernández

FARMERS' LIVELIHOODS AND LAND USE CHANGE IN A TROPICAL AGRICULTURAL SOCIAL-ECOLOGICAL SYSTEM

SPEAKER: Carolin Antoni

ABSTRACT. Understanding the causes of land use dynamics and land cover change is fundamental in the light of targeting sustainable development. It requires insight into land use types and management practices and their complex relations to local farmers' livelihoods. Tropical small-holder livelihoods are based on subsistence and commercial crop production; hence land use type, management, and crop selection may depend on climatic conditions and socio-economic opportunities or constraints. This study examined the diversity of livelihood types associated with sugarcane production in Laguna del Mante, located in the tropical region of San Luis Potosí, Mexico. In particular, we examined how socioeconomic, political, institutional, and biophysical drivers contributed to differentiation in livelihood development and its respective changes in land use and management. In this locality, farmers' livelihoods depend mainly on the production of sugar cane (60.4%) for a local sugar factory and maize (30.6%) for self-supply. Participatory observations and 70 structured interviews were conducted to identify the key characteristics of different households with specific economic activities. The focus group of interviewees included "ejidatarios" and children of "ejidatarios", i.e. farmers with certain rights of communal land use. As we were interested in the analysis of different livelihood types in relation to land use/land use change, we linked land use variables to the following household categories: age, education, sources of income, and area of total land-holding and used for agriculture. To identify different livelihood groups considering the selected criteria hierarchical cluster analysis was applied. Based on the resulting dendrogram we distinguished among five types of livelihoods: sugar cane producers without and with irrigation system, diversifiers, sugar cane and livestock producers, and livestock producers. In Laguna del Mante, livelihoods mainly depend on sugar cane production in combination with wage labor opportunities both in a near-by foreign lime-factory and sugar cane harvest as an employee at the sugar cane mill. 55.3 % of the farmers changed from corn to sugar cane production in 1995, after the validity of the NAFTA, what caused changes in land property rights. 10,6 % of the farmers changed from corn to livestock production between 2000 and 2007 because of decreasing prices of corn. 76 % of the farmers decided to switch crops, because sugar cane was more profitable than corn or livestock, while 19,6 % were attracted by social benefits (pension, health insurance) provided by the sugar cane mill. External and internal socioeconomic drivers have been responsible for changes and adaptations in livelihood development and land use in Laguna del Mante. Over the last 30 years, the rise in agribusiness companies have fundamentally changed the nature of farming and thereby transformed diverse landscapes shaped by family-farming into monocultures of sugar cane at the high cost of eradicating the potential of agriculture-based livelihood diversification. Income from wage-labor in nearby factories may buffer temporary fluctuations in sugar prices, however these livelihoods are becoming increasingly vulnerable to unpredictable external drivers such as pest outbreaks, shifting markets, climate change, etc.

Giacomo Livan, Giuseppe Pappalardo and Rosario Nunzio Mantegna

Specialization in a heterogeneous environment: The case of Stack Overflow

SPEAKER: Giacomo Livan

ABSTRACT. The spectacular growth of online knowledge-sharing platforms has created unprecedented opportunities both to access and to create knowledge. The prime and most successful example of such environments is Wikipedia, with a vast number of other platforms (e.g., Quora, Reddit, Yahoo Answers, etc) providing users with a multitude of options to develop knowledge online. Most of such environments are largely decentralized and rely on the voluntary contribution of large numbers of users. This naturally gives rise to very heterogeneous systems, where a small minority of engaged users frequently contribute to the platform, while the vast majority of users contribute occasionally. An additional source of complexity is also related to the interests and specialization of the users: whereas some users develop a broad set of interests and contribute to the production of knowledge in several of them, other users specialize in a limited and well defined set of topics. In this work we study the evolution of specialization in Stack Overflow, the flagship site of the Stack Exchange network. Stack Overflow provides a discussion platform based on questions and answers on a wide range of topics related to computer programming, and it currently boasts more than 4 million registered users. We investigate Stack Overflow data spanning 8 years, going from August 2008 (shortly after the launch of the platform) to July 2016. For each month in the data we form two bipartite networks associated with questions and answers. Links in the networks connect users and tags, i.e. the identifiers associated with questions and answers (e.g., C++, Python, Matlab), and their weights denote the number of questions or answers that a user has posted which contain the tag in question. Within this framework, we identify specialization by resorting to network statistical validation techniques: we associate a p-value to each link by measuring the likelihood of observing a link of the same weight under a null assumption of random link reshuffling which, however, takes into account the heterogeneity in the users' activity. If a link's p-value falls below a multivariate significance level we label the associated user as a specialist of the corresponding tag. Our results show that the platform is essentially split up between users who specialize in posting questions and users who specialize in answering them, with very small transition rates between the two groups. Furthermore, we show that specialization in the answers network is considerably persistent, i.e. when users specialize in answering questions on a certain topic, they tend to keep doing so for several months in a row. However, when analyzing tags our results show that user specialization has evolved towards an increased concentration on a relatively restricted set of highly popular tags. Symmetrically, we show an increased similarity in the expertise profiles of specialist users, which in turn leads to an increased competition to earn the reputation points awarded by the platform.

Juan Carlos Pascual

Adaptive recover of the ecosystem in a remote Mexican island in the Pacific. Complex Dynamics of the Human Impact.

SPEAKER: *Juan Carlos Pascual*

ABSTRACT. Complex dynamic systems in the ecosystems can have abrupt shifts in the pelagic fish populations of islands and in the wildlife of the island, based on the human impact and new species introduced by man. The Clipperton Island in the Pacific, once Mexican territory is an excellent example of how marine ecosystem recovers from the impact of the periodic visits of human population during last century. The aim of this study explain the dynamics of this unique ecosystem near critical points, their generic properties, and transitions of possible bifurcation in the critical threshold that could become catastrophic. That will give us warning signs for the impact on ecosystems and at which point they can recover or adapt, before collapsing. The Clipperton Island had been studied by scientific expeditions from 1880 to the present and we are using this well-documented source of data about the fauna and flora of the island. The use of new technologies allows us to measure areas by satellite and aerial photography, from which comparison to photography of the 1900's can be compared. Human presence in the island is well defined by time and impact, from a period of 25 years (1892 to 1917, with introduction of new species to the island and impact on the population of species, later in 1958 a specific intervention to eliminate one species change the ecosystem and recently the presence of rats, new to the island also had an impact on the Ecosystem. We are using models with Lotka-Voltera equations, Time series analysis and Verhulst Model into the long period data available to find critical transition points and possible collapsing or transition of the ecosystem in Clipperton. We will make a trip in 2018 to validate such model and the predictive capacity of ecosystems.

Linda Russell and Said Abud

The hybrid modelling of socio-ecological systems epistemological issues and ontological considerations

SPEAKER: Linda Russell

ABSTRACT. This presentation reiterates Bourdieu´s argument concerning the importance of making manifest the epistemological basis for the construction of the research object. The issues arising from the hybrid modelling of SES are ones incumbent to the peculiarity of the Western world view based on the underlying ontological divide between the nature of being of human entities and that of the rest of the entities in the world. A host of epistemological incommensurability issues consequently arise from any attempt to explain the form of interaction of human and non-human systems using a hybrid model which reflects this basic divide of the naturalist ontology. One type of epistemological approach is characterised by the attempt to seek to sidestep these hybrid issues by adopting the concept of a material economy. One option is to consider the human solely in terms of bodies with material needs and hence “users” of “resources” and consider “nature” in terms of the supplier of those resources; so that positive change involves realistically pricing the resources nature “supplies”. Another option, is under the concept of social capital to consider human relations themselves as a resource which can be coupled in a variety of ways with ecosystem resources, and any change would need to be systemic. The second type of epistemological approach chooses to delineate hybrid or asymmetrical SES models, in which nature continues to be considered in terms of material biotic or abiotic systems, whilst human social systems are considered in non-material terms and, depending upon the theoretical framework, maintaining a particular form of interaction with the material world. This second epistemological group can be organised into three main theoretical types. The first option, considers human systems as constituted by rational autonomous reflexive agents, and their interaction with the natural world is on the basis of rational design with regard to an objective world of empirical facts, so that change must be cognitive, generally at the level of education and public policy. The second option, considers human systems as symbolic systems (or symbolic economies) into which humans are born and within which they assimilate the existing forms of interaction with other humans and non-humans, so that any option of change would need to be systemic. The third option, one which arises from Kant’s formulation of the difference between the, thing-in-itself and the thing-for-me, has been described as ineffabilist, and is based on the constructivist position regarding human knowledge with an ineffable realm beyond the limits of human cognitive systems, but possibly not beyond human interaction per se, whether it be artistic, spiritual, religious, or some form of bodily experience. Recently Descola, following Merleau-Ponty, suggests that the human body at an ontological level is a location of interaction with what Cooper refers to as the ineffable. The presentation considers the relevance of comparative ontological analysis, and also whether particular concepts such as that of memory (cognitive, material or genetic), body or habitus/habitat, possibly serve as a bridge to both epistemological and ontological divisions.

Edmundo Molina

Combining Data Science Methods and Mathematical Modeling for Analyzing Complex and Uncertain Socio-Technological Systems: An Application to Technology Based International Climate Change Mitigation

SPEAKER: *Edmundo Molina*

ABSTRACT. Considering social and technological systems in an integrated way is becoming increasingly important as many of our most vexing policy challenges occur at the intersection of society and technology. Yet, contemporary socio-technological systems are inherently complex and deeply uncertain. This paper describes an analysis framework by which Data Science Methods and Mathematical Modeling can be combined to provide useful and policy relevant analysis.

This paper exemplifies this approach considering the inherently complex and uncertain context of international climate change mitigation. The findings suggests that the combination of these methods can lead to the identification of robust, adaptive strategies for triggering low cost international decarbonization. Specifically, the framework helps illuminate under which conditions multi-country technology based policies can successfully enable the international diffusion of sustainable energy technologies at reasonable costs.

The study combines four interconnected analytical components. First, optimal climate policy response is determined through an Exploratory Dynamic Integrated Assessment Model (EDIAM) that connects economic agents' technological decisions across advanced and emerging nations with economic growth and climate change, making the system highly path dependent (i.e. chaotic property of sensitive dependence). Second, the EDIAM model is used in a mixed experimental design of a full factorial sampling of 12 general circulation models and a 300-element Latin Hypercube Sample across various technological properties of sustainable and fossil energy technologies (i.e. R&D returns, innovation propensity and technological transferability). Third, this large experimental database is analyzed using jointly two data mining techniques: scenario discovery methods (Bryant and Lempert, 2010) and high-dimensional stacking (Suzuki, Stern and Manzocchi, 2015; Taylor et al., 2006; LeBlanc, Ward and Wittels, 1990) which are used for characterizing quantitatively the vulnerability conditions of different policy alternatives. Finally, non-supervised learning algorithms are used to develop a dynamic architecture of low cost technology based climate cooperation. This dynamic architecture consists of adaptive pathways (Haasnoot et al., 2013) which begin with carbon taxation across both regions as a critical near term action. Then in subsequent phases different forms of technological cooperation are triggered in response to unfolding climate and technological conditions.

The application of Data Science Methods and rigorous Mathematical Modeling to the context of climate change demonstrates that optimal climate policy response is not an invariant proposition, but rather a dynamic one which adapts to unfolding climate and technological conditions. The analysis presented in this paper shows that different technological cooperation regimes across advanced and emerging nations are better suited for different combinations of climate and technological conditions, such that it is possible to combine different policies into a dynamic framework for low cost technological cooperation that expands the possibilities of success across the uncertainty space.

Theo Geisel, *Henri Degueldre*, *Ragnar Fleischmann* and *Jakob Metzger*

Random Focusing in Complex Media - Is it possible to Forecast Tsunamis?

SPEAKER: *Theo Geisel*

ABSTRACT. Wave flows propagating through weakly scattering disordered media exhibit random focusing and branching of the flow as universal phenomena. Examples are found on many scales from ballistic electron flow in semiconductor nanostructures [1-4] to tsunamis traveling through the oceans. Even for very weak disorder in the medium, this effect can lead to extremely strong fluctuations in the wave intensity and to heavy-tailed distributions [4]. Besides statistically characterizing random caustics and extreme events by deriving scaling laws and relevant distribution functions we have recently studied the role of random focusing in the propagation of tsunami waves [5]. We model the system by linearized shallow water wave equations with random bathymetries to account for complex height fluctuations of the ocean floor and determine the typical propagation distance at which the strongest wave fluctuations occur as a function of the statistical properties of the bathymetry. Our results have important implications for the feasibility of accurate tsunami forecasts.

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Lluís Arola-Fernández, *Albert Díaz-Guilera* and *Alex Arenas*

Synchronization Transitions Induced by Topology and Dynamics

SPEAKER: *Lluís Arola-Fernández*

ABSTRACT. We analyze structural transitions to synchronization in evolving complex topologies of Kuramoto oscillators. We give numerical evidence and analytical insight to a phenomena that is widely seen in nature. By constructing functionally equivalent networks and using mean field arguments, we are able to quantify the close relation between structural and dynamic perturbations in a quasi-static process, where the changes in the macroscopic response can be induced by the coupling strength and the topology of the network.

Jean-Guy Caputo, *Imene Khames*, *Arnaud Knippel* and *Panayotis Panayotaros*

Periodic orbits in nonlinear wave equations on networks

SPEAKER: *Imene Khames*

ABSTRACT. We consider a cubic nonlinear wave equation on a network and show that inspecting the normal modes of the graph Laplacian, we can immediately identify which ones extend into nonlinear periodic orbits. Two main classes of nonlinear periodic orbits exist: modes without soft nodes and others. For the former which are the Goldstone and the bivalent modes, the linearized equations decouple. A Floquet analysis was conducted systematically for chains; it indicates that the Goldstone mode is usually stable and the bivalent mode is always unstable. The linearized equations for the second type of modes are coupled, they indicate which modes will be excited when the orbit destabilizes. Numerical results for the second class show that modes with a single eigenvalue are unstable below a treshold amplitude. Conversely, modes with multiple eigenvalues seem always unstable. This study could be applied to coupled mechanical systems.

Alvaro Diaz-Ruelas and Alberto Robledo

Crossover between statistical-mechanical structures in the dynamics associated with chaotic attractors at band-splitting points

SPEAKER: Alvaro Diaz-Ruelas

ABSTRACT. We consider both the dynamics towards and within the chaotic attractors at band-splitting points in the route out of chaos in unimodal maps [1, 2, 3]. We find two kinds of statistical–mechanical structures associated with the dynamics separated by a crossover episode. The structures correspond, respectively, to the dynamics towards and the dynamics within the attractor, and the crossover reflects the arrival at the attractor. In the first regime the partition function consists of the sum of the chaotic-band widths and the associated thermodynamic potential measures the rate of approach of trajectories to the attractor. The statistical weights are deformed exponentials. In the second regime the partition function is made of position distances within the attractor bands and the statistical weights become exponential. The time duration of the first regime increases as the number of bands 2N increases, and in the limit $N \to \infty$, the chaos threshold, it becomes the only statistics, when phase-space contraction leads to a set of zero measure. We discuss our findings in terms of the approach of a system to equilibrium.

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[2] Diaz-Ruelas A., Fuentes, M.A., Robledo, A., Scaling of distributions of sums of positions for chaotic dynamics at band-splitting points, Europhysics Letters, 108, 20008 (2014).
[3] Diaz-Ruelas, A., Robledo, A., Sums of variables at the onset of chaos, replenished, European Physical Journal Special Topics 225, 2763 (2016).

Javier Livas

Kubernetes

SPEAKER: Javier Livas

ABSTRACT. Kubernetes is a fiction “edudrama” about the past, present and future of Cybernetics. The writer and producer of the film was a very close friend and disciple for more than 20 years of Stafford Beer, the creator of Management Cybernetics and author of many groundbreaking books, among them The Brain of the Firm and The Heart of Enterprise. Stafford Beer was also the chief scientist behind the creation of PROJECT CYBERSYN in the early 1970’s. The project died with the abrupt ending of Salvador Allende’s tenure as President of Chile in September 11th, 1973.
In this film, many of Stafford Beer’s ideas are discussed, including a look at the iconic “operations room”. The plot has ramifications to the 1970’s as a group of beautiful minds with very different cybernetic backgrounds are invited to a meeting to find a way to change the world by changing the way organizations of all types operate. Each one of the organizer’s guest brings a statement to the meeting. Once there, they ask questions about the issue of complexity, religion, government, Newtonian science, the purpose of human beings, criticize organizations and reflect on the possible existence of God.
The screening will be followed by a Q&A session with the writer and producer of Kubernetes.
[Mexico, 2017, 95 min. In Spanish with English subtitles]

James Pang, Erika Fille Legara and Christopher Monterola

Understanding the dynamics and robustness of multilevel marketing via dendritic growth model

SPEAKER: Christopher Monterola

ABSTRACT. Multilevel marketing (MLM) scheme (a.k.a. network marketing) uses “word of mouth” strategy to sell products and grow its members through recruitment, exploiting the network connections of its members. MLM has been proven to be effective as such marketing program has allowed companies to sell products to the tune of 180 billion US dollars in 2014 alone, more than twice the sales of the video gaming industry and about a dozen times more of the music industry. Here, we demonstrate how biologically inspired dendritic network growth can be utilized to model the evolving connections of an MLM enterprise and develop insights on its inherent dynamics. Starting from agents situated at random spatial locations, a network is formed by minimizing a distance cost function controlled by a parameter, termed the balancing factor bf, that weighs the wiring and the path length costs of connection. The paradigm is compared to an actual MLM membership data and is shown to be successful in statistically capturing the membership distribution, better than the agent based preferential attachment or analytic branching process models. Moreover, it recovers the known empirical statistics of previously studied MLM, specifically: (i) a membership distribution characterized by the existence of peak levels indicating limited growth, and (ii) an income distribution obeying the 80-20 Pareto principle. Extensive types of income distributions from uniform to Pareto to a \winner-take-all" kind are also modeled by varying bf. Finally, the robustness of our dendritic growth paradigm to random agent removals is explored and its implications to MLM income distributions are discussed. Our research, well-anchored on the growth dynamics observed in actual dendrites, provides some groundwork in which the profitability and the equality of earnings among members of an MLM scheme can be evaluated.

Laura Hernandez, Annick Vignes and Stéphanie Saba

The role of social interactions in market organization

SPEAKER: Laura Hernandez

ABSTRACT. What is the role of social interactions in trading? While it is clear that human beings rely on cooperation with others for their survival, the economic theory suggested for a while that auction markets, where the information is the same for all the actors and there is no possibility of arbitrage are an efficient way of organizing the exchanges. Following on, a vast literature has promoted the auction theory. More recently it has been argued that when goods are heterogeneous and there exists no signal of quality, a decentralized mechanism (bilateral transactions) allow people to gather information and better evaluate the intrinsic quality of goods. In order to study the role of markets' structure one needs to compare centralized and decentralized markets functioning under the same conditions . This rare situation is found in the Boulogne-Sur-Mer Fish Market, where every day, the actors can freely choose to exchange either through a bilateral process or through an auction one, both sub-markets functioning simultaneously, at the same location. This old daily market, which had operated historically in a decentralized way, was led by EU regulations to adopt a centralized structure. This new regulation was firmly rejected by economic actors and, in 2006, it was finally admitted to allow the auction and bilateral negotiation sub-markets to function in the same place. Since then, detailed data concerning the daily transactions is registered, allowing for a comparison of both sub-markets under same economic, seasonal, climatic and social, conditions. Following Economic theory, if one market structure were more efficient than the other, one would expect that one market overtakes the other. It is then interesting to understand the reasons that explain their coexistence. In this work we focus on the interactions among buyers and sellers, therefore we map data on to a complex bipartite network. We analyse these networks using the tools developed for the study of mutualistic ecosystems , like plant-pollinator networks. The pattern of interactions observed in such systems displays a particular structure called nestedness. We investigate if a similar pattern, revealing some degree of organization is observed in either of the studied sub-markets. This method also allows us to define a loyalty index, measuring the relative frequency of interaction of a couple of sellers-buyers with respect to their total number of interactions during the period. We show that the loyalty distribution characterizes each market. It is scale-free in the bilateral negotiation market and on the contrary, it shows a characteristic value beyond which the loyalty rapidly decreases in the auction one. On the other hand, the auction market appears to be more robust face to targeted attacks that consist on eliminating, high degree agents. Our results show that each market has a characteristic property : the development of trust relationships in the bilateral market and the robustness of the auction one. This complementarity may be at the origin of their observed coexistence.

Vladimir Petrov, Anton Golub and Richard Olsen

Agent-Based Model and Directional Change Intrinsic Time for Market Simulation

SPEAKER: Vladimir Petrov

ABSTRACT. One of the most attractive topics for researchers from the world of finance is theoretical models of complex networks based on interacting agents behaviour of which coincides with the actions of real market participants. These models can be used to better understand the structure of financial markets and to test different theories on the synthetically generated time series. One of the main reasons why the agent-based models have been often used for this research question is a well-known fact that time series of real financial markets have several statistical properties, called stylized facts, which cannot be replicated by simple Geometrical Brownian Motion (GBM) for years used as the main benchmark in the market analysis. These stylized facts include fat-tailed distribution of returns, the absence of autocorrelations, volatility clustering and others. In some of the analytical solutions, authors try to overcome this problem by adding jumps or stochastic volatility to the model based on the GBM. Results, achieved by this enhancement, are much more precise but the solution of the problem also becomes much more complex.

In our work, we developed an agent-based model which is also designed to replicate the abovementioned stylized facts, but, unlike many others models, our network of interacting agents is extremely simple. Each agent has only one factor which determines whether the agent is going to buy or sell fixed volume of the traded asset at a given moment of time. The decisive factor is a tick of the directional change intrinsic clock which ticks when the price experiences a reversal of a given fixed threshold from the local extreme. Thus, the only source of information used by the agents is the price itself. All agents from this network receive a new price quote and analyze it using their individual intrinsic time mechanism. Since square root function is a good approximation of the volume impact, the generated by the agents net volume moves price upward or downward to the size of the square root of this volume. Surprisingly, even such trivial system is able to successfully go through several benchmarks. First of all, we checked if the generated by the intrinsic events agents set of prices replicates stylized facts mentioned before. In addition, we verified the presence of one more scaling law which was the first time presented by Glattfelder et al. in 2011 and is universal for all markets: the overshoot scaling law. This stylized fact states that the average distance between a directional change point and the previous extreme price (called overshoot) is equal to the length of the corresponding directional change price moves. Finally, the number of the intrinsic event agents with long and short positions was compared to the position information from a big forex and CFD exchange OANDA. Even in this experiment the shape of the generated position ratios mostly had the same shape which we can detect in the real market.

In general, analyzed time series, generated by the introduced agent-based model, and prices from Forex market demonstrate striking resemblance of their statistical properties. Taking into account simplicity and even primitiveness of the constructed model, we conclude that the underlying directional change intrinsic event approach indeed can shed some light on the market's nature, agents' behaviour and the cumulative impact they have on the structure of financial markets.

Juan Hernandez and Casiano Manrique de Lara Peñate

Topological characteristics of economic transaction networks

SPEAKER: Juan Hernandez

ABSTRACT. Economic networks play a central role in the exchange of goods and services. Studying the network structures underlying these trade relations should help understand the way agents interact and how the trade flows evolve.

The information requested by some administrative tax requirements can be of great help towards analyzing these economic flows. One such example is the information required to buyers and sellers on their exchanges in most legislation on VAT. Following this legislation, buyers and sellers are obliged to declare those transactions that exceed a certain level. Since both sides of the trade are obliged to reveal their operations, both statements should coincide. However we find situations where only one of the sides declare the transaction and others where both declare different amounts. Using the information of such flows for a region in Spain during year 2002, we have generated a network of transactions. In this network, all edges are directed from buyer to seller.

There are actually six different networks: (1) Joint, it includes both the buyer and seller declarations, an edge appears if an operation between two operators is declared; (2) Matched, an edge appears between a buyer and a seller if their respective declared amounts agree exactly; (3) Matched ?10%, similar to previous one when the declared amounts disagree by less than a ?10% margin; (4) Differed amount, the edges are defined between operators if their respective declared amounts between them disagree by more than a ?10% margin; (5) Non reciprocal buyer, an edge appears between operators if a seller declares an operation, which is not declared by the buyer; (6) Non reciprocal seller, in this case, the edge appears if a buyer declares an operation, which is not declared by the seller. These last two groups need further filtering processes since some agents are not obliged to declare, what could justify the existence of many of these “missing” links.

An initial statistical analysis of the six empirical networks was conducted and some revealing results were found. For example, the different buyer/seller declaration networks present small-world effect, as usual in many real networks. Moreover, some of them also exhibit a power-law fit. In particular, the Matched network presents a gamma-parameter clearly higher than those for differed or non-reciprocal declaration networks. This observation shows that a specific topology of the matched declaration network is presented, which point to a macroscopic behavior for the individuals belonging to this group different to the rest of operators.

Ian Wood, Jaehyuk Park, Yizhi Jing, Azadeh Nematzadeh, Michael Conover and Yong-Yeol Ahn

Labor flow network reveals the hierarchical organization of the global economy

SPEAKER: Ian Wood

ABSTRACT. The global economy is a complex interdependent system that emerges from interactions be tween people, companies, and geography. Understanding the structure and dynamics of the global economy is critical for adapting to its rapid reorganization. While the network framework has uncovered insights into the evolution of national economies [1], existing frameworks cannot expose the organization of industries that arises across a wide range of geographical scales, nor capture the full spectrum of industries. Here, we construct a global labor flow network [2] from a dataset from LinkedIn, the largest professional networking service, and reveal the deep hierarchical organization of industries. Furthermore, we demonstrate that geo-industrial clusters organically identified by network community detection can serve as a more coherent unit for studying the growth and decline of industrial sectors.

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Samuel Fraiberger, Roberta Sinatra, Christoph Riedl and Laszlo Barabasi

Reputation and Success in Art

SPEAKER: Samuel Fraiberger

ABSTRACT. How does an artist's reputation evolve and how does it affect the success of his endeavors? To shed light on these questions, we have collected a unique dataset on 463,632 artists between 1980 and 2016 and across 142 countries. We document the existence of a rich club of prestigious artistic institutions, and a poor club of institutions of low prestige. The evolution of an artist's career is strongly impacted by the prestige of the institutions in which his work was first exhibited. His chance of success in the auction market can be improved by exhibiting in more venues, appealing to a more international audience and exhibiting at institutions of higher prestige. These findings have implications on our understanding of the role reputation plays in cultural markets.

Juan Sebastian Ivars and Daniel Matias Fernandez

Market equilibria with imperfect information and bounded rationality

SPEAKER: Daniel Matias Fernandez

ABSTRACT. In Microeconomics, the First and Second Welfare Theorem assume the existence of perfect information in the market prices, that is, they contain all relevant information for decision making and are available permanently for all the agents. However, these assumptions are little strong. As a consequence, the economists have developed diverse tendencies whose objective is to analyze the behavior of the agents in front of the existence of asymmetries in the information that they have. In this work, is made an approach allowing the existence of these asymmetries, but also, considering that the agents have biases in their decision making and, consequently, they develop a learning mechanism on market prices. Through this process they define their roles as buyers or sellers within the market in order to maximize their individual utility. Thus, a model of complex systems known as Naming game is used as motivation, which allows the implementation of a first stage of learning costless (cheap talk), based on the random interaction of the agents, and a second stage, where they make decisions, participate in the market and obtain new information from their particular experiences. Through this trial and error mechanism, the agents reach a stable equilibrium. This is integrated into a computational agent-based model, which is set on a single set of valuations, simulating the interactions, decisions and evolution of buyers' preferences over T periods. Since the algorithm has a random component in its calculations, the same case is repeated N times, in order to distinguish those patterns that result from non-deterministic behavior, and those that persist due to the restriction in the assumption of perfect information. To draw conclusions from the data, it required to repeat the algorithm numerous times, in order to verify how it behaved in front of different set of valuations. In this sense, the first results are consistent with the traditional approaches: the information about prices is very important to achieve a paretian equilibrium, and this is not often achieved. However, it also demonstrates that agents can build market power by knowing their relative valuation early. As one could intuit, those agents that determine their role as firms within the market and start selling early, may have a greater impact on the preferences of agents perceiving themselves as buyers, which gives them an advantage in long term, and therefore, higher profits at the end of the simulations. This is not surprising, and seems to indicate that it is not just about having accurate information about market prices, but about having it just in time.

Christopher Stephens, *Hugo Flores* and *Ana Ruiz*

The Evolution of Complexity seen as a problem of Search: Can we predict a priori which search algorithm will work best on which problem?

SPEAKER: *Christopher Stephens*

ABSTRACT. Much of science, both in the physical and biological domains, can be characterized as a problem of search. The reason why is that all systems - physical, biological, ecological and social - are composed of hierarchies of building blocks - atoms, molecules, cells, tissues, individuals, species etc. with corresponding interactions - and the dynamics of such systems is characterised by a search through the space of possible configurations. Nucleosynthesis and biological evolution are examples of search algorithm wherein some consequences of the search were large nuclei, such as iron, formed from many protons and neutrons as constituents, and the human eye? Both were formed via a search algorithm that constructed a hierarchy of intermediate building blocks. Yet, we know very little about why one search algorithm is preferred versus another. There are, in principle, many ways by which iron nuclei and eyes could be formed. The No-Free Lunch theorems assure us that no search algorithm, no matter how complex, is better than any other, and, moreover, no better than random search, when considered over all possible problems. So what characteristics do the “problems” of nucleosynthesis and evolution possess that implies that a given search algorithm exists that is better than another? Here we will consider this problem in the context of machine learning – which search algorithm works best on which problem? In spite of the No Free Lunch theorem, a great deal of research in machine learning is associated with looking for a “magic bullet” algorithm that offers better performance across multiple problem areas, where multiple algorithms are compared and contrasted across multiple test data sets to determine which one performs best on average across the whole spectrum. Unfortunately, the variance in performance of a given algorithm between different problems is far greater than any average performance enhancement across many problems, as one would well expect given the No Free Lunch theorem. The fundamental question is: which search algorithm is appropriate for which problem? Knowing that no single one is better than any other across all problems. Can we predict a priori which algorithm will perform better on which problem, and what problem diagnostics will help us to predict? Here, I will present research that begins to answer this question, using as an example a set of much used machine learning algorithms: the Naive Bayes approximation, and generalisations thereof (AODE, WAODE, HBA), as well as some standard tree-based algorithms. We will present statistical diagnostics that examine the correlation structure between the variables of a search problem, use them to characterise the problem and then to predict what algorithm type will perform best. We thus end up with a meta-prediction algorithm that predicts which algorithm will work best on which problem. We will discuss the opportunities and challenges that arise from this research and relate it back to the problem of understanding both physical and biological evolution as search problems.

Jorge Flores, *Sergio Sanchez*, *Carlos Pineda* and *Carlos Gershenson*

The Shifting Traveling Salesman Problem

SPEAKER: *Jorge Flores*

ABSTRACT. The traveling salesman problem (TSP) is central in the field of combinatorial optimization. A salesman must visit several cities exactly once, return to its starting point and should do it following the shortest path. It is therefore a problem which can be stated in a simple form but which is extremely difficult to solve. It represents a complex system, indeed, and many different techniques have been used in the past to deal with the properties of the TSP. In particular, the rank distribution has been studied. To do this all trajectories that the salesman can follow are given a rank according to the path length. The lowest rank corresponds to the shortest path (i.e. the one looked for in the standard TSP) and the highest rank is given to the longest trajectory. The distribution is found to be a Beta distribution.

The rank distribution is inherently an instantaneous measure, in the sense that it captures ranking at a given time and does not take into account how ranks change under perturbations. To tackle this problem we have introduced the rank diversity which is a measure of the number of different elements occupying a given rank over a length of time. In order to do that for the TSP, we consider two time-dependent traveling salesman problems.

The first model, which we shall call the relocation of sites, consists in picking a subset of sites at random and afterwards locate them at new positions with random coordinates. All the trajectories are given a new rank. Proceeding now with the new map, the random annihilation and creation process is repeated (with the same subset), and a rank is given to the new trajectories. The procedure is repeated several times, and the rank diversity is calculated. It has a semicircle form, with small values for low and large ranks.

The second model is obtained if one lets the sites move, as if they were boats instead of cities, with random velocities. The rank of a given trajectory changes with time, and the rank diversity can be obtained. The shape of it is the same in all situations and very similar to the one obtained with the first model.

From our calculations, and previous work in languages [PLoS ONE 10(4): e0121898 (2015)] and sports [EPJ Data Science 5:33 (2016)] it seems that the rank diversity is a general property of complex systems of very different nature.

Mile Gu, *Mathew Palsson*, *Joseph Ho*, *Howard Wiseman* and *Geoff Pryde*

Realizing Simpler Quantum Models of Complex Phenomena with present day Quantum Technology

SPEAKER: Mile Gu

ABSTRACT. Mathematical modelling of observable phenomena is an indispensable tool for engineering new technology, understanding the natural world, and studying human society. However, the most interesting systems are complex, such that modelling their future behaviour demands immense amounts of information regarding how they have behaved in the past. From a theoretical perspective, such processes to not admit simple models where there is a succinct characterization of what elements of the past are meaningful for future prediction. From an operational perspective, the adoption of such models in computer simulators require immense amounts of memory.

In this talk, we discuss recent experimental efforts to reduce this cost by use of quantum technology. We first review recent developments, where it was shown that the statistical complexity of general complex processes – a quantifier of how much information one must store about the past of a process to simulator its future – can be drastically reduced by use of quantum information processing [1]. We then introduce our recent proof-of-principle experiment, where each bit is replaced with a quantum bit (qubit) encoded with the polarization states of a photon [2]. Our quantum implementation observes a memory requirement of 0.05 ± 0.01, far below the ultimate classical limit of $C = 1$. We discuss the unique features of such quantum models and potential extensions, such as their capacity to output quantum super-positions of different conditional futures and potential generalization to simulate general input-out processes [3].

The talk is designed to be accessible to audiences with minimal knowledge of quantum theory.

[1] Nature Communications 3, Article number: 762 [2] Science Advances 03 Feb 2017: Vol. 3, no. 2, e1601302 [3] Nature Partner Journal: Quantum Information 3, Article number: 6

Jayne Thompson, Andrew Garner, John Mahoney, James Crutchfield, Vlatko Vedral and Gu Mile

Causal Irreversibility in a Quantum World

SPEAKER: Jayne Thompson

ABSTRACT. In computational mechanics there is significant interest in how much information must be communicated from past to future in a process. This quantity is known as the process's statistical complexity, and is a widely adopted quantifier of structure and complexity [1]. Operationally it captures the minimum amount of information any predictive model must record about the past, in order to make statistically accurate predictions about the future.

Surprisingly the statistical complexity generally displays an asymmetry in time. If you take a process and reverse the temporal order of events, so that the past becomes the future and vice versa, then in general the statistical complexity will change. This divergence has been heralded as a source of time's barbed arrow in complex processes [2,3].

Here we examine what happens to this arrow of time in the quantum domain. Recent advances show the potential for quantum mechanics to instigate predictive models that store less past information than any classical counterpart [4,5]. This motivates an interesting possibility –- the barbed arrow of time may arise in the process of classicization. Can a stochastic process exhibit an arrow of time when modelled classically, yet have this arrow vanish when quantum models are considered?

In this talk we answer this question in the affirmative, by directly constructing a process where there is a classical arrow of time, but at the quantum level this arrow vanishes. Our work suggest that this arrow of time could be an artefact of forcing classical causal explanations in a fundamentally quantum world.

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Leonardo Ermann

Complex networks, Google matrix and quantum chaos

SPEAKER: Leonardo Ermann

ABSTRACT. The Google matrix G of a directed network is a stochastic square matrix with nonnegative matrix elements and the sum of elements in each column being equal to unity. This matrix describes a Markov chain of transitions of a random surfer performing jumps on a network of nodes connected by directed links. This matrix is the fundamental part of the origin of the crawler. In this talk I will show some spectral properties of this matrix for real matrices coming from different fields as computer science and economics or built from models of chaotic systems. We will use tools coming from the field of quantum chaos to study this networks [1-3]. We will analyze the eigenvectors of the matrix which can be related with network communities. Other interesting result will be that the number of long lived eigenvalues of the matrix is associated with the fractal dimension of the network. Also a two dimensional ranking of the networks will be defined using the time inversion of PageRank, and using phase-space properties developed in dynamical systems. The relationship between this two different fields as "complex networks" and "quantum and classical chaos" would be clarified in this talk with different examples of real networks.

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Predrag Tosic

Modeling Open and Closed Cyber-Physical Systems with Graph Automata and Boolean Network Automata

SPEAKER: *Predrag Tosic*

ABSTRACT. We are interested in suitable abstractions and formal dynamical systems foundations for modeling, analysis and behavior prediction of a broad variety of critical cyber-physical infrastructures. In that context, we have been investigating prediction and characterization of asymptotic dynamics of several classes of Boolean Network Automata (BNA) and Graph Automata (GA) such as Discrete Hopfield Networks, Sequential/Synchronous Dynamical Systems, and (parallel, sequential and asynchronous) Cellular Automata (CA). Within that general framework, one line of our recent research has been on identifying the key differences in behavior between open vs. closed cyber-physical systems (CPSs), abstracted as various types of BNA and GA.

A closed CPS can be formalized as a BNA or GA in which each node is an "agent" whose local interactions and therefore possible behaviors we know; the challenge then is, to characterize and/or predict the emerging behavior or collective dynamics of an agent ensemble. We note, that the typical sizes of such agent ensembles, in the context of applications of our interest (such as ensembles of unmanned autonomous vehicles, smart sensor networks, power micro-grids, etc.), range from a few hundred in the smaller-scale CPSs to many thousands. Moreover, in the context of other applications of BNA and GA models, such as biological and life sciences or computational social sciences, the underlying "networks" may have millions or more of autonomously or semi-autonomously (inter-)acting agents. In contrast to the closed systems, in an open CPS (or other complex network of interacting agents), not all "nodes" correspond to agents whose local behaviors are known; some nodes may correspond to external agents whose behavior may be unknown, or to other ("non-agent") aspects of the environment that may be exercising influence on our agents in potentially complex and unpredictable ways. Importantly, those who design, analyze and/or monitor the underlying cyber-physical system in general have little or no control over the external agents, the "control nodes" or other behavioral aspects of the "environment".

We identify several interesting aspects of the global behavior and asymptotic dynamics of such distributed cyber-physical and other networked systems, abstracted as BNA, GA or CA. Our focus is on the differences in asymptotic behaviors between open and closed such systems with the same or similar "types" of simple deterministic individual agents and same or very similar (sparse) network structures. Furthermore, to make the open vs. closed system dynamics differentiation as sharp as possible, we severely restrict the allowable kinds of impact of the "control nodes" or "external environment" on the agents whose collective dynamics we are trying to understand. Our formal study of the systems dynamics, therefore, is done by mathematically and computationally analyzing the configuration space properties of the appropriately restricted types of BNA, GA and CA. In this talk, we mostly focus on those properties capturing the underlying system's asymptotic collective dynamics. In that problem setting, we summarize several recent theoretical results that establish a provable "complexity gap" in the dynamics of closed vs. open systems in a formal BNA/GA based setting.

Raul Toral, Maxi San Miguel and Agnieszka Czaplicka

The biased voter model

SPEAKER: Raul Toral

ABSTRACT. The voter model is arguably the simplest and one of the most widely studied out-of-equilibrium models with application to different scenarios of social interest. The rules are very simple: consider a network such that in each node lies an agent capable of holding one of the possible values of of a binary variable. Then, a node is randomly selected and the agent in that node copies the value of the variable held by another agent in another randomly selected connected node. Most of the literature assumes that both values of the binary variable are equivalent. In this work we focus in the situation where there is a bias towards of the two values. This situation has been considered previously as, for example, indicating the lack of asymmetry in the social preference for one or another language in a bilingual community. We introduce bias by letting a fraction of the agents to copy with a higher probability one the two options (the preferred option). We first assume that there is no correlation between the connections of the biased agents and revisit some of the results about the dependence of the time to reach consensus as a function of the bias parameter. We then ask the question of how the ratio of the density of connections between biased nodes (B) and unbiased nodes (U) influences the behavior of the system. To this end we use two different strategies to connect nodes and compare the results with the random network. Both strategies keep the same average degree and the total number of links as in a random network of the same size. Case I assumes that we cut links between unbiased nodes and draw additional links between biased nodes (i.e. a UU node becomes BB. The strategy in case II is to rewire links to increase the number of biased-biased connections (BU becomes BB) or to decrease the number of unbiased-unbiased connections (UU becomes UB), keeping the degree of each node constant. It seems that a crucial role for reaching consensus are the degrees of biased and unbiased nodes, rather than the number of links between pairs of biased or unbiased nodes. Even if the majority of the nodes is biased but weakly connected, the probability to reach consensus in cases I and II cannot be larger than in a random network. On the other extreme case, when biased nodes form a well-organized minority, case I gives higher probability to order for the preferred state. In the thermodynamic limit any non-zero value of the bias leads to preferred consensus. In contrary, when the network is finite, there is always a chance to order in the not preferred state. For random network case we find that behavior of the system depends of the effective bias, which is the value of bias parameter multiplied by the number of biased nodes. When the topology is not random that scaling disappears. Our analytical results are supported by numerical simulations.

Luis Tamayo Pérez

Dismantling the generalized dumbing process: a key to the mitigation of climate change

SPEAKER: Luis Tamayo Pérez

ABSTRACT. Dismantling the generalized dumbing process: a key to the mitigation of climate change Luis Tamayo, PhD

As described by numerous studies (Kolbert, 2014), humanity is on the way to the sixth extinction of the species. This phenomenon is not only anthropogenic but derives from social control and dumbing process described in various ways by numerous authors (Diamond, 2007; Klein, 1999, 2007, 2014; Tamayo, 2010). Understanding the nature of such a process is a key element to the formulation of viable proposals for global warming mitigation.

Hugo Hernández Saldaña

Partisanship or corporatism: a comparison of models and actual data in Mexican elections

SPEAKER: Hugo Hernández Saldaña

ABSTRACT. How we vote and what influence it deserved a lot of attention of physicists and mathematicians during the last two decades. Models and searches of "power laws" in electoral results are in the current literature. However, unfortunately, politician are involved within and deviations from models appear. In this work we discuss how corporatism, more than partisanship, plays a role in elections in Mexico. We use actual data from the federal elections during the last fifteen years. We look for some evidence of such a behaviour in Indian and Argentinian elections.

Lucas Almeida

Shadow Capital: Emerging Patterns of Money Laundering and Tax Evasion

SPEAKER: *Lucas Almeida*

ABSTRACT. Among the many social structures that cause inequality, one of the most jarring is on the use of loopholes to both launder money and evade taxation. Such resources fuel the "offshore finance" industry, a multi-billion dollar sector catering to many of those needs. As part of the push towards greater accountability, its crucial to understand how these decentralized systems structure and operate. As its the usual case with emergent phenomena, the efforts of law enforcement have had limited effects at best. Such challenge is compounded by the fact that they run under the logic of "Dark Networks" avoiding detection and oversight as much as possible. While there are legitimate uses for offshore services, such as protecting assets from unlawful seizures, they are also a well documented pipeline for money stemming from ilegal activities. These constructs display a high amount of adaptiveness and resilience and the few studies done had to use incomplete information, mostly from local sources of criminal proceedings.

The goal of this work is to analyze the network of offshore accounts leaked under the “Panama Papers” report by the International Consortium of Investigative Journalists. This registers the activities of the Mossack Fonseca law firm in Panama, one of the largest in the world on the Offshore field. It spans over 50 years and provide us with one of the most complete overview thus far of how these activities are networked. There are over 3 million links and 1.5 million nodes, with accompanying information, including time of operation, ownership and country of registry.

The preliminary analysis already performed by cleaning the dyadic relations allow for a snapshot of this universe, which is very receptive to the metrics already current in network science. The betweenness centrality of nodes is extremely skewed, with less than a hundred being the “backbone” of the system, mostly on countries that are already known to be tax heavens (like the Cayman Islands , Bahamas and Jersey). The degree distribution is very similar to the power-law produced by the Bianconi-Barabasi model of preferential attachment with changing fitnesses. These patterns will be explored in order to better understand the evolution of the system. This work will also model how different strategies of law enforcement intervention can disrupt the flow of illegal resources by testing local(and network-level) targeting metrics.

By crossing the methods from data analysis with the public policy perspective, we expect to contribute to the literature of compliance, as well as the growing field of dark networks. It can also provide an important baseline for understanding other recently uncovered schemes such as the “Car Wash” scandal in Brazil. The perspective of complexity is uniquely well-positioned to shed light on this enigma that neither economics nor law alone have been able to tackle.

Luís F Seoane, *Xaquin Loredo*, *Henrique Monteagudo* and *Jorge Mira*

Is the coexistence of Catalan and Spanish possible in Catalonia?

SPEAKER: *Luís F Seoane*

ABSTRACT. The dynamics of language shift have received a lot of attention during the last decades. Non-linear differential equations inspired by ecological models [1] have been widely used to reconstruct how two tongues would coexist or how a hegemonic language would push another, minority one towards extinction [2]. Some attempts were made towards prediction in scenarios still far from a steady state [3], cases which often involve a multifactored political scenario. The additional social complexity should be a further incentive for us to test simple mathematical models. By finding out how far our equations can hold, and when do they fail, we have the needed ingredients to advance the theory.

With this spirit, we study the stability of two coexisting languages (Catalan and Spanish) in Catalonia (north-eastern Spain). There, a very complex political setup is confronting nationalistic forces of diverse sign within one of the most prominent European regions (Catalonia ranks 4th among all European regions both by nominal GDP, by GDP in Purchasing Power Standards, and by population size [4]). Our analysis [5] relies on recent, abundant empirical data that is compared to an analytic model of populations dynamics. This model contemplates the possibilities of long-term language coexistence or extinction – both plausible outcomes of the socio-political system under research. We establish that the most likely scenario is a sustained coexistence. However, the data needs to be interpreted under very different circumstances, some of them leading to the extinction of one of the languages involved. We delimit the cases in which this can happen, and find that the fostering of a broad bilingual group shall be a key stabilizing element. As an intermediate step, model parameters are obtained that convey important information about the prestige and interlinguistic similarity of the tongues as perceived by the population. This is the first time that these parameters are quantified rigorously for this couple of languages. Limited, spatially segregated data allows us to examine dynamics within two broad sub-regions, better addressing the likely coexistence or extinction. Finally, variation of the model parameters across regions tells us important information about how the two languages are perceived in more urban or rural environments.

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Damian Ruck, *Alex Bentley* and *Dan Lawson*

Identifying patterns of global change in attitudes and beliefs using the World Value Survey.

SPEAKER: *Damian Ruck*

ABSTRACT. The Word Value Survey (WVS) is an international, cross sectional survey of beliefs and attitudes of a thousand people in each of 107 different nations, administered since 1990. We extract a reduced set of cultural units using Exploratory Factor Analysis which offers the best explanation for the high dimensional survey data and utilize a Bayesian regression to estimate recent cultural change. Using Multilevel Granger Causality we investigate the direction of causation between cultural values and economic development. Then we present a dynamic nonlinear relationship between religious subscription and secularization which has the hallmark of cultural inheritance.

Aernout Schmidt and *Kunbei Zhang*

Agent-based Modeling to Understand Brexit

SPEAKER: *Aernout Schmidt*

ABSTRACT. UK subjects' "swarming away" from the EU is not only a political, but also a legal concern. Actually, a court judgment has been solicited. The United Kingdom Supreme Court ruled on the UK Secretary of State's authority to decide for Britain to exit from the EU without hearing Parliament. The judgment is in 96 pages of print. This document is/contains our data.

As legal scholars we are aware that adequate comprehension (cf Bobbitt [1982]) of almost all complex situations involving deliberate human behaviors requires blending the arts with the sciences. Our goal is to provide a proof of concept for how two agent-based models of the same situation can support this. Our working hypotheses are (i) that the UK Supreme Court judgment cannot be properly understood in different (alpha,beta) cultures without mitigation and (ii) that agent-based models can be designed, combined and used for simulations that support constructive cross-disciplinary analysis and comprehension.

Assuming that agent-based models create toy worlds, our main pont of departure is (apart from experimentation with valid laws, which we consider contempt of democratic/legislatory procedure) this: we cannot reasonably discuss the capabilities of the law to help a complex social system survive in the real world without having a model of how a toy complex system will react to internal and external adaptations in technology, culture, economics and law. No single discipline is capable of finding the best solution to such toy complex's behaviors. Finding and designing working examples of adequate mechanisms is the next best thing. Agent Based Model Simulation (ABMS) can help deliver those.

Our approach is a new one. We use the 96-page judgment document as source material for study. From it we harvest modeling requirements through two different disciplinary filters: alpha and beta (for arts and sciences) in a manner that takes de Marchi [2005] seriously. Running these models leads to repeatable stochastic encounters between agents. The encounters translate into working towards the selection of the best strategy sequence, conditional to the "political season" these evolve in. Inspired on Alexander [2007] the games that can dynamically form in this manner are prisoner's dilemmas, stag hunts and bargaining games. "Political seasons" reflect stable political periods as presented in the judgment. The two (alpha, beta) collections of available strategy-payoff combinations are also harvested from the document.

Our results show that we can use the UK Supreme Court judgment to design working toy versions of the UK subjects, the UK and the EU as a dynamic complex social system both from an arts and from a science perspective. And that the evolutionary-game-theoretic simulation approach allows for blending these perspectives' expectations in a rational manner.

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Manlio De Domenico and Alex Arenas

Modeling structure and resilience of the dark network

SPEAKER: Alex Arenas

ABSTRACT. While the statistical and resilience properties of the Internet are no longer changing significantly across time, the Darknet, a network devoted to keep anonymous its traffic, still experiences rapid changes to improve the security of its users. Here we study the structure of the Darknet and find that its topology is rather peculiar, being characterized by a nonhomogeneous distribution of connections, typical of scale-free networks; very short path lengths and high clustering, typical of small-world networks; and lack of a core of highly connected nodes. We propose a model to reproduce such features, demonstrating that the mechanisms used to improve cyber-security are responsible for the observed topology. Unexpectedly, we reveal that its peculiar structure makes the Darknet much more resilient than the Internet (used as a benchmark for comparison at a descriptive level) to random failures, targeted attacks, and cascade failures, as a result of adaptive changes in response to the attempts of dismantling the network across time.

Reference:

Manlio De Domenico and Alex Arenas Phys. Rev. E 95, 022313 (2017)

Guido Caldarelli, Tiziano Squartini, Giulio Cimini, Andrea Gabrielli and Diego Garlaschelli

Reconstruction methods for networks: the case of economic and financial networks

SPEAKER: Guido Caldarelli

ABSTRACT. Partial information is a problem that is systematically encountered in studying complex networks, irrespective of the specic case (typically a social, economic or biological system) that we describe with a graph. In order to compensate for the scarcity of data, researchers have tried to develop algorithms to achieve the best possible reconstruction of the networks under analysis. The techniques proposed to make optimal use of the available information have led to the birth of a research eld which is now known as \network reconstruction". Many researchers working in disciplines as dierent as physics, economics and nance have contributed to it, but each method has been tailored, so far, on the specic needs of each domain, often popularizing a particular algorithm exclusively into the eld where it was originally proposed. Therefore, the results achieved by dierent groups are still scattered across heterogeneous publications and a systematic comparison of the analytic and numerical tools employed for network reconstruction is currently missing. We provide a unifying framework to present all these studies; we also provide examples from various elds even if we focus mostly on economic and nancial networks since their structure is particularly dicult to access because of privacy issues. Unfortunately, partial information on the set of interconnections between nancial institutions dramatically reduces the possibility of providing a realistic estimate of crucial systemic properties (e.g., the resilience of the considered networks to the propagation of shocks and losses). Therefore the ability of reconstructing a reliable nancial network is not only important from a scientic point of view, but also from a societal one.

Enrico Ubaldi, *Alessandro Vezzani*, *Nicola Perra*, *Márton Karsai* and *Raffaella Burioni*

Burstiness and ties reinforcement in social temporal networks

SPEAKER: *Enrico Ubaldi*

ABSTRACT. The growing availability of high-quality and longitudinal datasets recording human activities allowed to gain a deeper understanding of how individuals interact and which strategies they apply in exploring their social circles.

In this work [1] we expand and generalise the activity-driven-network (ADN) modelling framework to account for three prominent mechanisms known to shape the individuals' ego-nets evolution, i.e., i) the diverse propensity to engage in a social interaction [2] (activity), ii), the heterogeneous time scales between two social events [3] (burstiness), and iii) their different strategies in allocating such interaction among their alters [4,5] (ties reinforcement).

The implementation of these mechanisms is usually done in a data-driven fashion, by directly measuring the distributions of inter-event time and the probability to engage a new social tie from empirical data. The question is then whether different scenarios of social exploration strategies and bursty inter-event time distributions, featuring different local scale behaviour but an analogous asymptotic limit, can lead to the same long time and large scale structure of the evolving networks.

Here, we tackle this problem in its full generality, by encoding a general functional form of these components into the ADN analytical framework, so as to account for both different strategies of ties activation and individual activity patterns. We then analytically solve the model in the asymptotic limit finding a rich phase diagram drawn by the dynamical interaction of the nodes activation mechanism and the ties reinforcement process. Their interplay is non trivial and, interestingly, the effects of burstiness might be suppressed in regimes where individuals exhibit a strong preference towards the reinforcement of previously activated ties. We also find that the asymptotic network evolution is driven by a few characteristics of the burstiness and reinforcement functional forms that can be extracted from direct measurements on large datasets.

The results are tested against numerical simulations and compared with two empirical datasets with very good agreement. Consequently, the framework provides a principled method to classify the temporal features of real networks, and thus yields new insights to elucidate the effects of social dynamics on spreading processes.

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Ian Wood, *Xiaoran Yan*, *Xiaozhong Liu* and *Yong-Yeol Ahn*

Community Detection with Selective Zooming

SPEAKER: Ian Wood

ABSTRACT. Many complex networks exhibit hierarchical structure across a wide range of scales. Prior work has shown that time-sweeping using Markov dynamics allows the creation of a “zooming lens” to detect communities at different scales [1]. In this work a continuous-time Infomap algorithm [2] is extended to selectively zoom into community structure based on pre-determined node importance, allowing prior information to be incorporated into the community detection algorithm. The capacity of our method is illustrated with simple block models and image segmentation problems, and applications to information retrieval are discussed.

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Leto Peel

Graph-based semi-supervised learning for complex networks

SPEAKER: Leto Peel

Michael Schaub and *Leto Peel*

Efficient detection of hierarchical block structures in networks

SPEAKER: Leto Peel

Sabin Roman and Markus Brede

Topology-dependent rationality and quantal response equilibria in structured populations

SPEAKER: Sabin Roman

ABSTRACT. Nash equilibria of games are frequently used to reason about the decision-making. However, the underlying assumption of perfect rationality has been shown to be violated in many examples of decision-making in the real world. Accordingly, we explore a graded notion of rationality in socio-ecological systems of networked actors. We parametrise an actors' rationality via their place in a social network and quantify system rationality via the average Jensen-Shannon divergence between the games' Nash and Logit Quantal Response equilibria.

Previous work by [1] has argued that scale-free topologies maximise a system's overall rationality in this setup. Here, we show that while, for certain games, it is true that increasing degree heterogeneity of complex networks enhances rationality, rationality-optimal configurations are not scale-free. For the Prisoner's Dilemma and Stag Hunt games, we provide analytic arguments complemented by numerical optimisation experiments to demonstrate that core-periphery networks composed of a few dominant hub nodes surrounded by a periphery of very low degree nodes give strikingly smaller overall deviations from rationality than scale-free networks. If isolated nodes are allowed to form during optimisation, optimal networks are found to consist of a core made up by a complete graph with all other nodes being isolated. Similarly, for the Battle of the Sexes and the Matching Pennies games, we find that the optimal network structure is also a core-periphery graph but with a smaller difference in the average degrees of the core and the periphery. If no connectivity constraints are enforced, then in the case of the Battle of the Sexes a graph with a strongly bi-modal degree distribution emerges, while for the Matching Pennies game we obtain a quasi-regular graph. So, in contrast to [1], we have demonstrated that highly heterogeneous degree distributions do not necessarily maximise system rationality for all classes of games.

These results provide insight on the interplay between the topological structure of socio-ecological systems and their collective cognitive behaviour, with potential applications to understanding wealth inequality and the structural features of the network of global corporate control.

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Johan Bollen

Studying the relation between online social networks, subjective well-being, and mental health

SPEAKER: Johan Bollen

ABSTRACT. Social media are now an integral part of our social lives. They allow billions of people to connect across social, economic, and geographic boundaries, as they weave intricate social networks through which individuals share the most minute details about their lives and conditions with others. Online social networking may have become so popular because it fulfills a basic human need for connection, but does it actually promote our well-being? In my presentation, I will discuss our recent work on two aspects of this puzzle. First, I will discuss our findings that suggest that the prevailing topology of social networks and the distribution of subjective well-being in human populations interact in such a way that we find significant homophily with respect to longitudinal mood states, i.e. people tend to be connected to others with similar mood states. We furthermore find that due to a strong friendship and happiness paradox most people will be surrounded by friends that are both more popular and happier on average than they themselves are. Second, I will discuss our work that leverages large-scale social media to study the mental health dynamics of individuals and populations. The outcomes of this work might lead to a better understanding of how social media affects our well-being and mental health, the creation of early warning indicators for mental health transitions in individuals, and more accurate models of how emotions and mental health issues typically emerge and evolve.

Riccardo Di Clemente and *Marta C. Gonzalez*

Detecting behavioral groups in sequences of labeled data

SPEAKER: *Riccardo Di Clemente*

ABSTRACT. Zipf-like distributions characterize a wide set of phenomena in physics, biology, economics and social sciences. Furthermore, in many human activities ranging from the type fo purchases with credit card and the offenses within the criminal careers the zipf-law is a peculiar property. These two datasets not only manifest the highly uneven frequencies where the vast majority of distribution is picked on few elements but have temporal sequences in the appearances of the events (purchases/offenses) which is typical for each individual. In this work, we are interested in detecting ubiquitous patterns of collective behavior extracted from this kind of data. A first approach to this problem from \cite{hidalgo2009dynamic} proposed to eliminate the redundant information inside the data and classify the users, analyzing the frequency-inverse document frequency (FT-ID). This method despite its results does not take into account temporal sequences in the appearances of the events. Our goal here is to eliminate redundancy while detecting habits and keeping the sequence of events and their order, which represent an important signature of an individual's routine. With this aim we apply the Sequitur algorithm \cite{nevill1997identifying} to the users' sequence of events to infer a grammatical rule that generate words, defined as two or more events that appear frequently in chronological sequence. To detect the words that are significant, we generate 100 randomized code sequences for each user. We extract for each user the set of significant words with z-score greater than 2. This represents the routines that indicate the sequences of significant events in the user habits. We calculate the matrix M of user similarity measuring the Jaccard similarity coefficient of the set of significant words between the individuals (in Fig.\ref{figure1} example obtained from the sequence of purchase). Finally we identify groups in M by applying the Louvain clustering algorithm. With this framework we are able to detect different behavioral groups in the data. Individuals within each group are also similar in a wide range of socio-demographic attributes such as age, gender, income, and mobility (in Fig. \ref{figure2} example for credit card). Taken together, we show that the detection of significant sequences is a critical ingredient in the process, because benchmark methods based on frequency ranking when applied to this data do not detect any habits \cite{roque2011using}. We presented a novel method to detect behavioral groups in labeled data \cite{di2017Crime,di2016revealing} that could also be applied to identify groups in other types of labeled datasets with Zipf-like distributions. Paralleling motifs in network science, which represent significant connections hidden within power law degree distributions, this method uncovers sets of significant sequences within labeled data with Zipf-type distribution.

Cristian Candia-Castro-Vallejos, Cristian Jara-Figueroa, Carlos Rodriguez-Sickert and Cesar Hidalgo

The laws of forgetting: How time, popularity, and death shape human collective memory

SPEAKER: Cristian Candia-Castro-Vallejos

ABSTRACT. Collective memory--the common representation of the past created by a group of people--originates from a balance between the transmission and forgetting of information. Yet, while the literature on the diffusion and transmission of information is vast, the literature describing how information is forgotten is relatively small. Here, we use data on the present and past popularity of songs, and on the daily online popularity of more than one thousand biographies, to study how the attention received by songs and biographies decays with time, initial popularity, and the death of cultural icons. First, we show that a song's present day popularity decays quickly as a function of its age for the first 1,600 days, and then, decays significantly more slowly during decades. Next, we find that initial popularity predicts present day popularity in songs, since a song's highest ranking in Billboard and the number of weeks it was ranked, predict a song's present day popularity once the effects of time have been removed. Then, we study the impact of the death of cultural icons on the online attention received by their biographies by using daily Wikipedia pageview. We focus on the biographies of famous people who died between July 2008 and April 2016 and show that the pageviews received by these biographies decay after their death following a power-law with an exponent of around -1.35. Moreover, we find that the biographies of people who have died experience a small but significant excess of attention, or ``attention premium," when compared to their pre-death popularity. We show this attention premium scales sublinearly with initial popularity, meaning that the premium is relatively larger for people who were relatively less popular prior to their death. Together, these findings show that the dynamics of human forgetting are characterized by a narrow set of mathematical functions and contribute to our understanding on the dynamics of human forgetting.

Juan C. Correa, Phillip Brooker and Gopal Sarkarkar

Urban Mobility and Food Ordering Services: A web mining perspective

SPEAKER: Juan C. Correa

ABSTRACT. Despite the popularity of online food ordering services (OFOS) few studies have attempted to understand their value in everyday life. A common motivation for using these services is their convenience for customers since they allow them to avoid traffic jams or traffic congestion in highly dense cities. Is heavy traffic related with patterns of online food ordering services in highly dense cities? Here we tackle this question by describing possible ways of extracting relevant information from Waze Live Map and online food ordering services in Bogotá city. Our approach highlights the potential benefits of using geographic coordinates to locate exact positions of food providers in the city and evaluate if their perceived quality is somehow affected by traffic dynamics as captured by Waze Live Map.

Petter Törnberg

The Gendered Selfie

SPEAKER: *Petter Törnberg*

ABSTRACT. As social media increasingly become part of our everyday lives, they do not only shape how we see the world, but also how we see ourselves and how we fit into the social world. Image-based expressions in particular are becoming a powerful source of self-perception, as we rely on others' views, judgments and appraisals to develop our social self. This is emphasized by the psychological concept of the “looking-glass self”, which describes how we develop our sense of self based on the perceptions of those with whom we interact. Some psychologists have argued that social media constitutes a powerful new such looking-glass (e.g. Gärdenfors 2017). Through such effects, social media also constitutes a channel for the spread and perpetuation of social norms. Some such norms can be undesirable, in particular, feminine and masculine gender-norms are widely understood to fit with and reinforce the problematic socialization of women into subordinate social roles, contributing to gender inequality (e.g. Millett 1971:26). This paper investigates to what extent the new “looking-glass” of social media distorts our reflection by being gendered, and whether it constitutes a conveyer of problematic gender-norms. As our self-image is one of the clearest expressions of how gender roles affect and limit how we understand and portray ourselves, this paper explores how gender plays out in self-portraits on social media. A large number of “selfies” and associated user comments are collected from the major image-based social networks Instagram and Flickr. These selfies are categorized by subject gender, using name classification databases and, in the cases where this is not possible, deep learning image classification. Image expressions are furthermore characterized, also by using deep learning, and various text analytic methods are applied to study differences in how men and women are commented as a function of the image expressions. Furthermore, as the photos are geotagged, the geographical distribution of gendered speech and visual expression is explored. This allows us to answer pressing questions regarding gendered expressions in social media: do men and women conform to gender-norms in their self-expression? Are there detectable differences on commonly theorized dimensions such as active/passive, hard/soft, powerful/weak, cold/warm, etc.? Can a policing of such gender-norms be detected in comments, in which ‘appropriate’ self-expression is reinforced, and deviant expressions discouraged? Are there geographical differences in gender-expressions? Are there differences between platforms, e.g. following from platform-specific social norms? This contributes useful insights as to how social media plays part in the perpetuation of problematic social norms, and furthermore serves to illustrate how digital trace data can contribute to the large theoretic framework associated to gender studies.

David Wolpert, Justin Grana and Brendan Tracey

Modeling Social Organizations as Communication Networks

SPEAKER: David Wolpert

ABSTRACT. Human social groups can achieve extraordinary levels of complexity. Examples range from individual firms competing in a market to ancient city-states to military units,to modern governmental institutions. One key element of such groups is how they are internally organized. Accordingly, the question of what determines the precise organizational structure that a given group adopts is a central concern of many social sciences, including economics, political science, sociology, and anthropology. Despite the importance of these issues, there has yet to be a formal and testable theory that explains what properties of the agents and external environment determine the organization's structure. While not formalized, many have suggested that it is the information requirements and constraints on an organization that determine the need and structure of an organization. For example, Ken Arrow conjectured, ``the desirability of creating organizations...is partially determined by the characteristics of network information flows." Nevertheless, such a conjecture was never formalized and expounded in economics or any other field that is concerned with organization structure. In this paper, we formalize and propose initial answers to the question ``how does informational requirements and limitations impact the optimal organization structure?"

We take a group selection approach and model human organizations as telecommunication networks. Specifically, we focus on how the agents' ability to receive, transmit and synthesize information determines the organization's (approximate) optimal structure in terms of network topology. In the model, agents (with a common goal) within an organization receive information from various sources and must decide how to transform such information and transmit the results to other agents in the organization. At the same time, information transmission is costly and noisy. We then use this model to show how the size of the organization, the noise in the communication channels and the informational requirements of each agent in the organization determine the organization's optimal structure. We focus on ``phase transitions" and show how at certain parameter specifications, the optimal organization structure switches from relatively flat to hierarchical. An ancillary contribution is that we show how to leverage the computational power of neural networks, regularizers and genetic algorithms to solve for the optimal network structure under each parameterization. Specifically, we use neural network to determine how each agent should transform and transmit information for a given network topology. We implement informational processing constraints with regularizers. Then, we use genetic algorithms to optimize over the network topology.

We also discuss several extensions to our baseline model. In particular, we discuss how to extend our model to analyze the dynamics of the optimal network topology. We also discuss augmenting the theory to analyze the organization's optimal network structure when there are multiple competing organizations. To contextualize our approach to modeling social organizations, we suggest other alternatives that include applying the new field of network coding.

Hyejin Youn, Logan Sutton, Eric Smith, Cristopher Moore, Jon Wilkins, Ian Maddieson, William Croft and Tanmoy Bhattacharya

On the universal structure of human lexical semantics

SPEAKER: Hyejin Youn

ABSTRACT. How universal is human conceptual structure? The way concepts are organized in the human brain may reflect distinct features of cultural, historical, and environmental background in addition to properties universal to human cognition. Semantics, or meaning expressed through language, provides indirect access to the underlying conceptual structure, but meaning is notoriously difficult to measure, let alone parameterize. Here, we provide an empirical measure of semantic proximity between concepts using cross-linguistic dictionaries to translate words to and from languages carefully selected to be representative of worldwide diversity. These translations reveal cases where a particular language uses a single “polysemous” word to express multiple concepts that another language represents using distinct words. We use the frequency of such polysemies linking two concepts as a measure of their semantic proximity and represent the pattern of these linkages by a weighted network. This network is highly structured: Certain concepts are far more prone to polysemy than others, and naturally interpretable clusters of closely related concepts emerge. Statistical analysis of the polysemies observed in a subset of the basic vocabulary shows that these structural properties are consistent across different language groups, and largely independent of geography, environment, and the presence or absence of a literary tradition. The methods developed here can be applied to any semantic domain to reveal the extent to which its conceptual structure is, similarly, a universal attribute of human cognition and language use.

Bernardo Monechi, Giulia Pullano and Vittorio Loreto

Dynamics of Social Interactions in a Collective Creativity Experiment

SPEAKER: Bernardo Monechi

ABSTRACT. The study of the dynamics behind the emergence of novelties and innovation is a relatively recent field of study in complex systems, fostered by the abundance of data about the creation and sharing of artworks and about on-line activity in general. Despite the recentness of the topic, many works have been able to discover and characterize many interesting statistical patterns related to the emergence of new creative elements and a very general mathematical framework describing the collective process of discovering and sharing novelties has been developed. However,a lot has still to be discovered concerning the conditions, either historical and social, fostering the emergence of creative elements from a group of interacting individuals. From a social perspective, many hypotheses have been suggested and tested concerning the relations between individuals, like the presence of ``weak ties'' in social networks or the ``folding'' of different social groups into larger ones sharing a common goal. To the best of our knowledge, Complex Systems Science has given little contributions to the understanding of how the dynamics behind social interactions can contribute to foster the emergence of creativity. \newline In this work we present the results of a collective social experiment in which individuals were asked to collaborate in the realization of a certain number of LEGO bricks sculptures. The participants were provided with particular RFID tags developed in the framework of the SOCIOPATTERNS project, that enabled a quite precise mapping of the social interactions occurring during their activity within the experiment. The interaction with the LEGO Sculptures were similarly mapped by means of other RFID tags placed around the sculptures, and their growth in volume has been recorded with the aid of infra-red depth sensors. The RFID sensors allowed for the reconstruction of the dynamical network of social interactions between the participants in the experiment. We looked for correlations between the evolving structure of this network and the growing patterns of the sculptures, spotting the local social structures more prone for a rapid growth of the volume in small amounts of times and in long term periods. In this way, we were able to identify the social patterns more fruitful in terms of ``local consensus'' around the development of the collective artwork, indicating a shared vision around the actions to be performed on it. Moreover, we were able to identify how the presence of ``influential individuals'' characterized by means of information spreading models favored the growth of the sculptures in the long-term. The novelty behind the proposed approach could contribute to shed light on the phenomena related to creativity and could innovate in the way in which collective creativity experiments are conceived and designed.

Maurice Lamb, Riley Mayr, Tamara Lorenz, Rachel W. Kallen, Ali Minai and Michael Richardson

Working with Machines: A Complex Dynamical Systems Approach to Human-Machine Interaction

SPEAKER: Maurice Lamb

ABSTRACT. When humans work together, coordination emerges from complex interactions within individual co-actors, between co-actors, and between co-actors and task relevant environmental properties. In contrast, when machines complete a task, while the mechanics and programming of the machine may be complicated, the behavior does not emergent from system complexity. When it coordinates with humans or other machines, it must do so deliberately with a specific plan and method for doing so. One potential result of these differences is that when humans and machines work in shared spaces, the fundamental dynamics of each are significantly different. When the machine and its behavior are simple or limited within clear spatial boundaries (often defined by brightly colored fences), the difference in dynamics is insignificant. When the machines behavior is simple, humans can easily learn the machines patterns and adapt their behavior. When the machine is kept separate, risk of injury is minimized and demands on close proximity coordination are eliminated or reduced. However, there are many potential applications where it would be beneficial for humans to be able to quickly interact and coordinate with a machine with little to no training on how to do so, including: neurorehabilitation, assistive robotics, local and remote operation of multi-agent robotic systems, and industrial applications. Building on complex dynamical systems research of human-human joint action, we have developed a method for implementing human inspired dynamics in artificial and machine systems. As a proof of concept, we have implemented a joint action dynamical pick-and-place algorithm in both a virtual avatar system and a robotic arm. In each case both the movements and task specific decisions of the algorithm driven system emerge from the interactions of the human-machine co-actors and their environment. We demonstrate not only that this approach can successfully accomplish the task with a human co-actor in a robust and adaptive way, but can do so in a way that mimics the dynamics that emerge from the complexity of human agents. Theoretically, our approach builds on the fact that in complex systems with many degrees of freedom, interaction among system degrees of freedom at different scales constrain the system resulting in dynamics that can be characterized by far fewer degrees of freedom, e.g. an order parameter. Along with implementation and demonstration of a joint action pick-and-place algorithm, we will discuss possible future extensions and applications of our method in domains of assistive and therapeutic technologies and teleoperation of multi-agent robotic systems.

Stefano Vincini, Yuna Jhang, Eugene Buder and Shaun Gallagher

Association but not Recognition: An Alternative Model for Differential Imitation from 0-2 Months

SPEAKER: Stefano Vincini

ABSTRACT. Skepticism toward the existence of neonatal imitation is fostered by views that assign it excessive socio-cognitive significance and generate unwarranted expectations about the kinds of findings experimentalists are supposed to look for. We propose a theoretical analysis that may help address the empirical question of whether early imitation really exists. We distinguish three models. The first posits automatic visuo-motor links evolved for socio-cognitive functions: we call it Genetically Programmed Direct Matching (GPDM). The second is Meltzoff's Active Intermodal Matching (AIM), which postulates a comparison between the acts of self and other. The third is the alternative we propose: we call it Association by Similarity Theory (AST), as it relies on this domain-general process. AST describes early imitation merely as the differential induction or elicitation of behaviors that already tend to occur spontaneously. Focusing on the contrast between AIM and AST (Figure 1), we argue that AST is preferable for three reasons. First, AST is more parsimonious and plausible than AIM. AST does not commit one to superfluous assumptions and to the problematic claim that a specific form of social cognition starts in the newborn period, i.e. the recognition of the similarity between the acts of self and others. In AST, similarity has a tacit functional role but is not the object of recognition experience. Moreover, AST fits better with the common coding/ideomotor approach as advocated by Wolfgang Prinz from 1990-2009. Second, whereas the extant findings tend to disqualify AIM, AST can account for them adequately. AST does not posit a propensity to match the gestures of others indispensable for socio-cognitive functions; hence it explains the extensive variability of the findings and the considerable absence of imitation in naturalistic environments. AST better accounts for the narrow range of gestures exhibiting imitation (perhaps just 2), the “drop out” after two months, the imitation/spontaneous behavior correlation, and the progressive increase in amplitude and vigor, which, however, does not exhibit goal-directedness. Additionally, AST does not inflate the operational definition of imitation (differential imitation does not look like ordinary imitation). Third, AST has the potential to give new impulse to empirical research because it discriminates promising lines of inquiry from unproductive ones. In contrast to AIM, AST predicts: (a) imitation will be low or absent in naturalistic (domestic) environments, but present in artificial laboratory settings designed to maximize attention to the kinematic features of the model; (b) imitation will hardly be detectable through research aiming at external validity (averaging data across large numbers of infants), but demonstrable through research emphasizing internal validity (where each infant is taken as its own control); (c) mouth opening will be more helpful to prove the existence of imitation than other facial gestures less clearly differentiated in proprioceptive experience; (d) eye tracking of inactive (presenting no imitative response) mouth opening observation will exhibit differentiation from equally arousing, but not-already-executed gestures. We intend to take up these directions of enquiry and invite other experimentalists to do the same in order to settle the debate on whether early differential imitation exists.

Gonzalo Castaneda-Ramos, Gerardo Iñiguez and Florian Chavez-Juarez

The Complex Network of Public Policies. An Empirical Framework for Identifying their Relevance in Economic Development

SPEAKER: Gonzalo Castaneda-Ramos

ABSTRACT. The traditional view that there is a set of common factors that precludes the possibility of closing the income gap between developing and developed countries is somehow misleading. When analyzing the relative relevance of policies and institutions, it is frequently assumed that their impact on countries' economic growth does not vary in terms of their current stage of development. However, there are many pieces of empirical evidence of policy interventions exhibiting a large heterogeneity in countries' outcomes, since they are implemented in a wide array of economic and governance structures. In this paper a data-driven framework for establishing development guidelines is elaborated based on the idea that societal outcomes are the result of a large set of public policies with many interactions. Consequently, for selecting a particular combination of policies, which could be helpful for the performance of a country with specific 'initial conditions', it is convenient to build a complex network of public policies. In particular, the inclusion of a large number of factors, or development pillars, in such a network allows analyzing the relative relevance of different categories of policies and governance variables. In order to identify which policies might be suitable for a specific country, it is assumed that, as countries evolve, they leave behind a 'development footprint' reflected in their set of policy indicators. Therefore, in the first step of the 'development footprint' framework, a set of targeted countries has to be selected for specifying the values of the policy indicators to be replicated by the country under treatment. Besides of choosing targeted countries positioned in the next income category of the treated country, the set is reduced even more by taking into account only those countries whose economic structure is similar to the one observed in the treated country. Then, in a second step, a complex network of public policies is used to simulate the impact that certain combinations of policy interventions have on the value of different policy indicators, with the aim that the treated country can move from its original policy indicators to those exhibited by the targeted countries. Because there is a large set of policy combinations to be attempted, the framework uses a genetic algorithm to find optimal solutions. In this case, the function to be minimized is a mean square error defined as the difference between the simulated values of policy indicators and the corresponding values prevailing in targeted countries. The main results generated when the model is calibrated with a panel of countries in all income categories for the period 2006-2012 are as follows: (i) public policies are context dependent; (ii) there are different development modes that any country can undertake; (iii) policy interventions within each mode are part of a consistent package and, thus, they cannot be easily substituted in isolation; (iv) bosting public governance indicators does not seem to be important for the poorest countries of income group 4, but this type of actions is very critical in the upper-middle income countries of group 2.

Fernando Gómez and *Edmundo Molina*

Economic Complexity of Special Economic Zones (SEZs) in Mexico: Networks analysis for diversification and regional productive sophistication

SPEAKER: *Fernando Gómez*

ABSTRACT. Regional economic development based on public policies aimed at the design, implementation and development of SEZs has gained special relevance at the international level in the last 30 years. Although it is not a new type of public policy, the observed impact on economic growth, the improvement in the incomes received by the local population and the increase in the general welfare in the regions of the world where its implementation has been successful have been sufficient reasons for many developing countries to continue implementing this scheme. However, success in some areas of East Asia and Latin America has not been uniform, and there are even a number of cases, mainly in Africa, where economic zones have failed to achieve their objectives.

In Mexico, the implementation of SEZs is predicated on the believed that this intervention will help close the growing economic gap between Mexico's northern and southern states. However, the current policy architecture does not consider the existing industrial base in these regions, their differences and ultimate the intricate web of economic links across the different economics activities in these regions.

This study focusses on quantitatively characterizing the economic complexity of the regions where the SEZs are being implemented in Mexico. For this, we applied the economic complexity framework by Hausmann and Hidalgo (2014) using data from the Economic Censuses generated by the National Institute of Statistics, Geography and Informatics (INEGI). Based on their framework, we estimate the product space of the economic branches in Mexico and quantitatively characterize the existing economic networks. Through this analysis, we determine how the Mexican SEZs are located in the national product space, as well as their possible routes of productive diversification (i.e. using the proximity between economic branches as a proxy for potential diversification). Finally, based on the estimation of distance within the network of capacities and products, and their historical dynamics we develop a framework that can be used to evaluate which industries are more likely to succeed in SEZs.

Alje van Dam and *Koen Frenken*

Synergies and scaling in the occupational composition of cities

SPEAKER: *Alje van Dam*

ABSTRACT. Understanding the economic structure of cities is becoming increasingly important as urbanization keeps increasing throughout the world. It has been posed that the economic output of a city is the product of the interactions between people with complementary and specialized skill sets and know-how, enabling the development of increasingly complex and hence economically valuable goods and services (Bettencourt et al., 2014). Hence a substantial part of a cities' economy is determined by the number of people living in it, the diversity of their skillset and perhaps more importantly how complementary the different skillsets of different people within a city are to each other. In this work we study these complementarities by considering the composition of the population of cities within the United States in terms of their occupational specializations. We propose a new measure of complementarity between occupations that determines which combinations of specific occupations account for the synergies that drive the productivity of cities. Our measure is grounded in information theory and naturally extends to measures that we believe capture in some way the 'economic complexity' of both occupations and cities, which can be interpreted as a measure of specialization of a certain occupation and the division of labor in a cities labor force respectively. We also relate our measure of the complexity of an occupation to the way specific occupations scale with city size, shedding light on the relation between the scaling behavior of occupations (Bettencourt et al., 2014, Youn et al., 2016) and the concept of economic complexity (Hidalgo & Hausmann, 2009), interpreted here as the level of specialization of a certain occupation. We validate our measure by seeing to what extent it can explain a cities' economic over- or underperformance given its population size, and the wages of individuals occupations. This work addresses the question of how scale, diversity and integration of occupations contributes to a cities' economic productivity and improves on existing methodologies (Muneepeerakul et al., 2013) to measure pairwise interdependence of occupations by starting from an information-theoretic basis, allowing to generalize to higher-order interactions.

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Fernando Buendía

Zipf distribution of artists' income

SPEAKER: *Fernando Buendía*

ABSTRACT. Despite the production and consumption of art have been important elements of human activity, it is only relatively recently, with William J. Baumol and William Bowen's (1966) Performing Arts: The economic Dilemma, that cultural economics or more particularly the economics of the arts emerged as an independent field of economic analysis. Economics of arts and culture cover several topics; from the participation of art markets in the GDP and sales of the major artists in auction houses (Christie's and Sotheby's) to the consumption of art as an addiction and the pecuniary and aesthetic nature of artworks. However, the major focus of the economics of the arts is on prices: How do rates of return on investment in art compare with returns elsewhere? Or what are the main determinants of the price of art works? This paper aims to contribute to the economics of arts by examining whether commercial success in the art market conforms to an empirical concentration. To do so, in this paper I provide empirical evidence about the dispersion of income among artists. Specifically, by using the publicly available data on art market trends from 2002 to 2013 in terms of annual auctions sales of the firm Artprices, I show that the distribution of rewards artists receive from the sale od their artworks is Zipf-distributed. The paper is organized as follows. In the next section, I provide a general perspective about the literature on artists' employment and earnings. Section three describes the self-organizing nature of many phenomena and how Zipf's law can explain them. In sections four and five I show that artists' income follows Zipf's law. This papers ends with some final remarks.

Filippo Simini

Testing the fundamental assumptions of singly-constrained models of spatial flows

SPEAKER: *Filippo Simini*

ABSTRACT. Domestic migrations, along with traffic congestion and the spread of infectious diseases, are processes in which the presence of flows induces a net change of the spatial distribution of some quantity of interest (population, vehicles, pathogens). The ability to accurately describe the dynamics of these processes depends on our understanding of the characteristics of the underlying spatial flows. Statistical models of spatial flows have been traditionally developed starting from the principle of entropy maximisation subject to various constraints such as the presence of a finite amount of resources for travels, or using utility theory to describe individual choices over competing alternatives. Despite being derived from different principles, many of these approaches share the same fundamental assumptions which lead to estimate flows as the product of two types of variables, one type that depends on an attribute of each individual location (e.g. the population), and the other type that depends on a quantity relating a pair of locations (i.e. a distance). The difference between the various models consists in the kind of variables considered, and the specific functional forms in which these variables enter. When the estimates of these models are not accurate it is impossible to determine whether this is due to a poor choice of the explanatory variables and functional forms, or because the fundamental assumptions are not satisfied. Resolving this ambiguity would require the development of a methodology to assess if a set of empirical flow data is compatible with the fundamental assumptions of a class of spatial flow models. Here we present a general framework to model spatial flows based on a limited number of fundamental assumptions on the model's structure that does not require to specify a priori a particular set of explanatory variables or functional forms, which are determined from the empirical flow data. In particular, we focus on singly-constrained models in which the probability of a unit flow from location i to j is $p_{ij} = w_j f(r_{ij}) \big/ \sum_k w_k f(r_{ik})$, where r denotes a distance and the weights w are characteristic variables of the locations. Differently from traditional approaches that introduce additional, arbitrary assumptions on the specific functional forms of the deterrence function f (usually exponential or power-law) and the weights w (usually function of local variables such as population or employment rate), in the proposed approach f is expressed as a sum of adaptive basis functions which can approximate any function with arbitrary precision, while w can assume any positive value. We will describe a procedure to calibrate the model using an iterative maximum likelihood algorithm and analyse its performance on synthetic data and empirical migration and commuting data.

Edmundo Molina, *Rodrigo Crespo* and *Aldo Ramirez*

An Integrated Participatory Computational Framework for Supporting Long-term Infrastructure Planning in Complex Policy Contexts: The Case of The Monterrey Water Master Plan

SPEAKER: *Edmundo Molina*

ABSTRACT. The City of Monterrey in Nuevo Leon is rapidly increasing its demand for potable water due to its growing industrial activity and population. It is widely believed that the expansion of the city´s water infrastructure is a key measure needed to support future water demand. However, environmental concerns of different projects and more importantly climate change and water demand uncertainty have increased the complexity of this decision.

This research describes an integrated computational framework that has been developed for supporting the State of Nuevo Leon's water infrastructure decisions. This framework uses conjunctively three different computational models: a water demand Monte-Carlo simulator, a water supply hydrological model and a dynamic optimization model. This framework is used in a computational experiment that uses a large ensemble of future scenarios exploring a vast space of water demand and water supply scenarios. The resulting database future scenarios is then analysed using statistical clustering algorithms to identify the factors that increase or reduce the vulnerability of different infrastructure portfolios. Finally, this vulnerability assessment is used to developed adaptive infrastructure investment plans. Our results show future water demand in the city can be met progressively through a combination of different projects. In the short term, small-to-medium scale grey infrastructure that take advantage of different water sources (i.e. surface and groundwater sources) can be used to meet future demand in the face of climate uncertainty. In the medium term, the combination of water efficiency and medium size grey infrastructure projects can help the city meet future demand and potentially save close to 1 billion dollars on grey infrastructure investments.

Juan Hernandez and *Christian González-Martel*

Spatially-dependent growth model for lodgings-services network in urban areas

SPEAKER: *Juan Hernandez*

ABSTRACT. We present a spatially embedded growing network model that reproduces the interrelationship between lodgings and services in urban areas. We assume that a lodging is linked to a specific service if a representative person hosted in the lodging enjoys/consumes the service. These nodes (lodgings and services) are located in a metric space which is represented by a planar network where distance is defined by the length of geodesic paths. The growing process assumes that, at every time step, a new lodging and m new services are created and located in the metric space. The probability that the new lodging is connected to a specific service follows a preferential attachment rule inversely weighted by the the length of a geodesic path form both nodes.

This attachment law is similar to the one proposed in by Xulvi-Brunett and Sokolov, Phys. Rev. E, 66, 02611870, 2002, but adapted to the case of a bipartite network. Moreover, we assume that the major determinant of the social distance to consume a service is the intermediate attractions and lodgings. Thus, the length of the geodesic path is preferred instead of the usually chosen euclidean distance.

We have tested the model with real data. Specifically we have sampled a real lodgings-services network in a tourist area (Maspalomas, Spain) from online data of recommendations published in tripadvisor.com during the period 2005-2016. The sample size is about 78.000 opinions on 223 lodgings and 3003 services/attractions. The geographic location of lodgings and services in the real data were used to build the planar network where the spatial network model is embedded. This planar network is not homogeneously distributed, since few major services (e.g. monument or man-made attractions) are more highly connected to lodgings than the rest. The comparison between the simulated and real network shows some topological similarities, such as the clustering coefficient and average path length, but also differences, such as the degree distribution. Other economic characteristics from the supply-side (promotion, quality of the service) or demand-side (visitor's preferences) may explain part of the gap between numerical and empirical results.

Andres Baeza, Marco Janssen, Luis Bojorquez-Tapia and Hallie Eakin

Vulnerability tradeoffs in an urban socio-hydrological agent-based model due to the decision-making dynamic of influential actors

SPEAKER: Andres Baeza

ABSTRACT. As urban environments become larger and more heterogeneous, they also come to be highly vulnerable to water-related hazards. Investment in “hard” or grey infrastructure has historically been the primary response by local, regional, and central governments to address such risks. These investments in turn respond to social and political factors (social-political infrastructure) associated with narratives or mental models about how the world is perceived by urban authorities, stakeholders and residents. While techniques to elicit these ontologies have been developed, few studies have gone beyond representing these priorities in space to include them into the dynamics processes that generate a continual feedback among social-political infrastructure, hard infrastructure and the production of urban vulnerability. In this talk we present an agent-based model to illustrate potential consequences for socio-hydrological vulnerability in a stylized urban landscape when considering feedback between social-political infrastructure and geospatial patterns of vulnerability outcomes, via different strategies for investments in physical “hard” infrastructure. The model is motivated by the Mexico City water management system and its socio-hydrological vulnerability. In the model, a water authority agent makes decisions as to where to invest limited resources to either create new infrastructure or invest in maintenance to reduce flooding or scarcity. These decisions are made by calculating a multi-decision criteria metric, which is constructed based on how authorities prioritize of a set of indicators of system performance, including the demand for immediate attention by neighborhoods. We simulated scenarios representing contrasting prioritization schemes by water authorities, and we conducted numerical experiments under similar biophysical and budgetary constraints. Our results indicate that minimal changes in prioritization can have significant consequences on the transient and steady state of sustainability indicators. We show that tradeoffs in performance can emerge under managers with different priorities, even under similar biophysical conditions. Finally, we observed that because of the complex interactions between the biophysical environment and neighborhood responses, managers can unwittingly exacerbate the problem that most concerns when they prioritizing specific criteria to guide their decision-making. We contrast these theoretical findings with the insights gained from the empirical finding from Mexico City’s water governance. We discuss the development of new methods to elucidate the specifications of the cognitive processes that can mechanistically connect the decisions of dominating actors with the dynamics of the biophysical environment in complex urban systems.

Mirijam Böhme

Detecting the Relationship Between Heuristic Decision-Making and the Complexity of Planning Processes

SPEAKER: *Mirijam Böhme*

ABSTRACT. A common observation in the study of complex systems is that those systems frequently become more complex as they evolve over time. Following John Holland, we can deduce this development to the application of simple rules; they can be a catalyst for the complexity of systems. This paper aims to shed light on the relationship of simple rules and increasing complexity in the planning of transport infrastructure. I propose that human decision-makers deploy heuristics – simple decision-making rules – to deal with the complexity of their environment. I further argue that due to this heuristic deployment decision-makers contribute to the increasing complexity of the planning situation. Planning processes involve continuous public decision-making where actors - including project managers and their teams, local politicians and administrators, and citizens - must deal with ever-changing technical details as well as with each other's desires and beliefs. They eventually need to decide on one planning option, taking into account environmental implications, effects on the population, questions of urban development, constructional feasibility etc. Often discussions take several twists, previously discussed options are eliminated, and new options and discussion points evolve over time: the situation becomes more complex. Actors deal with this complex environment but being the human beings they are, they cannot possibly consider all the information available to them and arrive at some rationally correct decision. As extensive previous psychological research has shown, they deploy heuristics, i.e., intuitively, often subconsciously activated decision-making mechanisms, instead. This paper's aim is to take a selection of experimentally well-researched heuristics and to investigate their operation in and their influence on the complexity of real-life decision-making processes. To this end, I analyze the decisions and interactions of stakeholders in the case of the ongoing railway planning processes in the cities of Bamberg (Germany) and Bergen (Norway). The analysis is based on secondary data, semi-structured in-depth interviews with stakeholders, and observations from city council meetings. In a first step, both cases are analyzed regarding (1) the stakeholders' heuristic deployment with the help of systematic coding and content analysis, and (2) the complexity of the planning process at t_0 and t_1 by application of a coding scheme based on Nicholas Rescher's taxonomy of complexity. In a second step, the influence of heuristics on the respective planning process is analyzed using within-case Process Tracing. Finally, both cases are compared, attempting to uncover potential patterns in heuristic deployment and their influence on the process evolution. Preliminary findings show that actors' perceptions of the process vary due to their heuristic deployment, leading to distorted intercommunications and decisions which contribute to the stagnation of the process rather than to a straight forward development towards its final decision. The analysis can show that both planning processes were considerably delayed due to heuristic decision-making of all actors. Both situations became more complex to the actors involved as more options and opinions arose during the decision-making.

Susannah Dickinson

The complexity of environmental infrastructure

SPEAKER: Susannah Dickinson

ABSTRACT. Most would agree that the majority of designs for contemporary buildings and the built environment are simplistic in a negative sense of the word. Generally they lack the materiality, scale and sense of life that many vernacular cities and spaces possess, not to mention issues of sustainability. Concepts of emergence and adaptation are ubiquitous in complex systems whose dynamics interact in non-linear ways. How can our design of the built environment from infrastructure to the design of cities, take advantage of this knowledge to promote more sustainable futures? Factoring in more variables and parameters is part of the equation; understanding the true costs and connections of what we do on a socio, economic and environmental level is a start. Even if we cannot measure or factor in everything, we need to start by incorporating more and not oversimplifying (being reductive). Adaptability and resiliency are also key in our current climate of multiplicity, inter-connectivity and indeterminacy.

Warren Weaver in his pivotal 1948 essay in American Scientist spoke of the scientific methodologies for dealing with organized complexity. He saw this as a historical development from the focus on problems of simplicity during the nineteenth centuries to the developments in disorganized complexity during the early 20th century. He saw organized complexity as a middle region of the two prior extremes, which was unsolvable by the statistical approach of disorganization. Organized complexity were all “problems which involve dealing simultaneously with a sizable number of factors which are interrelated into an organic whole”. Is this where we are now in the contemporary design fields? Have we finally moved past the false simplification of classicalism and modernism, beyond the realms of deconstruction and meaningless parametricism to the study of organized complexity? In the same article Weaver states that there were two promising developments that had come out of World War II to aid in this new field of organized complexity; computation and inter-disciplinary team work.

This paper will present various connections between complexity theory and designs for the built environment, highlighting some of the most promising examples of digital methodologies. Hypothesizing on how we evaluate the success of these strategies in a world which is more pluralistic and open-ended: showing that disciplinary boundaries are being dissolved and how computation is the necessary glue that is binding these elements.

Carlos Perez and Adolfo De Unánue

Bayesian networks for air quality analysis in Mexico City

SPEAKER: Carlos Perez

ABSTRACT. The application of Bayesian networks learning has been useful to get a better understanding of certain domains or to make predictions based on partial observations; for example in applied science fields like medicine, finance, industry, environment, and recently social sciences. Air quality in Mexico City is a major problem because the levels of air pollution are of the highest in the world, with a high average of daily emissions of several primary pollutants, such as hydrocarbons, nitrogen oxides and carbon monoxide. The pollution is due primarily to transportation and industrial emissions, and when this pollutants are exposed to sunshine, they undergo chemical reactions and yield a variety of secondary pollutants, ozone being the most important. People at risk from breathing air containing ozone include people with asthma, children, older adults, and people who are active outdoors, especially outdoor workers. This indicates a real need of models able to forecast the pollution level several hours, or even a day in advance in order to be able to take emergency measures, make contingency plans, estimate pollution where there are no measurements and to take preventive actions to reduce the health hazard produced by high pollution levels. This work poses some straightforward results that provide a deeper and better understanding of the air quality problem in Mexico, primarily determine which factors are more important for the ozone concentration that leads to a data driven estimation answer, by taking into account only the relevant information and as a byproduct sheds light in the discovery of critical causes of pollution. Learning algorithms are applied to obtain initial structure of the phenomena and Bayesian networks are used to model the variables interactions and reveal the relevance of this factors for estimating pollutant levels. The analysis is extended to other major cities and its possibility of generalization is assessed. The most relevant results conform a cornerstone to environmental policy in terms of its potential application to planning and evaluation endeavors. The complex system framework enables to discover unknown relations, estimate unobserved measurements and evaluate different scenarios through revealed information about data interactions. In other words, this Bayesian network approach constitutes solid ground for decision making in environmental policy.

Dina Mistry, Ana Pastore Y Piontti, Evangelia Panagakou, Marcelo Ferreira Da Costa Gomes, Syed Haque, Laura Fumanelli, Marco Ajelli, Stefano Merler, Maria Litinova and Alessandro Vespignani

Using heterogeneous contact patterns in the modeling of infectious diseases

SPEAKER: Dina Mistry

ABSTRACT. The dynamics of infectious diseases strongly depends on the structure of the social contact patterns among individuals.In order to have an accurate estimate of the impact of epidemic outbreaks and which effective control measures to take, we need an appropriate description of these patterns. A simple way to improve the homogeneous mixing assumption is to introduce age contact patterns. Here we follow the approach of Fumanelli et al (PLoS Computational Biology, 8(9):e1002673, 2012) to estimate the age mixing patterns of virtual populations using highly detailed census data for Argentina, Australia, Brazil, Canada, India, Mexico, Turkey and the United States. Considering age contact matrices for these countries we study the epidemiological relevant quantities and their relation with the sociodemographic data. Our results show that even for the same country the impact of epidemics outbreaks could be very different when we consider age contact matrices. These results can be explained as a result of a change in the average age of the population in the different regions of the countries. This study also provides the first estimates of contact matrices for the previously mentioned countries.

Leonor Huerta, Germinal Cocho and Carlos Villarreal

New Insights on HIV-1 infection dynamics

SPEAKER: Carlos Villarreal

ABSTRACT. We present a multi-compartment model for the HIV-1 infection dynamics. The model considers the interactions of HIV-1 with naive, activated and memory T-cells of the immune system in different body compartments: blood plasma, interstitial spaces of lymphoid tissue, and virus attached to follicular dendritic cells in the form of immune complexes. We show that the viral and T-cell dynamics under the administration of potent antiviral drugs observed in clinical trials can be understood in terms of virus and cell creation, destruction, and circulation among the different compartments. Our study suggests that the main features and characteristic parameters of HIV- dynamics measured in blood of infected patients reflect a complex dynamics taking place in lymphoid tissues.

Mariana Esther Martinez-Sanchez, Elena Pacheco, Carlos Villarreal, Leonor Huerta and Elena Alvarez-Buylla

Lymphocytes differentiation, plasticity, and immune-mediated diseases

SPEAKER: Carlos Villarreal

ABSTRACT. We study the differentiation process of CD4 T lymphocytes by means of a regulatory network that integrates transcriptional regulation, signaling pathways, and a micro-environment determined by cytokine expression. The network interactions are characterized by dynamic Boolean propositions involving fuzzy logics. As a result, the model yields immune cell phenotypes giving rise to cellular, humoral, inflammatory, and regulatory responses, as well as other reported T-cell types. Plasticity and reprogramming of T-cell fates are attained by altering the micro-environmental conditions. We discuss the results of our model within the context of several immune-mediated diseases.

Rion Brattig Correia, Ian B. Wood, Nathan D. Ratkiewicz, Wendy Miller and Luis M. Rocha

Public health monitoring of drug interactions, patient cohorts, and behavioral outcomes via network analysis using multi-source user timelines

SPEAKER: Rion Brattig Correia

ABSTRACT. Social media and mobile application data enable population-level observation tools with the potential to speed translational research. We have shown recent work demonstrating Instagram's importance for public surveillance of drug interactions [1]. Our methodology is based on the longitudinal analysis of social media user timelines at different timescales: day, week and month. Weighted graphs are built from the co-occurrence of terms from various biomedical dictionaries (drugs, symptoms, natural products, side-effects, and sentiment) at various timescales. We showed that spectral methods, shortest-paths, and distance closures [2,3] reveal relevant drug-drug and drug-symptom pairs, as well as clusters of terms and drugs associated with the complex pathology associated with depression [1]. Here we extend the approach to include validation measures for discovered drug interactions and adverse reactions via curated databases (DrugBank & SIDER); additional social media sources: Twitter, Facebook, ChaCha and the Epilepsy Foundation public forums; and multi-level network analysis with data from single patients in multiple mediums. We present preliminary results on the prediction of behavioral transitions for patient cohorts at risk for "Sudden Unexpected Death in Epilepsy" (SUDEP) from Facebook, where we scored their written text to sentiment dimensions used in the prediction. We also present new links between drugs and symptoms related to depression, epilepsy, and the recent opioid epidemic in the US using user data from Twitter and Instagram. We present a methodology to identify user biographical information solely from self-reported information – available in clinical settings but often lacking in online settings – needed for estimating population-level statistics such as age and gender of cohorts of interest. Finally, we will showcase a general-purpose web-tool environment – featuring a virtual reality 3D knowledge network visualization – that can facilitate public health monitoring of social media for conditions, drugs, and cohorts of interest, expanding upon our previous Instagram Drug Explorer tool [1].

[1] R.B. Correia, L. Li, L.M. Rocha [2016]. Pac. Symp. Biocomp. 21:492-503. (PMCID: PMC4720984) [2] T. Simas and L.M. Rocha [2015]. Network Science, 3(2):227-268. [3] G.L. Ciampaglia, P. Shiralkar, L.M. Rocha, J. Bollen, F. Menczer, A. Flammini [2015]. PLoS One. 10(6): e0128193.

Christopher Stephens, Jonathan Easton and Osvaldo Trujillo

Lifestyle diseases as Complex Adaptive Systems: Perspectives and Challenges

SPEAKER: Christopher Stephens

ABSTRACT. The phenomenology of Complex Adaptive Systems is immensely richer than that of physical systems, both structurally and, more importantly, behaviourally. Although the possible microscopic configurations of 1023 atoms that make up a gas may be similar to that of a similar number of atoms that make up a living organism, the phenomenology of an organism is immensely more difficult to describe than that of the gas. Correspondingly, the amount of data required to organize and understand the phenomenology and then adequately describe the organism is much greater. Although this is a seemingly abstract consideration, it lies at the very heart of developing a better understanding of disease. Any disease, seen correctly as a Complex Adaptive System, is immensely multifactorial. However, chronic diseases that are highly lifestyle dependent, such as obesity, type 2 diabetes, many cancers etc. are even more challenging, involving factors across the entire spectrum of scales and disciplines: genetics, epigenetics, cell biology, physiology, psychology, neuroscience, epidemiology, sociology, economics, politics and ethics. An important reason why, in spite of a huge investment in research, such diseases are still on the increase, is that there is no “cure” associated with a particular discipline, such as a vaccine. Rather, the risk factors form a complex causal network of interactions and no particular factor is much more important than the others. In this presentation we will discuss the challenges of the predictive modelling of chronic diseases. In particular, we will discuss those challenges in the context of the construction of predictive models for obesity developed from data obtained from a cohort of 1,076 workers and researchers at the UNAM. Over 3,000 variables were measured – epidemiological, social, physiological and genetic. From the analysis of this data we can show explicitly how different factor types – nutrition, lifestyle, personal and family antecedents, genetics, health knowledge and demographics – all contribute to the overall risk, emphasising that each risk factor can be individually quantified and contrasted with others, and noting that such risk is dependent on an enormous spectrum of factors, indicating that there is no “magic bullet” solution. We will show that, although very predictive models can be created, there are significant challenges in understanding what the model is telling us and how to turn it into actionable information both at the clinical and public policy levels. We believe that this type of model also illustrates many of the difficulties to be faced in modelling any Complex Adaptive System.

Laura Ozella, Jared Wilson-Aggarwal, Michele Tizzoni, Ciro Cattuto and Robbie McDonald

Animal social networks relevant to disease transmission among free-roaming dogs in Chad

SPEAKER: Laura Ozella

ABSTRACT. Animal social network analysis is increasingly used to understand many ecological and epidemiological processes. The knowledge of the contact structure of an animal population is the first step for predicting and controlling disease outbreaks, including zoonosis. Free-roaming domestic dogs (Canis familiaris) are hosts of a variety of zoonosis (e.g., rabies) in most of Africa, and little is known about the population dynamics of these animals. Usually, modeling efforts are challenged by the limited availability of data on dogs movements and mixing patterns. We used wearable proximity sensors to detect close-range interactions between free-roaming domestic dogs living in 4 villages in rural Chad. The study included 138 dogs, 60 females and 78 males, classified by age as: pups (birth to 6 months), juveniles (6 months to 1 year), subadults (1-2 years), and adults (more than 2 years). Every dog belonged to one of 91 different households, with 32 households hosting more than one dog. The experimental period lasted from 2 to 12 days, depending on the village. We also used GPS trackers to estimate their home range, and to understand their movement behavior. Furthermore, we combined the proximity sensors data and the GPS data to obtain a multi-layer proximity network description based on different contact definitions. We defined temporal contact networks and contact matrices, and determined mixing patterns by age and by gender. Contacts occurred mostly between dogs living in the same household, however, 98% of the dogs had contacts with dogs living in a different household. Contacts within households occurred mainly among pups, while inter-household contacts were between subadults and juveniles and subadults and adults. Results show that the pups are more sociable with dogs of the same litter, while dogs more than 6 months tend to interact with dogs living in different households. With respect to their gender, contacts occurred mainly between males and females both within and across households. The temporal evolution of the number of contacts showed, in each village, some distinct temporal features, specifically daily oscillations with two activity peaks, one in the morning (6AM - 8AM) and one in the evening (6PM - 8PM), according to the typical daily activity patterns of dogs. Moreover, our results showed a positive and significant correlation between the time spent in proximity by dogs detected by the proximity sensors and by the GPS. Our study shows the feasibility of accurate measures of contact patterns among free-roaming dogs in a rural context in Africa, providing novel insights into the structure and behavior of animal contact networks and their implication for disease transmission.

M. Verónica Ponce-Castañeda, Blanca Castro-Magdonel, Ma. De Lourdes Cabrera-Muñoz, Adda-Jeanette García-Chéquer, Manuela Orjuela and Noé Durán-Figueroa

True miRNOME Landscape in Retinoblastoma Analysis Reveals a Critical 30 miRNA Core

SPEAKER: M. Verónica Ponce-Castañeda

ABSTRACT. miRNAs exert their effect through a negative regulatory mechanism silencing protein expression upon hibridizing to their target mRNA, thus miRNAs have a prominent position in the control of many cellular processes including carcinogenesis. High throughput tools to assess a miRNome are mainly based on microarrays and RNA-seq. Analysis and published results of expression microarrays whether miRNA or mRNA species especially in the cancer field, lack at large, a proper and robust approach to describe their findings with a real integrative approach. In this work we examine and show with a broad perspective the whole miRNome expression using a high throughput microarray platform including 2578 mature miRNAs in 12 samples of primary human retinoblastoma, an intraocular malignant tumor of early childhood and probably the most robust clinical model of genetic predisposition to develop cancer on which, the first tumor suppressor gene RB1 was identified. miRNA studies on retinoblastoma are limited to specific miRNAs previously reported in other tumors or to medium density arrays. This work delineates the miRNA landscape in human retinoblastoma samples with a non-biased approach using as an initial guide, discretized data from detection call scores as an approximation to the “ON”/”OFF” or expressed/not expressed state for each miRNA. With this data we generated a very informative hierarchical map of miRNAs on which we discovered a core-cluster of 30 miRNAs highly expressed in all the cases, a cluster of 993 not expressed in all cases and 1022 variably detected in the samples accounting for inter tumor heterogeneity. We explored mRNA targets, pathways and biological processes affected by some of these miRNAs, from this exploration we propose that the 30 miRs core represent a shared miRNA machinery in retinoblastoma affecting most pathways considered hallmarks of cancer. Interestingly, 36 miRNAs were differentially expressed between males and females, some of their potential pathways were associated with hormones and developmental processes. We also identified miR-3613 as a potential down regulator hub, because is highly expressed by all the samples and has at least 36 tumor suppressor genes as potential mRNA targets including the RB1 gene itself. Our results indicate that human retinoblastoma share a common and fundamental miRNA expression profile regardless of heterogeneity. This work also shows how relevant oncology concepts like inter tumor heterogeneity or oncogene addiction can be uncovered and described with high throughput data, closing the vocabulary and tool use gap frequently found when different fields intersect.

Noshir Contractor

Leveraging Computational Social Science to address Grand Societal Challenges

SPEAKER: Noshir Contractor

ABSTRACT. The increased access to big data about social phenomena in general, and network data in particular, has been a windfall for social scientists. But these exciting opportunities must be accompanied with careful reflection on how big data can motivate new theories and methods. Using examples of his research in the area of networks, Contractor will argue that Computational Social Science serves as the foundation to unleash the intellectual insights locked in big data. More importantly, he will illustrate how these insights offer social scientists in general, and social network scholars in particular, an unprecedented opportunity to engage more actively in monitoring, anticipating and designing interventions to address grand societal challenges.

Carlos Gracia-Lázaro, Julia Poncela-Casasnovas, Mario Gutiérrez-Roig, Julian Vicens, Jesus Gomez-Gardenes, Josep Perello, Yamir Moreno, Jordi Duch and Anxo Sanchez

Humans display a reduced set of consistent behavioral phenotypes in dyadic games.

SPEAKER: Carlos Gracia-Lázaro

ABSTRACT. Socially relevant situations that involve strategic interactions are widespread among animals and humans alike. These situations are commonly studied in economics, psychology, political science, and sociology, typically using a game theoretic framework to understand how decision-makers approach conflict and cooperation under highly simplified conditions, generating valuable insights about human behavior. However, most of the results reported so far have been obtained from a population perspective and considered one specific conflicting situation at a time. This makes it difficult to extract conclusions about the consistency of individuals' behavior when facing different situations and to define a comprehensive classification of the strategies underlying the observed behaviors.

Here, we attempt to shed light on this issue by focusing on a wide class of simple dyadic games that capture two important features of social interaction, namely, the temptation to free-ride and the risk associated with cooperation. For this purpose, we present the results of a lab-in-the-field experiment in which subjects face four different dyadic games, with the aim of establishing general behavioral rules dictating individuals' actions. The games used in our study are the Prisoner Dilemma, the Stag Hunt, the Snowdrift and the Harmony. We recruited 541 subjects of different ages, educational level, and social status. The experiment consisted of multiple rounds, in which participants were randomly assigned partners and assigned randomly chosen payoff values. By varying two parameters of the payment matrix, we obtained 121 different games, which allowed us to study the behavior of the same subject in a wide range of situations, simultaneously obtaining data from various observables, such as the tendency to cooperate and the risk aversion of the subjects.

By analyzing our data with an unsupervised robust classification algorithm, the K-means clustering algorithm, we find that all the subjects conform, with a large degree of consistency, to a limited number of behavioral phenotypes (Envious, Optimist, Pessimist, and Trustful), with only a small fraction of undefined subjects. In agreement with abundant experimental evidence, we have not found any purely rational phenotype: the strategies used by the four relevant groups are, to different extents, quite far from self-centered rationality. We also discuss the possible connections to existing interpretations based on a priori theoretical approaches. Our findings provide a relevant contribution to the experimental and theoretical efforts toward the identification of basic behavioral phenotypes in a wider set of contexts without aprioristic assumptions regarding the rules or strategies behind actions. From this perspective, our work contributes to a fact-based approach to the study of human behavior in strategic situations, which could be applied to simulating societies, policy-making scenario building, and even a variety of business applications.

Poncela-Casasnovas, Julia, et al. "Humans display a reduced set of consistent behavioral phenotypes in dyadic games."Science Advances 2.8 (2016): e1600451.

Mathieu Génois, Clemens Lechner, Beatrice Rammstedt, Markus Strohmaier, Alain Barrat and Ciro Cattuto

Mixing, homophily and avoidance in a scientific conference

SPEAKER: Mathieu Génois

ABSTRACT. During the GESIS Winter Symposium 2016, we set up a SocioPatterns experiment in order to study how people mix during a scientific conference. Using the SocioPatterns system, we recorded the face-to-face contacts between participants. We also asked them to answer a survey about general sociodemographic information, along with a personality test based on the Big Five model. The Big Five model is a standard test in Psychology, that scores five aspects of an individual's personality: openness, conscientiousness, extraversion, aggreeableness, and neuroticism.

We have thus gathered data on how participants interacted during the conference, and measured their mixing behaviour based on sociodemographic attributes. We found for instance that no gender bias could be measured, but that there existed avoidance strategies based on age class. We were also interested in investigating the existence of homophilic or heterophilic behaviours between individuals of various personality types, i.e. for example whether extraverted individuals are more likely to connect with other extraverts, or whether neurotic individuals avoid other personality types. We could not find evidence of such homophilic or heterophilic behaviour linked to personality types.

Finally, we aimed at determining whether personality types, as defined and measured by the Big Five model, could predict features of real social interactions, such as the number of person encountered, the average time of interaction, etc. Preliminary results seems to show that personality traits have no predictive power for social behaviour in such a context. These results need to be confirmed by future studies.

Federico Battiston, Jesus Gomez-Gardeñes, Vito Latora, Andrea Migliano and Lucio Vinicius

Hunter-gatherer networks and cumulative culture

SPEAKER: Federico Battiston

ABSTRACT. Social networks in modern societies are highly structured, usually involving frequent contact with a small number of unrelated friends. However, contact network structures in traditional small-scale societies, especially hunter-gatherers, are poorly characterized. We developed a portable wireless sensing technology (motes) to study within-camp and inter-camp proximity networks among Agta and BaYaka hunter-gatherers in fine detail. We show that hunter-gatherer social networks exhibit signs of increased efficiency for potential information exchange (see Refs.[1,2] for full details).

In particular, to estimate global network efficiency[3], we first built weighted social networks using our motes proximity data from Agta and BaYaka camps, and subdivided the networks into three decreasing levels of relatedness: close kin, extended family and non-kin. We estimated the contribution of each relatedness level to global network efficiency by comparing our hunter-gatherer network structures with randomly permuted networks. Our analyses show that randomization of interactions among either close kin or extended family (including affinal kin) does not affect the global efficiency of hunter-gatherer networks. In contrast, randomization of non-kin relationships (friends) greatly reduces global network efficiency. Therefore, increased global efficiency in our networks results from investing in a few strong close friends in addition to an extended net of social acquaintances, or a combination of strong and weak ties[4]. In agreement with classic studies of small-world networks[5], our results show that only a few shortcuts (friendships) connecting closely knit clusters (households consisting mostly of close kin) suffice to significantly reduce the average path length or distance between any two points across the whole network, thus reducing redundancy and the cost of maintaining strong links with a large number of unrelated individuals. Since unrelated individuals often live in different households, they provide a small number of reliable shortcuts between households. Both the Agta and BaYaka had between one and four unrelated close friends with whom they interact as frequently as with close kin. This number is consistent across ages and camps, and with the finding that people in western societies are in close contact with an average of four friends[6].

We also show that interactions with non-kin appear in childhood, creating opportunities for collaboration and cultural exchange beyond family at early ages. We also show that strong friendships are more important than family ties in predicting levels of shared knowledge among individuals. We hypothesize that efficient transmission of cumulative culture[7-10] may have shaped human social networks and contributed to our tendency to extend networks beyond kin and form strong non-kin ties.

Laura Alessandretti, Piotr Sapiezynski, Sune Lehmann and Andrea Baronchelli

Evidence for a conserved quantity in Human Mobility

SPEAKER: Laura Alessandretti

ABSTRACT. Faced with effectively unlimited choices of how to spend their time, humans are constantly balancing a trade-off between exploitation of familiar places and exploration of new locations. Previous analyses have shown that at the daily and weekly timescales individuals are well characterized by an activity space of repeatedly visited locations. How this activity space evolves in time, however, remains unexplored. Here we analyse high-resolution spatio-temporal traces from 850 individuals participating in a 24-month experiment. We find that, although activity spaces undergo considerable changes, the number of familiar locations an individual visits at any point in time is a conserved quantity. We show that this number is similar for different individuals, revealing a substantial homogeneity of the observed population. We point out that the observed fixed size of the activity space cannot be explained in terms of time constraints, and is therefore a distinctive property of human behavior. This result suggests an analogy with the so-called Dunbar number describing an upper limit to an individual's number of social relations, and we anticipate that our findings will stimulate research bridging the study of Human Mobility with the Cognitive and Behavioral Sciences.

Auriel Washburn, Rachel Kallen, Maurice Lamb, Nigel Stepp, Kevin Shockley and Michael Richardson

Self-Organized Anticipatory Synchronization of Chaotic Human Behavior by Artificial Agents During Real Time Interaction

SPEAKER: Auriel Washburn

ABSTRACT. Rapid advances in cyber-technologies and robotics present increasing opportunities for the implementation of interactive, artificial agents within contexts of human behavior. This includes, but is not limited to, assistance during the performance of everyday tasks and the development of new skills. Work has already been done, for example, on the development of virtual agents able to assist elderly individuals with the organization of daily activities, and to create a robot whose structured interaction may help to improve interpersonal coordination in children with autism spectrum disorders. However, researchers have recently drawn attention to the fact that engineers working to design virtual and robotic agents do not always prioritize those aspects which will allow for smooth, effortless human interaction, while psychologists studying interpersonal or joint-action do not always take into account technical realizability in describing what they see as the fundamental aspects of successful multi-agent coordination. One potential solution to this issue is to identify and model the behavioral dynamics of natural human-human interaction using low-dimensional differential equations that can be easily implemented within interactive robotic or machine systems. Recent work has provided support for the idea that relatively simple self-sustaining, nonlinear dynamical systems can be used to construct virtual interaction partners capable of successful, flexible coordination with human actors. The development of these agents has primarily focused on their ability to exhibit coordination with periodic behaviors, or synchronize with fluctuating movement speeds using a velocity estimation algorithm. However, one only has to consider a pedestrian navigating a busy city sidewalk to be reminded that people are often capable of prospectively coordinating their behavior with highly variable, seemingly unforeseeable events in an effortless manner. Our own recent research in human motor control and joint-action has demonstrated that small perceptual-motor feedback delays, such as those known to exist within the human nervous system, may actually facilitate the ability to achieve anticipation of such continuous chaotic events. This phenomenon, referred to as strong anticipation or self-organized anticipatory synchronization, has been found to emerge when a unidirectional coupling exists between a “slave” system and a chaotically behaving “master” system. Surprisingly, as the slave system begins to synchronize with the chaotic behavior of the master system, the introduction of small temporal feedback delays results in the slave system anticipating the ongoing behavior exhibited by the chaotic master system. Understanding human anticipatory behavior as defined by the same universal dynamical laws as other physical systems provides a novel opportunity to inform the advancement of artificial agents. The goal of the current project was therefore to harness the phenomenon of anticipatory synchronization in developing an artificial agent capable of achieving adaptive anticipation during interaction with a human co-actor. Here individuals interacted with a robot avatar defined by a time-delayed, low-dimensional dynamical model via a virtual reality headset. This agent displayed prospective coordination with seemingly unpredictable human behavior, making this work the first to employ the understanding of anticipatory synchronization in physical systems for the creation of an artificial agent capable of anticipating complex human behavior in real time.

Dries Maes and Nadine Roijakkers

Options for transfer of ecosystem research methodologies from ecology to innovation research

SPEAKER: Dries Maes

ABSTRACT. During the last decades, companies have increasingly moved from short-term oriented closed innovation towards more lasting open innovation structures. Open innovation indicates the use of external knowledge during R&D processes, as well as the application of internal knowledge for the benefit of external partners. These growing networks are described as innovation ecosystems featuring higher innovation capacities and regional stability. In parallel, the study of open innovation has moved towards a system level thinking during the last years. This has led to the concept of innovation ecosystems to characterize the intricate complex structure of innovation network activities in a region. The ecosystem metaphor reflects the increasing interconnectedness of the innovation networks, and the ever-present changes in network structures and dynamics.

The study of innovation ecosystems has received criticism lately for using a mere ecosystem analogy as a concept for research. This criticism has led to scholars to review the merits of the innovation ecosystem concept and to call for increasingly rigorous applications. This discussion however is for a large part held within the domain of innovation research. Reviews or conceptual discussions rarely include the latest developments in concepts or methodologies from ecology and biological sciences. This not only limits the scope of the discussion, it also prevents potential opportunities for interdisciplinary learning. Other concepts, like resilience, have shown that crossing disciplinary boundaries can open up an entirely new perspective, and may induce new avenues of research, such as the research on resilience of socio-ecological systems.

In this paper we review side-to-side the methodologies used for ecosystem research in ecology and in economic science, with the aim of identifying the instances where innovative methodologies from ecology can be transferred to the study of innovation ecosystems. We focus on methodologies to go beyond the concepts and thinking frameworks. For each methodology, the theoretical foundation, underlying assumptions and benefits are reviewed. The review of the underlying assumptions takes the differences between the two scientific domains into account, and controls whether ecological methods are applicable in systems that exhibit markets, coordination and foresight. Some methodologies, such as input-output analysis, seem to have evolved separately in the two scientific domains. Others, such as ascendency measurements, see a growing interest in ecology, but are only scarcely applied in socio-ecological systems, revealing options for new approaches in innovation research.

Colm Connaughton

Scaling laws and collective dynamics in far from equilibrium growth-fragmentation processes

SPEAKER: Colm Connaughton

ABSTRACT. The kinetic theory of far from equilibrium growth-fragmentation processes provides natural mathematical models for many types of complex systems. The phenomenology of such models is very rich. They sometimes reach steady states that exhibit power law scaling of the cluster size distribution over some range of scales. However, depending on the details and relative strength of the growth and fragmentation mechanisms, we may find a transition between a stationary stable phase in which some maximum characteristic size is reached and a non-stationary growing phase in which the characteristic cluster size grows indefinitely. In some growing phases, the characteristic cluster size can diverge in a finite time - a mechanism for very rapid formation of very large clusters. In some stable phases, the stationary cluster size distribution can be unstable and transitions to a regime in which the kinetics become oscillatory with the largest clusters appearing and disappearing in a periodic fashion. In this talk, I will discuss recent developments in this area and try to relate them to some of the commonly discussed phenomenology of complex systems.

José Roberto Nicolás Carlock, José Luis Carrillo Estrada and Víctor Dossetti

Universality of fractal to non-fractal transitions in stochastic growth processes

SPEAKER: José Roberto Nicolás Carlock

ABSTRACT. From the formation of lightning-paths to vascular networks, stochastic growth processes of pattern formation give rise to intricate structures spread everywhere and at all scales in nature, often referred to as fractals. One striking feature of these growth processes are the fractal to non-fractal morphological transitions that they undergo as a result of the interplay of the entropic and energetic aspects of their growth dynamics, that ultimately manifest in their structural geometry. However, due to the lack of a complete far-from-equilibrium scaling theory to describe them, an important aspect of the theory dealing with the nature of these transitions and the best quantities to characterize them, is still in need of a comprehensive description. In this work, we present a framework for the study of these transitions that is based on the concepts and tools of information theory and fractal geometry. First, by means of two-dimensional fundamental aggregation models, the Diffusion-Limited Aggregation, the Ballistic Aggregation, and the Mean-Field infinite interaction model, we present four fractal to non-fractal transitions that are able to reproduce all the main morphologies observed in fractal growth. Second, we present a general dynamical model for the information dimension of the clusters, whose solution is able to describe their fractality along the respective transition. As the main result, we found that the effective scaling and fractality of all these transitions, including that of the paradigmatic Dielectric Breakdown Model (the base of the fundamental Laplacian growth theory), can be described by a single universal equation regardless of the symmetry-breaking process that governs the transition, the initial configuration of the system, and the Euclidean dimension of its embedding space.

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Verena Schamboeck, Ivan Kryven and Pieter Iedema

Universal modeling approach for the topological structure of multifunctional polymer networks using random graphs

SPEAKER: Verena Schamboeck

ABSTRACT. When speaking about soft matter and its physical properties, most of the time the material is thought of and modeled as being continuous. However, if one zooms in on the material, its discrete structure comes into sight, consisting of single molecules that are connected with each other. Often, these molecules have not only formed simple chains, but appear as strongly crosslinked, complex networks. It is the topology, which defines the macroscopic, physical properties of a material. Considering the example of a polymerization process, the emerging topology defines the phase transition from the liquid to the solid state. We developed a novel mathematical model to predict the topology of highly crosslinked growing networks and to derive global properties of these networks. The complex topology of these networks can be described by a graph. If we model polymer networks, the nodes of the graph are interpreted as the monomer units, the edges as the chemical bonds between monomer units and the connected components describe the whole molecules consisting of connected monomers. Further, we view the evolution of the growing network as a random process. Hence, the network is modeled as a configurational model for random graph with directed and undirected edges using generating functions. The trivariate degree distribution that defines the random graph is given for every moment of time and obeys the statistics of the local chemical reactions. Utilizing our extended random graph formalism we derive an expression for the weak component in the generating function domain. An exact analytic criterion for a phase transition in the network (the emergence of the giant component) is obtained, which corresponds to the physical phase transition in the chemical system from the pre-gel to the gel regime. This criterion only utilizes the moments of the trivariate degree distribution as an input. Furthermore, global properties are calculated as the component size distribution, the gel fractions for different classes of species as well as the distribution of distances between crosslinks. The method is illustrated on the example of photocuring of hexanediol diacrylate (HDDA) including initiation, propagation and termination reactions. As the method is highly universal, it can be applied on various other chemical systems.

Benjamin V Ramirez, Rosa M. Benito and Ana L Benavides

Topological properties of hydrogen bond networks for water in different thermodynamic phases

SPEAKER: Benjamin V Ramirez

ABSTRACT. The study of water has always been a very active area of research among the scientific community because it is the most abundant liquid in the planet, it is fundamental for life, and it presents a very rich phase diagram. Besides, although water has a very simple molecular structure, it exhibits a great number of anomalies not found in most of simple one component fluids. These anomalies are mainly related with the formation of hydrogen bonds among molecules. So, a good water model should be able to reproduce the hydrogen bond network at different thermodynamic states. In this work, we have used the Molecular Dynamics simulation technique to study several water models (TIP5P, TIP4P/2005 and TIP4P/Ice) at different temperature and pressure conditions to simulate single phase properties and their transitions. From the equilibrated simulated configurations we have built networks for the structure of water characterizing the hydrogen bonds with three different geometrical criteria. Once the corresponding networks are well established, we computed some topological properties like the average degree, the clustering coefficient (C), the average path length (L) and the degree distributions. The networks were created with the purpose of analyzing the behavior of the topological properties in different single thermodynamic phases (gas, liquid and solid) and in the neighborhood of the transitions between them. In general it was observed that the topological properties are sensible to the selected water model and/or hydrogen bonding criteria in the different single phases. Besides, some of the topological properties can detect a change of phase, like for example, the clustering coefficient or the average degree. The single phase properties near the coexistence lines can differ approximately in one order of magnitude. As a conclusion we can say that the topological properties of the hydrogen bond networks are a good indicator for characterizing the distinct water thermodynamic phases (solid, liquid and vapor) and their transitions. Besides, the topological properties provide an economical way of testing different hydrogen bonding criteria while building better water models.

Yuliia Orlova, *Ivan Kryven* and *Pieter Iedema*

Auto-generated Reaction Networks for Polymerization of Triacylglycerides

SPEAKER: *Yuliia Orlova*

ABSTRACT. Many phenomena in life and nature can be viewed as stochastic process where the system goes from one state to another following some finite number of rules. Knowing the initial state of the system and the mechanism of metamorphosis between different states, one can recover the whole configuration space of the process. In mathematical linguistics, this principle has been long since exploited to generate a set of well-formed sentences by applying a generative grammar to the initial dictionary of simple words. In the same way, we define rules on molecules and automatically form new species, which are able to react further and keep the system alive till the whole reaction network is completely recovered. In this manner we explore the polymerization process of triacylglycerides, where thousands of competitive reactions are happening from the very beginning of the polymerization process. Our main purpose is to construct the kinetic model, which captures the distribution of concentrations of all the intermediate species and products over time. We suggest a new methodology, which consists of automated generation of reaction mechanisms and results in a complete chemical reaction network. In order to generate this network, we define reaction rules for each type of the reaction in the system. Molecules are viewed as molecular graphs. Thus, the reaction rules are described as grammar on patterns (subgraphs of molecular graphs), which correspond to the reactive sites of the molecule. In this setup, a reaction happens only between the patterns of a reactant and a product. The next issue to tackle is to recognize these patterns in the molecule. It brings us to subgraph isomorphism problem. For this purpose we utilize FastOn algorithm, which is based on Ulman algorithm and aims to reduce the subgraph search space. Every time a transformation of patterns happens, it is recorded in the reaction network. Thus, we end up with a list of all configurations of the triacylglyceride monomer and the complete reaction network. Having this information we convert the network into a kinetic model, which provides detailed information about the concentrations of all species in our system. Furthermore, one can extract and investigate species of interest and analyze the behavior of the system in different points of time. In particular we focus on obtaining the distributions of crosslinked species. Further these distributions will be used as an input for the random graph model that recovers macroscopic structure of the resulting polymer network.

Ivan Kryven

Branched Polymers: The Most Real-world of All Networks

SPEAKER: *Ivan Kryven*

ABSTRACT. During the last two decades the community that gathered around a freshly coined concept of network science has been chasing new models explaining the “real-world” networks. This process was bristled with constantly redefining what ‘real-world’ means by trying to associate the concept with social sciences: power law in degree distribution, small average shortest path, clustered structure. This talk focuses on a different type of networks. Networks that are not less ‘real’ and certainly more tangible: the polymer networks. From materials for tables and chairs to nano-robots transporting drugs in the human body, polymer networks comply with the most extraordinary demands due to a broad range of physical properties they exhibit. In conditions of fluidity and constant change of shape it is mostly connection between molecules (or molecular topology) that makes the same molecular network being the same at different points in time. We model formation of a polymer network from multifunctional precursors with a temporal random graph process. The process does not account for spatial positions of the monomers explicitly, yet the Euclidean distances between the monomers are derived from the topological information by applying self-avoiding random walk formalism. This allows favouring reactivity of monomers that are close to each other, and to disfavour the reactivity for monomers obscured by the surrounding. The phenomena of conversion-dependent reaction rates, gelation, and structural inhomogeneity are predicted by the model.

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Minjun Kim and Hiroki Sayama

Predicting stock market movements using network science: An information theoretic approach

SPEAKER: Hiroki Sayama

ABSTRACT. A stock market is considered as one of the highly complex systems, which consists of many components behaving up, down and/or staying still interdependently with each other in their publicly known market values over time. This complex nature of the stock markets challenges us on making a reliable prediction of its future movements. In this research, we aim at building a new method to forecast the future movements of the stock markets by constructing complex networks of Standard & Poor's 500 Index (S&P 500) underlying constituents with companies representing network nodes and mutual information of 60-minute price movements of the pairs of the companies representing network link weights. By studying the relationship between the dynamics of the measurements we have created with the degree information of the nodes and (S&P 500), we show that the changes in degree distributions of the networks provide important information on the network's future movements. To show the predictability of over time degree distribution changes to the S&P 500, we built two predictors using the degree distribution information, the relative strength (the strength, average degree of all nodes, of a network relative to that of the average of the previous networks) and Kullback-Leibler divergence (KLD) of the networks. We found that, through a linear combination of the two metrics, the combined predictor and the future (one hour to the future) changes in S&P 500 shows a quadratic relationship from which we can predict the amplitude of the future change when we have a new observation of the predictor. The result shows large fluctuations in S&P 500 Index when the predictor makes hikes. These findings are useful for financial market policy makers as an indicator based on which they can interfere with the markets before the market makes a drastic change.

Fabio Caccioli, Imre Kondor and Gabor Papp

Analytic solution to variance optimization with no short positions

SPEAKER: Fabio Caccioli

ABSTRACT. A portfolio of independent, but not identically distributed, returns is optimized under the variance risk measure with a ban on short positions, in the high-dimensional limit where the number N of the different assets in the portfolio and the sample size T are assumed large with their ratio r=N/T kept finite. To the best of our knowledge, this is the first time such a constrained optimization is carried out analytically, which is made possible by the application of methods borrowed from the theory of disordered systems. The no-short-selling constraint acts as an asymmetric L1 regularizer, setting some of the portfolio weights to zero and keeping the out-of-sample estimator for the variance bounded, avoiding the divergence present in the non-regularized case. However, the ban on short positions does not prevent the phase transition in the optimization problem, only shifts the critical point from its non-regularized value of r=1 to 2, and changes its character: at r=2 the out-of-sample estimator for the portfolio variance stays finite and the estimated in-sample variance vanishes, while the susceptibility diverges at the critical value r=2. We have performed numerical simulations to support the analytic results and found perfect agreement for N/T<2 in the large N limit. Numerical experiments on finite size samples of symmetrically distributed returns show that above r=1 solutions with zero in-sample variance start to sporadically arise, their probability of appearance increasing as r approaches 2, steeply rising around the critical point, and becoming nearly one beyond r=2. A closed formula obtained for this probability shows that in the large N limit the transition becomes sharp. The zero in-sample variance solutions are not legitimate solutions of the optimization problem, as they are infinitely sensitive to any change in the input parameters, in particular they will wildly fluctuate from sample to sample. With some narrative license we may say that the no-short constraint, with prohibiting large compensating positions, takes care of the longitudinal (length) fluctuations of the optimal weight vector, but does not eliminate the divergent transverse fluctuations of its direction arising from the reshuffling of the vector components. We also calculate the distribution of the optimal weights over the random samples and show that the regularizer preferentially removes the assets with large variances, in accord with one's natural expectation.

Kenta Yamada, Hideki Takayasu and Misako Takayasu

Construction of stochastic order book models based on real data analysis

SPEAKER: Kenta Yamada

ABSTRACT. We introduce a new order book model which reproduces all major stylized facts such as a power law distribution of price changes, abnormal diffusions and distribution of transaction intervals. Maslov introduced a basic order book model[1] which describes the dynamics of an order book as a stochastic process. Namely in this model we give the dynamics of limit orders and market orders stochastically. The Maslov model reconstructs a power law distribution of price changes, however the market price produced by the Maslov model shows much greater oscillation than the real data and the diffusion properties of price are also different from the real data.

In order to construct a more realistic model, we analyzed the order book data of financial markets and give the base model the characteristics observed from the data. We find an important rule for the position where a new limit order is placed, that is the place of a new limit order depends on the volatility. When the market is volatile, limit orders tend to be placed in deep positions where the distance is away from the best price, while on the other hand when the market is stable limit orders tend to be placed in shallow positions. We also find the normalized distance by volatility follows the unique exponential distribution except for the special day such as government intervention. This feedback of volatility implies that dealers observe the volatility and they tend to extend their spread between the bid(buying) and the ask(selling) prices when the market is volatile.

The revised model, which contains the properties of a new limit order position, reproduces the power law distribution of price changes. We can also find volatility clustering and temporal non-uniformity of dispersion in time series of price changes as seen in the real data.

We also give two more effects to the revised model in order to reproduce abnormal diffusion of the market price, potential properties[2] observed from the market price and the statistical properties of transaction intervals: the first is the trend follow effect, i.e. feedback effect of price changes, and the second is expansion and contraction effect of phycological time, i.e. feedback effect of transaction intervals. These effects are discussed in the dealer model[3].

From our analysis, these three feedback effects are very important to describe real market fluctuations in market prices and transaction intervals, and these endogenous feedback effects are caused by dealers' observation of trends and volatility in market prices and market activities. We can simulate various situations such as a government intervention in our new model by adding special properties which are observed in the government intervention from the data.

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Alejandro de La Concha, Serafin Martinez Jaramillo and Christian Carmona

Multiplex financial networks: revealing the level of interconnectedness in the banking system

SPEAKER: Serafin Martinez Jaramillo

ABSTRACT. The network approach has been useful for the study of systemic risk; however, most of the studies have ignored the true level of interconnectedness in the financial system. In this work we show the missing part on the study of interconnectedness of the banking system. Recently, complexity in modern financial systems has been an important subject of study as well as the so called high degree of interconnectedness between financial institutions. However, we still lack the appropriate metrics to describe such complexity and the data available in order to describe it is still scarce. In addition, most of the focus on the subject of interconnectedness has been on a single type of network: interbank (exposures) networks. In order to have a more complete view of the complexity in the Mexican banking system, we use a comprehensive set of market interactions that include transactions in the securities market, repo transactions, payment system flows, interbank loans, cross holding of securities, foreign exchange exposures and derivatives exposures for banks. This the first attempt, to the best of our knowledge, to describe so comprehensively the complexity and interconnectedness in a banking system. By resorting to the multiplex paradigm we are able to identify the most important institutions in the whole structure, the most relevant layer of the multiplex and the community structure of the Mexican banking system.

Torsten Heinrich and Davoud Taghawi-Nejad

Systemic effects of homogeneity of risk models in the insurance sector

SPEAKER: Torsten Heinrich

ABSTRACT. While the insurance sector has been extensively studied from game theory and risk modelling perspectives, systemic risk in the insurance sector has not been sufficiently investigated. Risk models are accurate only up to a certain degree. In particular, they may err with respect to the correlation of risk events. With a small but significant probability, they would therefore lead to the insolvency and bankruptcy of the company. If all insurance companies use the same risk model, bankruptcies in the insurance sector would happen in clusters. This results in structural problems for the entire sector. Nevertheless, the number of risk models employed in the insurance sector remains very small. Risk models are research-intensive and must be carefully maintained. Official accreditation, a densely connected professional network and cautious attitudes in the face of considerable potential losses add to the entry barriers in this field.

We develop an agent-based model of the insurance sector and study the effects of unanticipated correlations of risk events in settings of varying diversity. We characterize the conditions under which bankruptcies result in structural effects on the system level and may thus be seen as systemic risk. We consider how different types of risks - hence different distributions - influence the systemic effects. We also study the effects of regulatory instruments.

We further provide some insights from historical cases of property insurance (hurricane, maritime, earthquake, flood, etc.) and associated claims and discuss causes for the lack of diversity in terms of risk models employed in the insurance business.

Justin Grana and David Wolpert

Event Driven Game Theory

SPEAKER: Justin Grana

ABSTRACT. Traditional game theory has considered time-extended, non-simultaneous move scenarios at least since the introduction of extensive form games. Almost all of this work assumes that the order and timing of the actions by the players occur at pre-fixed times. This is the case even in games with important stochastic elements. In particular, in Markov games, each player moves at each (integer-valued) time steps. However in very many realistic scenarios the assumption that all actions occur at pre-fixed times is wrong.

For example, in financial markets the times at which players act are not pre-fixed but are determined dynamically as players react to randomly arriving information. Similarly, in computer network security games, the underlying computer network that provides the strategic environment is stochastic and subject to asynchronous timing. Crucially, this stochasticity and resulting uncertainty regarding the timing of events has important strategic implications. In this paper, we present an event driven game formulation in which the timing and sequence of actions are not pre-fixed by the modeler but are governed by a stochastic process that unfolds as the game progresses. Our formulation allows players to act and receive information at random and asynchronous times that are determined by the underlying stochastic process as well as players' past actions.

After introducing the specification, we illustrate the applicability of the formulation in a variety of domains including collusive cartel formulation in industrial organization and computer network security. In our examples, we show how the parameters that govern the underlying stochastic process have important strategic implications that do not arise in traditional discrete time formulations. For example, in our industrial organization model, firms compete for customers by setting prices. However, each firm receives information at random times and can change their price at random times. At the same time, the demand for the firms' product is evolving according to a stochastic process that the firms only imperfectly observe. We prove that the rate at which firms monitor one another and the rate at which they receive information regarding demand determines their incentives to form a collusive cartel. In our computer network security model, an attacker attempts to traverse a computer network to gather valuable information while the defender's goal is to detect malicious activity while also limiting the number of false alarms. We show how to use our event driven game theory formulation to solve for equilibrium attacker and defender policies and show how a defense strategy based on the event driven game outperforms a baseline anomaly detector. We also explicitly treat the issue of solving event driven games and show how to use state-of-the-art recurrent neural networks to approximate both fully rational and behavioral solutions of event driven games. Finally, we discuss future directions of event-driven games. These include establishing folk theorems, future computational challenges and a litany of other possible application domains.

Alberto Robledo and *Carlos Velarde*

Dynamical analogues of rank distributions

SPEAKER: *Alberto Robledo*

ABSTRACT. We present an equivalence between stochastic and deterministic variable approaches to represent ranked data and find the expressions obtained to be suggestive of statistical-mechanical meanings [1,2,3]. We show that size-rank distributions $N(k)$ from real data sets can be reproduced by straightforward considerations based on the assumed knowledge of the background probability distribution function $P(N)$ that generates samples of random variable values similar to the real data. The choice of different functional expressions for $P(N)$, such as power law, exponential, Gaussian, etc., leads to different classes of size-rank distributions $N(k)$ for which we find examples in nature. We show that all of these types of rank distributions can be alternatively obtained from deterministic dynamical systems. These correspond to one-dimensional nonlinear iterated maps near a tangent bifurcation whose trajectories are proved to be precise analogues of the rank distributions. We provide explicit expressions for the maps and their trajectories and find that they operate under conditions of small Lyapunov exponent and therefore near a transition out of chaos. We give explicit examples that range from exponential to logarithmic behavior, including Zipf's law.

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Clara Granell and *Peter Mucha*

EPIDEMIC SPREADING IN LOCALIZED ENVRIONMENTS WITH RECURRENT MOBILITY PATTERNS

SPEAKER: *Clara Granell*

ABSTRACT. The spreading of infectious diseases has been proved to be radically dependent on the population networked structure of interactions and on the mobility of individuals. Network scientists have made significant progress assessing the critical behavior of spreading dynamics at large geographic scales, but the prediction of the incidence of epidemics at smaller scales, localized environments, is still a challenge.

Representative examples of localized environments are university campuses, schools and work offices, to mention a few. The problem of modeling such realistic scenarios relies on finding the appropriate level of abstraction to grasp the main singularities of the epidemic spreading process for individuals using the particular environment. The analysis of these oversimplified model abstractions is of outmost importance to separate the effect of single parameters on the incidence of spreading process, yet allowing an analytical approach that could be used for prediction purposes and to test prevention actions.

In particular, we are interested in studying the spreading dynamics of influenza-like illnesses (ILI) inside university campuses. In most U.S. universities, most of the students live in the university residence halls and university dorms. The main activity of the students within campuses is dominated by a recurrent pattern of mobility that consist of attending classes and residing in dorms. This recurrent pattern of mobility between the bipartite structure of dorms and classes, is identified as a major player on the endogenous spreading of diseases between students. We propose a metapopulation model on a bipartite network of locations, that account for the interplay between mobility and disease contagion for this particular scenario. The model is as follows: there are two types of nodes (populations): dorms and classes. Individuals correspondence to a dorm is unique, while classes are shared by individuals of any dorm. Each individual returns to its dorm after their academic activities are over. These recurrent pattern turns out to be essential to understand the impact of quarantine-like policies on the sick students, and specially on the determination of the proper time to be assigned to these isolation strategies.

The results of our analysis for a SIS dynamics on this particular scenario allows to test different strategies to contain the spreading of epidemics, identifying for example the lowest quarantine bound to be applied to sick students for the containment of the disease spreading. We find analytical expressions amenable to quantify the final incidence of the epidemics on these localized scenarios with recurrent mobility patterns.

Samuel Unicomb, Gerardo Iñiguez and Márton Karsai

Not all friends are equal: How heterogeneous social influence promotes or hinders behavioural cascades in complex networks

SPEAKER: Márton Karsai

ABSTRACT. Social influence is arguably among the main driving mechanisms of many collective phenomena in society, including the spreading of innovations, ideas, fads, or social movements. Many of these processes have been studied empirically in the past, particularly with regards to the existence of so-called adoption cascades, where large amounts of people adopt the same behaviour in a relatively short time. These phenomena have been commonly modelled either as simple contagion (where adoption is driven by independent contagion stimuli, like the Bass model of innovation diffusion [Bass 1969]), or as complex contagion (where a threshold on the number of adopting neighbours in a social network determines spreading, like the Watts model of adoption cascades [Watts 2002]). However, in these models social influence is usually considered homogeneous across ties in the network, implying that all acquaintances are equally likely to influence an ego while making decisions. In reality, the strength of social influence may vary from neighbour to neighbour as it depends on the intimacy, frequency, or purpose of interactions between acquaintances. Neglecting such local heterogeneities may lead to overly simplistic models and potentially undermine a detailed understanding of real spreading phenomena.

We address this problem by studying a dynamical cascade model on weighted networks, where tie heterogeneities capture diversity in social influence. First we focus on a bimodal weight distribution, such that spreading is determined by the adoption threshold ϕ of nodes (defined as the sum of link weights to adopting neighbours relative to the total strength of the actual node) and the standard deviation σ of weight distribution. We find that the presence of tie weight heterogeneities induce unexpected dynamical behaviour, as they either speed up or slow down contagion with respect to the unweighed case, depending on ϕ and σ. We demonstrate this effect to be present in synthetic and data-driven simulations of adoption dynamics on various artificial and real networks. We show that the structure of this non-monotonous parameter space can be understood by combinatorial arguments, and we provide an analytical solution of the problem for networks with arbitrary degree and weight distributions, using approximate master equations [Gleeson 2013]. These results may be instrumental in developing more accurate spreading models that manage to gauge the rise and extent of real behavioural cascades in society.

Xin-Zeng Wu, Peter Fennell, Allon G. Percus and Kristina Lerman

Onset of Global Cascades in Correlated Networks

SPEAKER: Xin-Zeng Wu

ABSTRACT. Influence maximization aims to identify nodes, which when seeded, produce an outbreak that cascades to a large fraction of the network. A variety of heuristic strategies and optimization-based approaches were proposed for seeding maximal cascades of information and product adoption, and other social contagions. We explore the impact of higher order network structure on the dynamics of cascades on random networks in which pairs of connected nodes have correlated degrees. We show that the onset of large outbreaks, as well their size, sensitively depend on higher order network structure.

Carlos Pineda, Carlos Gershenson, Gerardo Iñiguez, Sergio Sanchez, José Antonio Morales and Albert-Laszlo Barabasi

The random nature of rank dynamics

SPEAKER: Carlos Pineda

ABSTRACT. Any set can be ranked by comparing a common property, such as size, age, or wealth. Ranks indicate who does one object compare to others of the same set. People have analyzed the rank distribution of words, cities, earthquakes, and networks, just to name a few. Rank distributions seem prevalent because they are general descriptions of diverse phenomena. As such, they have applications in many areas, from science to business. How does rank change in time? To explore this question, we have proposed the measure "rank diversity". Assuming that elements change their rank in time, the elements' trajectories can be tracked in rank space. Rank diversity is the normalized number of different elements that appear at a specific rank at different times.

We have measured the rank diversity of a broad range of phenomena: languages, sports, earthquakes, economic systems, transportation systems, and social systems. We have found two different universality classes of rank diversity curves: for open systems (where elements enter and leave the ranking in time), rank diversity increases as a sigmoid with rank. The second class is for closed systems (where most elements do not leave or enter the ranking during the evolution); the diversity behaves as a semicircle.

If rank diversity is so similar for different phenomena, and considering that the mechanisms to determine rank change in every system might differ, what are the minimal assumptions required for reproducing the two classes of rank diversity? To answer this, we present a single null model, for both classes.

In this model an element from a list is picked at random and replaced at a new random position. The solutions have a drift component that obeys a leaking diffusion-like equation with quadratic coefficients, and a Levy-type component that increases in size linearly with time. Its predictions show that a good portion of the data analyzed can be explained with it. Important quantities such as the first step probability can be accurately described with such a model, both in the open and closed situations.

Iacopo Pozzana, Kaiyuan Sun and Nicola Perra

Epidemic Spreading on Activity-Driven Networks with Attractiveness

SPEAKER: Nicola Perra

ABSTRACT. We study SIR epidemic spreading processes unfolding on a recent generalisation of the activity-driven modelling framework. In this model of time-varying networks each node is described by two variables: activity and attractiveness. The first, describes the propensity to form connections. The second, defines the propensity to attract them. We derive analytically the epidemic threshold considering the timescale driving the evolution of contacts and the contagion as comparable. The solutions are general and hold for any joint distribution of activity and attractiveness. The theoretical picture is confirmed via large-scale numerical simulations performed considering heterogeneous distributions and different correlations between the two variables. We find that heterogeneous distributions of attractiveness facilitate the spreading of the contagion process. This effect is particularly strong in realistic scenarios where the two variables are positively correlated. The results presented contribute to the understanding of the dynamical properties of time-varying networks and their effects on contagion phenomena unfolding on their fabric

Cree White, Armin Mikler and Sanjukta Bhowmick

A Network-Based Model of Exposure Risk Among University Students

SPEAKER: Cree White

ABSTRACT. Contacts between individuals influence the dynamics and spreading processes of disease. Data about these interactions can be used to build a network of contacts for simulating disease dynamics and facilitating disease mitigation strategies. These contact networks give insight into the underlying properties that affect the spread of disease and provide valuable information on which individuals may be at greatest risk of exposure to disease. Data for these contact networks can be obtained from University registrar records to model the exposure risk of students attending the university. Students are especially susceptible to outbreaks of many different types of diseases, including influenza, meningitis, measles, etc. We propose methods for creating reliable contact networks of students and identify corresponding network communities in order to quantify their exposure risk. Using these strategies, we are able to identify candidates for mitigation or preemptive treatment once an index case has been recognized. For this study, we obtained course schedule data from two sources, the University of North Texas (UNT) and the University of Nebraska at Omaha (UNO). Each dataset includes enrollment information pertaining to the student id, the course number of the class they are enrolled in, the room number, and class meeting times. Preliminary work has been done with the UNT registrar data to create a contact network of the UNT engineering campus. This data was used to create a contact network where nodes represent the students and edges were assigned when a pair of students were in the same room at the same time. From this contact network, distinct clusters and communities were observed that provide a wide variety of characteristics which might affect exposure risk. Several types of analysis and experiments can be performed on such networks for various schools to determine students who might be at disproportional risk of exposure to disease given their membership in network communities. Certain topological metrics of the vertices were used to help calculate and assign risk vectors, including using its respective degree, local clustering coefficient, closeness, and centrality. By comparing these local properties across the vertices of the network, we were able to identify the students which were most likely to become infected in the event of an outbreak starting at a particular seed. We also identify the community membership of all vertices to assign the risk vector, since a student is at a greater risk to exposure if someone in their respective community is infected. Lastly, different types of network models, static and dynamic, have been generated depending on how we defined contacts and frequency of contacts between individuals. We then performed experiments to evaluate how these network variations affected the values assigned for the exposure risk vector. By using these methods, the proposed model can be used to identify students who may need to be treated during an outbreak of a disease and can be used to determine how different parameters and course scheduling data affect the overall network structure.

Michele Starnini, James Gleeson and Marian Boguña

Equivalence between non-Markovian and Markovian dynamics in epidemic spreading processes

SPEAKER: Michele Starnini

ABSTRACT. A general formalism is introduced to allow the steady state of non-Markovian processes on networks to be reduced to equivalent Markovian processes on the same substrates. The example of an epidemic spreading process is considered in detail, where all the non-Markovian aspects are shown to be captured within a single parameter, the effective infection rate. Remarkably, this result is independent of the topology of the underlying network, as demonstrated by numerical simulations on two-dimensional lattices and various types of random networks. Furthermore, an analytic approximation for the effective infection rate is introduced, which enables the calculation of the critical point and of the critical exponents for the non-Markovian dynamics.

Michele Starnini, Andrea Baronchelli and Romualdo Pastor-Satorras
Effects of temporal correlations in social multiplex networks
SPEAKER: Michele Starnini
ABSTRACT. Multi-layered networks represent a major advance in the description of natural complex systems, and their study has shed light on new physical phenomena. Despite its importance, however, the role of the temporal dimension in their structure and function has been barely scratched. Here we show that empirical social multiplex networks exhibit temporal correlations between layers, which we quantify by extending entropy and mutual information analyses proposed for the single-layer case. We demonstrate that such correlations are a signature of a 'multitasking' behavior of network agents, characterized by a higher level of switching between different social activities than expected in a uncorrelated pattern. Moreover, temporal correlations significantly affect the dynamics of coupled epidemic processes unfolding on the network. Our work opens the way for the systematic study of temporal mutliplex networks and we anticipate it will be of interest to researchers in a broad array of fields.

Xin-Zeng Wu, Allon G. Percus and Kristina Lerman
Higher Order Structure Distorts Local Information in Networks
SPEAKER: Xin-Zeng Wu
ABSTRACT. The information that is locally available to individual nodes in a network may significantly differ from the global information. We call this effect local information bias. This bias can significantly affect collective phenomena in networks, including the outcomes of contagious processes and opinion dynamics. To quantify local information bias, we investigate the strong friendship paradox in networks, which occurs when a majority of a node's neighbors have more neighbors than it does itself.
Our analysis identified certain properties that determine the strength of the paradox in a network: attribute-degree correlation, network assortativity and neighbor-neighbor degree correlation. We also discovered that the neighbor-neighbor degree correlation is significant in real world networks. Understanding how the paradox biases local observations can inform better measurements of network structure and our understanding of collective phenomena.

Johann H. Martínez, Stefano Boccaletti and Javier Buldú
The Effect of Interlayer Links in Multiplexed Artist Networks
SPEAKER: Johann H. Martínez
ABSTRACT. The way information goes from a decoupled state into a coupled one in a multiplex network has been widely studied by means of in-silico experiments involving models of artificial networks. Those experiments assume uniform interconnections between layers offering, on the one hand, an analytical treatment of the structural properties of multiplex networks but, on the other hand, loosing generalization for real networks. In this work, we study multiplex (2-layer) networks of musicians whose layers correspond to: (i) collaboration between them and (ii) musical similarities. In our model, connections between the collaboration and similarity layers exist, but they are not ubiquitous for all nodes. Specifically, interlayer links are created (and weighted) based on structural similarities between the neighborhood of a node, taking into account the level of interaction of each artist at each layer. Next, we evaluate the effect that the weight of the interlayer links has on the structural properties of the whole network, namely the second smallest eigenvalue of the Laplacian matrix (also known as algebraic connectivity). Our results show a transition in the value of the algebraic connectivity that can only be adequately predicted when the real distribution of the weights of the interlayer links is taken into account.

Claudia Payrato Borras, Laura Hernandez and Yamir Moreno

Towards the end of a ”chicken-egg” problem: nestedness or degree distribution?

SPEAKER: Laura Hernandez

ABSTRACT. n mutualistic ecosystems, typically plant-pollinator or plant-seed dispersers networks, the interaction between two agents is naturally beneficial for both (pollinators eat and plants increase their reproductive efficiency). They may be described in terms of bipartite networks, where the two different kind of nodes correspond to the plant species and the animal species and the interaction takes place only between elements of different kind. A widespread particular ordering called nestedness has been observed in these systems: when ordering the network in decreasing degree one of the guilds, the other appears automatically ordered in the same way. This order reveals that the ecosystem is composed of generalists species which hold contacts with many different counterparts and specialist species, which prefer contacts with generalist counterparts; specialist-specialist interactions being very rare. The ubiquity of nestedness in mutualistic ecosystems data has triggered an intensive research aiming at measuring this particular ordering and explaining its origin. In the ecological community it is widely admitted that this organization is responsible for the robustness of the ecosystems, as well as the persistence of biodiversity. However, in the recent years the relevance of nestedness as the pertinent magnitude to describe the ecosystems has been questioned. In other words: is nestedness a relevant property issued from the ecosystems dynamics or does it just derive from lower order statistical properties of the network, as the observed (truncated) powerlaw like degree distributions? In this talk we present a theoretical work showing that nestedness is a consequence of the degree distributions of both guilds. Unlike methods based on the randomization of real networks under different schemes, our work is based on the Exponential Random Graph (ERG) model, where one obtains the probability distribution of networks with a given average degree distribution as constraint. Following the work of Squartini and Garlaschelli [5] we obtain the corresponding grand canonical ensemble to which that real network belongs with maximum likehood. We measure nestedness using NODF index (nestedness based on overlapping and decreasing field), which can be written analytically in terms of the adjacency matrix, and we obtain the theoretical expectation value and the standard deviation of the nestedness distribution in such ensemble. Our results show that the nestedness of the observed network is statistically equivalent to the expected value of the generated random ensemble, thus showing that this global organization is a consequence of the degree distribution. Additionally, we can use the obtained probability distribution in order to simulate the ensemble to which each observed real network belongs and we can measure average nestedness and standard deviation over the sampling. The results, which are consistent with the theoretical model, show the importance of finite size effects concerning the network size, in simulated ensembles. These size effects which may depend on the chosen nestedness metrics, are investigated in another work.

Genki Ichinose, *Yoshiki Satotani* and *Hiroki Sayama*

Mutation differently affects cooperation depending on social network structures

SPEAKER: *Genki Ichinose*

ABSTRACT. Cooperation is ubiquitous in every level of living organisms. In principle, cooperators benefit others by incurring some costs to themselves, while defectors do not pay any costs. Therefore, cooperation cannot be an evolutionarily stable strategy for a noniterative game in a well-mixed population. In such a situation, spatial (network) structure is a viable mechanism for cooperation to evolve. However, until quite recently, it has been difficult to predict whether cooperation can evolve at a network (population-wide) level. To address this problem, Pinheiro et al. proposed a numerical metric, called Average Gradient of Selection (AGoS), to characterize and forecast the evolutionary fate of cooperation at a population-wide level [1]. AGoS can analyze the dynamics of the evolution of cooperation even when nontrivial selection pressure is introduced [2], and also when structures and states of networks change over time (adaptive social networks) [3]. In these earlier studies, however, stochastic mutation of strategies was not considered yet. It is important to incorporate such mutation because they frequently occur in real societies and also because results obtained with stochastic fluctuations of strategies would provide more robust observations and conclusions. Here we analyzed the evolution of cooperation using AGoS where mutation may occur to strategies of individuals in networks. Our analyses revealed that mutation always has a negative effect on the evolution of cooperation regardless of the fraction of cooperators and network structures, because local clusters of cooperators can easily be destroyed by mutation. Interestingly, we found that mutation is particularly harmful to cooperation when the fraction of cooperation is high in homogeneous networks (e.g., homogeneous random network, regular lattice), but so it is when the fraction of cooperation is low in heterogeneous networks (e.g., scale-free networks). This may be due to that hubs surrounded by cooperators are robust to mutated defectors. These results indicate the importance of considering random noise (mutation), which was largely overlooked in the literature, in studying the evolution of cooperative behavior in social networks.

Alfredo Morales, *Xiaowen Dong*, *Yaneer Bar-Yam* and *Alex Pentland*

Coupling Patterns of Virtual and Physical Behavior

SPEAKER: *Alfredo Morales*

ABSTRACT. The relationship between the way people explore urban spaces and behave on the Internet is not fully understood so far. In this work, we analyze multiple types of human activities, i.e., urban mobility, online communication, and shopping, in order to characterize patterns of collective behavior that emerge from virtual and physical interactions. We found that the multiple types of data are consistent with each other and show an interplay of the way people inhabit geographical space and behave online. Even though physical limitations are not present on the Internet, we show that online collective behaviors are highly coupled to the physical ones.

Javier Borondo, *Alfredo Morales*, *Rosa M. Benito* and *Juan Carlos Losada*

Opinion leaders on social media: A multilayer approach

SPEAKER: *Rosa M. Benito*

ABSTRACT. Twitter is a social media outlet where users are able to interact in three different ways: following, mentioning, or retweeting. Accordingly, one can define Twitter as a multilayer social network where each layer represents one of the three interaction mechanisms. We analyzed the user behavior on Twitter during politically motivated events: the 2010 Venezuelan protests, the decease of a Venezuelan President, and the Spanish general elections. We found that the structure of the follower layer conditions the structure of the retweet layer. A low number of followers constrains the effectiveness of users to propagate information. Politicians dominate the structure of the mention layer and shape large communities of regular users, while traditional media accounts were the sources from which people retweeted information. Such behavior is manifested in the collapsed directed multiplex network that does not present a rich-club ordering. However, when considering reciprocal interactions the rich-club ordering emerges, as elite accounts preferentially interacted among themselves and largely ignored the crowd. We explored the relationship between the community structure between the three layers. At the follower level users cluster in large and dense communities holding various hubs, that break into smaller and more segregated ones in the mention and retweet layers. We also found clusters of highly polarized users in the retweet networks. We analyze this behavior by proposing model to estimate the propagation of opinions on social networks, which we apply to measure polarization in political conversations. Hence, we argue that to fully understand Twitter we have to analyze it as a multilayer social network, evaluating the three types of interactions.

J Borondo, AJ Morales, RM Benito, JC Losada, Multiple leaders on a multilayer social media, 2015, Chaos, Solitons & Fractals 72, 90-98.

AJ Morales, J Borondo, JC Losada, RM Benito, Measuring political polarization: Twitter shows the two sides of Venezuela, 2015, Chaos: An Interdisciplinary Journal of Nonlinear Science 25 (3), 03311

Rosa M. Benito orcid.org/0000-0003-3949-8232

Albert Sole, *Sergio Gómez* and *Alex Arenas*

Congestion induced by the multiplex structure of complex networks

SPEAKER: *Albert Sole*

ABSTRACT. Multiplex networks are representations of multilayer interconnected complex networks where the nodes are the same at every layer, and there exist different kinds of edges connecting them, which form the layers. They turn out to be good abstractions of the intricate connectivity of multimodal transportation networks, the activity of individuals using multiple online social platforms, among other types of complex systems.

One of the most important critical phenomena arising in transportation networks is the emergence of congestion when the nodes are forced to work beyond their processing capacity. Here we prove analytically that the structure of multiplex networks can induce congestion for flows that otherwise will be decongested if the individual layers were not interconnected [1]. We provide explicit equations for the onset of congestion and approximations that allow to compute this onset from individual descriptors of the individual layers. The observed cooperative phenomenon reminds the Braess' paradox in which adding extra capacity to a network when the moving entities selfishly choose their route can in some cases reduce overall performance. Similarly, in the multiplex structure, the migration of paths to the more efficient layer yields an unbalanced load that results in unexpected congestion.

[1] Albert Solé-Ribalta, Sergio Gómez and Alex Arenas: Congestion induced by the structure of multiplex networks, Physical Review Letters 116 (2016) 108701.

Oriol Artime, Juan Fernández-Gracia, Jose J. Ramasco and Maxi San Miguel

Joint effect of ageing and multilayer structure prevents ordering in the voter model

SPEAKER: Oriol Artime

ABSTRACT. Last years have witnessed an increasing interest on multilayer networks. In many cases, the multilayer structure is necessary to describe the topology of real-world systems that may include different levels of interaction. The multilayer topology induces profound changes in the dynamics of systems running on networks. Jointly with the structural part, the temporal dimension of the interactions plays also a crucial role in the dynamics. Given the strong temporal inhomogeneities found in empirical data, it is interesting to include this ingredient in the models and to explore in detail the effects of the time-topology relationship.

In particular, in this work we study the voter model embedded in a two-layered network with an ageing mechanism in the nodes. The voter model is a opinion dynamics model, where agents (nodes) hold a state (opinion) and interact by copying the opinion of a randomly selected nearest neighbor. A fundamental question is under which conditions it is possible to attain global consensus, which is the absorbing state of the system dynamics. To take into account time heterogeneities, the model can be modified by adding ageing in the nodes: the probability of agents to switch opinion depends on the time elapsed since the last change \cite{stark,juan}. We use as a control parameter the fraction of nodes sharing states in both layers, the so-called multiplexity parameter $ q $. We find that the dynamics of the system suffers a notable change at an intermediate value of q, $ q^{*} $. Above it, the voter model always reaches global consensus through a coarsening process. Below it, a fraction of the realizations fall into dynamical traps that indefinitely delay the arrival at the absorbing state (Figure \ref{fig}). These traps are associated to a spontaneous symmetry breaking process leading to a dominant layer with old nodes and a dominated layer with younger nodes. Once this configuration is reached, the system dynamics slows down indefinitely. We are able to give analytical insights into the asymptotic values of the voter model's order parameter. We further explore the competition of time scales driving the evolution of the dynamics by employing different update rules in the layers, namely the standard update rule and the ageing one in every layer. Our results will help to understand better the interplay between topology and time and confirm the relevance of combining both ageing and multilayer topology to give rise to new phenomenology. This phenomenon does not appear when these ingredients are considered separately, but it emerges as the consequence of their interaction. Further details on our results can be found in the Ref. \cite{ours}.

Aleix Bassolas, Maxime Lenormand, Jose J. Ramasco and Riccardo Gallotti

Scaling in the recovery of cities from special events

SPEAKER: Aleix Bassolas

ABSTRACT. The aim of this work is to understand the resilience and recovery of public transport networks from special events where a huge amount of people concentrates in a small part of cities. We use a packet based model of individuals going from origin to destination using the different lines of transport, taking into account the limited capacity of real transport networks. For this purpose we will study the performance of networks with two different routing protocols, the shortest path routing where the individuals follow the shortest paths in the weighted network and the adaptive routing with local knowledge where they are able to adapt their trajectory depending on the local information of the current stop. With this two protocols we are able to simulate the normal flow of people in multimodal public transport networks considering the real capacity and speed of the different modes of transport. Above this normal flow of people we will introduce different amount of agents in small places of the cities (200m x 200m) with a distribution of destinations according to the places of residence. We will study, depending on the routing protocol, the scaling of recovery times with the amount of agents in the perturbation and the place of the city as well as the average delay and the number of individuals and origins affected. The first we observe is that while in the case of the shortest path routing, the recovery of the networks is linear with the amount of individuals independently of the network. However in the case of the adaptive routing the structure of the network and the embedded space become relevant. In a first approximation we will apply our model in 1D and 2D lattices and studying how the recovery time and delays change with the position of the perturbation and the amount of individuals in it. In the case of the scaling in the recovery times, we solve analytically and use simulations to proof that it is related with the dimension of the embedded space, finding an exponent of 1 in the 1D case and 0.5 in the 2D case. While the average delay is not related to the place of the perturbation, in the case of the agents affected we find that the peripheral nodes have more influence on the number of origins and packets affected. When studying the recovery of cities we observe a scaling below 0.5 due to the different modes in public transport networks. While a public transport network with only one mode of transport has a dimension similar to a 2D lattice, the combination of modes with different speed and coverage increases the local dimension. We propose a new metric of local dimension which is related to the exponent governing the recovery of cities. We prove for different cities that our new definition of local dimension in weighted networks with capacity is able to predict the scaling and in a similar way the perturbations in peripheral areas affect a higher amount of origins and individuals.

Ivan Kryven

Multidimensional Networks with Arbitrary Degree Distribution

SPEAKER: *Ivan Kryven*

ABSTRACT. In the infinite configuration network the links between nodes are assigned randomly with the only restriction that the degree distribution has to be predefined. Among the most interesting results derived from such models are the distribution of component sizes and the phase transition connected to emergence of the giant component. It is generally thought that the distribution of component sizes has exponential decay before and after the phase transition, whereas such decay is algebraic with universal exponent -3/2 precisely at the phase transition itself. Another wide-spread idea, is that if the links have direction then the phase transition for weak giant component coincides with the phase transition in the non-directional network. In this talk, by applying tools borrowed form analytical combinatorics, I will show that this two ideas are misconceptions. Firstly, I will demonstrate that heavy tailed degree distributions lead to a whole zoo of asymptotical classes of component-size distributions. Within this classes are component-size distributions of exponential, sub-exponential, and power-law decays with arbitrary exponents below -3/2. Secondly, I will show that if links have direction, the associated phase transitions cannot be related to the phase transition in non-directional networks. Finally, I will present an effective analytical toolbox for studying connected components in the case when links have many different types: i.e. multidimensional networks.

[1] I. Kryven. “General expression for the component size distribution in infinite configuration networks” Physical Review E 95 (2017): 052303

[2] I. Kryven. "Emergence of the giant weak component in directed random graphs with arbitrary degree distributions." Physical Review E 94 (2016): 012315.

Keith Burghardt, Paul Smaldino, Luba Levin-Banchik, Michelle Phillips, Raissa D'Souza and Zeev Maoz

Cooperation Network Responses to Shocks

SPEAKER: Keith Burghardt

ABSTRACT. Cooperation networks, such as international alliance and trade networks, are constantly in flux due to long-term trends, as well as short term “shocks”, such as coups, wars, and economic collapse that can dramatically affect how interactions occur both locally and globally. An open problem, however, is determining the mechanism of network evolution, especially after shocks. Furthermore, the coupling between many cooperation network layers, which can be modeled as a multiplex network, complicates this mechanism: alliances can occur with trading partners or the social networks of CEOs could affect how businesses collude. We begin to understand the effect of shocks on coupled networks using both simulations and human experiments, in which agents try to make links with other agents that maximize their individual utility. We define shocks in this context as an increase or reduction in the marginal utility of each link. We find that, in simulations, agents acting in their own best interest can create emergent network “hysteresis” or resilience: a network will resist a change in its topology even after a significant network shock. Therefore, a network where the cost of links was always high, and a network where the cost of a link was low but then increases, will look very different, despite having the same utility function in equilibrium. We measure resilience through the size of the largest connected component, average degree, clustering, and the mean profit as we vary the utility that can be gained by clustering, or link correlations across network layers. We compare the result of the simulations to experiments employing human subjects, where shocks appear to affect emergent networks, but in ways that can sometimes differ from a utility-maximizing model. In this experiment, users add or drop links with others in two separate networks in order to maximize their utility, measured in game “points” that are converted to dollars at the end of the experiment. Utility can increase when users make links that are the same in both networks, or if the link completes a “triangle” in which a neighbor of a neighbor is a neighbor, while utility decreases when users make too many links. After some period of time, a shock occurs which either increases or decreases the utility of creating a link. We find that users who undergo a shock from low link utility to high link utility tend to drop more links when the points they gain per round is low, while simulations do not predict a strong correlation, therefore the utility users see before they make a decision affects their behavior even as they separately attempt to maximize their utility. Adding realistic additions to our utility-maximizing model does not completely close the gap between it and our experiment, which warrants further investigation in the future. Overall, we have created novel ways to elucidate how networks evolve, especially for networks of cooperating agents.

Kaj Kolja Kleineberg and Dirk Helbing

Collective navigation of complex networks: Participatory greedy routing

SPEAKER: Kaj Kolja Kleineberg

ABSTRACT. Many networks are used to transfer information or goods, in other words, they are navigated. The larger the network, the more difficult it is to navigate efficiently. Indeed, information routing in the Internet faces serious scalability problems due to its rapid growth, recently accelerated by the rise of the Internet of Things. Large networks like the Internet can be navigated efficiently if nodes, or agents, actively forward information based on hidden maps underlying these systems. However, in reality most agents will deny to forward messages, which has a cost, and navigation is impossible. Can we design appropriate incentives that lead to participation and global navigability? Here, we present an evolutionary game where agents share the value generated by successful delivery of information or goods. We show that global navigability can emerge, but its complete breakdown is possible as well. Furthermore, we show that the system tends to self-organize into local clusters of agents who participate in the navigation. This organizational principle can be exploited to favor the emergence of global navigability in the system.

Michele Tizzoni, *André Panisson*, *Daniela Paolotti* and *Ciro Cattuto*

Collective attention patterns during public health emergencies: the 2015-2016 Zika virus epidemic in the USA

SPEAKER: *Michele Tizzoni*

ABSTRACT. Background: The influence of human behavior on epidemic spreading has long been recognized as a key component in infectious disease modeling and epidemiology. In the past years, a number of studies have addressed the impact of awareness and information spread during epidemic outbreaks and it has been reported that the degree of public attention and concern induced by a health threat, such as an outbreak of an infectious disease, might play an important role in disease dynamics. Individual behavior has also been key in the 2015 − 2016 Zika outbreak, which has posed peculiar communication challenges to the public due to its association with microcephaly in newborns, its transmission modalities, and its prevalence in areas, such as the American continent, in which the surveillance had never detected the presence of Zika virus before and was suddenly characterized by intense international travel due to the Rio Olympics in 2016.

Objective: To quantify and characterize the patterns of public attention and awareness during the Zika epidemic through the analysis of Wikipedia pageview data, with a focus on the United States which, from December 2015 until the end of 2016, experienced an importation of travel- related Zika virus confirmed cases.

Methods: We analyzed geolocalized pageview data for a number of selected Zika-related Wikipedia pages and studied the dynamics of collective attention in relation to the timeline of importation of Zika cases, the global timeline of the Zika epidemic worldwide and the risk of local transmission due to the presence of the vector. Moreover, to understand the interplay between the attention measured by Wikipedia and the events media coverage, we compared pageview data with the coverage of the Zika epidemic in the US local and national media obtained by mining about 110,000 news from the GDELT project (http://gdeltproject.org/) and ~900,000 Zika related Twitter posts, generated in 2016.

Results: The temporal dynamics of attention to the Zika outbreak displayed three main phases: a pre-epidemic phase, where Zika-related pageviews were constantly below 1% of the total pageviews in the US; a high attention phase with two distinct peaks in pageview data, correlated to global events such as the WHO international alert; a declining phase, from June 2016 until the end of the year. Although the temporal profile of attention was consistent across the 50 States, spatial patterns of collective attention were highly heterogeneous. As shown in Figure 1, differences in the attention among States appeared to be highly correlated to the volume of Zika-related media coverage in each State (Spearman correlation $\rho = 0.76$) and also to the number of Zika-related tweets mentioning each State ($\rho = 0.66$).

Conclusions: Wikipedia geolocalized pageview data can be harnessed to capture the dynamics of collective attention during epidemic outbreaks, with potential implications for the calibration of epidemic-behaviour models.

Christian Schulz, Brian Uzzi, Dirk Helbing and Olivia Woolley-Meza

A citation impact indicator based on author network distances

SPEAKER: Christian Schulz

ABSTRACT. Scientists are embedded in social and information networks. These networks influence and are influenced by the scientific ideas that scientists are exposed to and give credit. The network that represents scientific collaborations has an important impact on the potential audience for a publication and therefore how it is cited. While it is already common practice to exclude self-citations when computing bibliometric indicators, we argue that it is even more important to control for effects generated by citations from co-authors, co-authors of co-authors and so forth. We introduce an indicator that controls for the citation potential authors have due to their position in the co-authorship network. Such an indicator allows for the detection of scientists and publications that far exceed this potential even if the absolute numbers would obscure their performance.

This large-scale empirical study analyzes network data from over 13 million scientific careers with at least 2 publications, which are extracted from Thomson Reuters' Web of Science, name disambiguated and cover a wide range of scientific disciplines and time. We construct a growing collaboration network of authors based on pair-wise co-authorships, accumulated until the year of evaluation. Links have no weight and indicate only whether any collaboration between a pair of authors happened in the past. For a reference between a citing and cited publication, we determine the degree of separation by computing the shortest path between the two corresponding sets of authors.

First, we show that distance on the collaboration network correlates with likelihood of citation and thus the more well connected authors a publication has, the more it is cited. The distribution of distances to all citing publications determines the reach of a publication or its spread through the network of scientists. Second, with the average distance to all publication author sets of a given year, we can measure a citation potential for a previously published article or an author. We see that for a low average distance, chances are significantly higher to receive more citations. While there is still high variance in the success of an individual publication, we find that the social distance better explains the different citation rates on average than other reputation based factors. Third, with these insights, we propose a bibliometric indicator which normalizes according to the citation potential. This allows a fairer comparison between researchers publishing in different scientific communities. The citation potential is computed for each publication or author individually by taking the whole focal network into account and contrary to typical field-normalized indices, without the need for explicitly specifying scientific disciplines.

With this work, we quantify the boost in citations that can result from social networking and collaboration that is part of the scientific profession. This points to the importance of these social processes in channeling the spread of information and must be considered when judging merit based on citations, specifically in the case of varying degree of collaboration.

Anna Sapienza, Alessando Bessi and Emilio Ferrara

Human Behavioral Patterns in Online Games

SPEAKER: Anna Sapienza

ABSTRACT. Multiplayer online battle arena has become a popular game genre. It also received increasing attention from our research community because they provide a wealth of information about human interactions and behaviors. A major problem is extracting meaningful patterns of activity from this type of data, in a way that is also easy to interpret. Here, we propose to exploit tensor decomposition techniques, and in particular Non-negative Tensor Factorization, to discover hidden correlated behavioral patterns of play in a popular game: League of Legends. We first collect the entire gaming history of a group of about one thousand players, totaling roughly 100K matches. By applying our methodological framework, we then separate players into groups that exhibit similar features and playing strategies, as well as similar temporal trajectories, i.e., behavioral progressions over the course of their gaming history: this will allow us to investigate how players learn and improve their skills.

Predrag Tosic

Internet of Autonomous/Intelligent Agents: Some Aspects of Distributed Computational Intelligence Behind the Next-Generation of Internet-of-Things

SPEAKER: *Predrag Tosic*

ABSTRACT. Internet-of-Things (IoT) is arguably one of the most important new paradigms and technological advances in the realm of the "consumer", present-in-every-household Internet-powered cyber-physical systems of the early 21st century. While IoT will likely undergo many architectural and other changes, clearly the paradigm and the actual IoT technologies and consumer products are here to stay, which is why IoT has been an R&D focus among the industry leaders in the Internet technologies, smart devices and platforms, and web-based applications, as well as an increasingly important area of fundamental and applied academic research. The list of technological and research challenges behind enabling the next-generation IoT is quite long and versatile. Our present focus is on the distributed intelligence, autonomous interacting agents and multi-agent systems (MAS) aspects of IoT, as well as on appropriate software design abstractions suitable for IoT. Some in the scientific community refer to this subset of IoT-related research problems and technology challenges as the "Internet-of-Agents" (IoA).
In this talk, we discuss three important aspects of "IoA-for-IoT". One, we review appropriate design principles and abstractions for the software agents providing inter-operability within IoT, enabling different devices and platforms to communicate, cooperate and exchange data with each other. In that context, we revisit agent-oriented programming paradigm, and focus on the classical Actor model as a suitable programming abstraction for an intrinsically open, decentralized and highly heterogeneous infrastructure such as the IoT. Second, we reflect on the cyber-security aspects of IoT, and outline some of the key elements of computational intelligence that could enable the sought-after self-healing and self-recovery capabilities of the next-generation IoT. The main purpose behind the desire for a self-healing/recovery design of IoT is so that the future cyber-attacks (like the Distributed-Denial-of-Service attack considerably disrupting the eastern USA in the fall of 2016) are guaranteed to cause much less damage, and in particular have strictly "sand-boxed", short-lasting adverse impact on users and IoT platforms. Third, closely related to the cyber-security aspect, and taking explicitly into account how humans interact with IoT devices and technologies, we outline how the recent and ongoing research on reputation and trust in multi-agent systems could enable the higher level of trust i) among different autonomous devices engaging in interaction and cooperation with each other, as well as ii) higher confidence and trust of users in their various devices and platforms within an IoT environment. In particular, it is our view that one of the most important challenges of the next-gen. IoT will be, how should the future IoT solutions be designed, so that the "ordinary folks" (that is, people who are not experts on the Internet computing, mobile technologies, or cyber-security) can build their confidence and trust that their "hooked-into-IoT" devices would never do anything malicious or detrimental to their end users. We outline and discuss some practical IoT scenarios where ensuring that humans can trust their devices and platforms is absolutely critical for the long-term success and massive-scale adoption of several promising IoT-based technologies.

Jessica Flack

Collective Computation in Nature & Society

SPEAKER: *Jessica Flack*

ABSTRACT. Biological (and social) systems are organized into multiple space and time scales. I have proposed this multi-scale structure functions as an information hierarchy resulting from the collective effects of components (cells, neurons, individuals) estimating regularities and using these perceived regularities to tune strategies in evolutionary, developmental, or ecological time. As coarse-grained (slow) or compressed variables become for components better predictors than microscopic behavior (which fluctuates), and component estimates of these variables converge, new levels of organization consolidate and components collectively construct their macroscopic worlds. This gives the appearance of downward causation. This intrinsic subjectivity suggests that the fundamental macroscopic properties in biology will be informational in character. If this view is correct, a natural approach is to treat the micro to macro mapping as a collective computation performed by components in a search for configurations that reduce environmental uncertainty. In this talk I will discuss what it means for biological systems to perform collective computations, give examples of dynamical and structural features resulting from collective computation, and outline the major open questions and challenges as I see them.

Riccardo Gallotti and *Jelena Grujic*

Modelling decision times in game theory experiments

SPEAKER: *Riccardo Gallotti*

ABSTRACT. What makes us decide whether to cooperate or not? The answer to this fundamental question goes necessarily beyond a simple maximisation of individual utility. Recent studies contributed in this sense by using decision times to claim that intuitive choices are pro-social while deliberation yield to anti-social behavior. These analysis are based on the rationale that short decisions are more intuitive than long one and summed up to keeping track of the average time taken by the subject of game theory experiment to make their decision under different conditions. Lacking any knowledge of the underlying dynamics, this simple approach might however lead to erroneous interpretations, especially on the light of our experimental evidence that the distribution of decision times is skewed and its moments strongly correlated.

Here we use the Drift Diffusion Model (DDM) to outline the cognitive basis of cooperative decision making and characterise the evolution of subject's behavior when facing strategic choices in game theory experiments. In the DDM, at each moment subjects randomly collect evidence in favour of one of two alternative choices, which are in our case cooperation and defection. This accumulation has a stochastic character as a consequence of the noisy nature of the evidence. The continuous integration of evidence in time is described by the evolution of a one-dimensional brownian motion

dx = v dt + \sqrt{D} \xi(t)

equivalent to the commonly called ``gambler's ruin problem'', where $x(0)= z\cdot a$ represents the initial bankroll of the gambler, the absorption at $x=a$ represents the gambler leaving a possibly unfair game (if $v\neq 0$) after collecting her target winnings a, and the absorption at $x=0$ represents the gambler's ruin. The probability distribution of the times at which the process reaches the origin $x=0$ before reaching the exit value $x=a$ is known as Fürth formula for first passages.

This distribution has been successfully used to model decision time in a wide range of contexts. Our findings extend this use to the strategic choices of iterated Prisoner's dilemma experiments. Analyzing the results of large-scale experiments (169 subjects making 165 decision each) through the new lens of DDM and its characteristics free parameters (drift v, threshold a, and initial bias z) allows us to clearly discern between deliberation (described by the drift) and intuition (associated to the initial bias). Our results show that rational deliberation quickly becomes dominant over an initial intuitive bias towards cooperation, which is fostered by positive interactions as much as frustrated by a negative one. This bias appear however resilient, as after a pause it resets to its initial positive tendency.

Cole Mathis, Alberto Antonioni, Massimo Stella, Leto Peel and Luis A. Martinez-Vaquero

Drunk Game Theory: An individual perception-based framework for evolutionary game theory

SPEAKER: Cole Mathis

ABSTRACT. We present Drunk Game Theory (DGT), a framework for individual perception-based games, where payoffs change according to player's previous experience. We introduce this novel framework with the narrative of two individuals in a pub choosing independently and simultaneously between two possible actions: offer a round of drinks (cooperation) or not (defection), which we dub the Pub Dilemma. The payoffs of these interactions are perceived by the individual dependent on her current state. We represent these perceptions using two different games. The first one constitutes the classic Prisoner's Dilemma (PD) situation, in which utility is computed as the amount of saved money and free drinks. In this case, one-shot game theory states that mutual defection is the only Nash equilibrium. The second game takes the form of the Harmony game, in which payoffs are computed solely as the number of received drinks. Players perceive one of the two games according to their current cognitive level. In an ordinary state players are more likely to perceive the PD payoffs, while players with altered cognition tend to play the Harmony game. The cognitive level of a player evolves according to the outcomes of her previous interactions. Cognitive level is diminished with the combined number of cooperative acts and is heightened by defection. We use evolutionary game theory to model the evolution of cooperation within well-mixed and structured populations. Our analytical results in well-mixed populations agree with the agent-based simulations. After completely exploring the Pub Dilemma, we consider all other possible pairings of 2-player, 2- strategy symmetric games. We explore the role of network-constrained interactions on the overall level of cooperation. In particular, we investigate the case of heterogeneous social networks in order to determine effect of hubs in determining the stability of cooperation. We find that, for hubs, initial perception, and initial tendency to cooperate play different roles in determining whether cooperation or defection is favored. By accounting for heterogeneous and feedback-dependent individual perceptions, this new framework opens new horizons to explore the emergence of cooperation in social environments when individuals have different perceptions over time.

Asim Zia, Scott Merrill, Chrisopher Koliba, Susan Moegenburg, Serge Wiltshire, Eric Clark, Gabriela Bucini and Julie Smith

Are Human Agents Myopic or Far-Sighted Under Differential Conditions of Risk and Ambiguity? A Bayesian Network Model of Biosecurity State Transitions in a Sequential Decision Experiment

SPEAKER: Asim Zia

ABSTRACT. Situated in the interdisciplinary literature on sequential decision games, Markov decision models and human risk perceptions under conditions of ambiguity and uncertainty, this research paper addresses two research questions: Given uncertainty and ambiguity about the behaviors of agents in their social/spatial networks, do agents behave with myopia or far-sightedness in perceiving biosecurity risk and adopting biosecurity practices in sequential games? How does a system-wide biosecurity risk state evolve when majority of the agents are far-sighted versus myopic in sequential games? A sequential decision experiment was designed with one control round where agents receive perfect information both about disease prevalence and the level of biosecurity adoption (either high or low) in a fixed network of 50 hog production facilities. Each agent can produce a maximum of 2500 hogs on a production facility. Seventeen treatment rounds expose agents to other possible combinations of perfect, partial and no information about the disease prevalence and the level of biosecurity adoption in the hog production network. In addition to one control and 17 treatment rounds, subjects also played two practice rounds. Each round consisted of 11 sequential biosecurity adoption decisions, simulating monthly decisions from February through December. During each of these 11 simulated months in a round, each agent can sequentially implement three levels of biosecurity, and only able to move from low level of biosecurity to high level (and not the other way around): (i) low biosecurity: development of a disease management protocol; (ii) medium biosecurity: adoption of cleaning and disinfecting protocols; (iii) high biosecurity: requiring a shower in, shower out protocol for all workers. Adoption of each level of biosecurity costed each agent $10,000 experimental dollars, while the absence of biosecurity randomly increased the probability of disease infection at the hog facility exposing agents to loss of revenues if infected. The effectiveness of sequential biosecurity adoption in reducing infection probability at each production facility remained ambiguous. The sequential decision experiment was played by 110 subjects on Microsoft Surface Pro Tablets and written in the R computer language, leading to (110x18 =) 1,980 rounds of observations. Subjects were paid a monetary reward as a fixed scaling factor of the experimental dollars that they earned. Two supervised (Naïve Bayes and Augmented Naïve Bayes) and two unsupervised (maximum spanning tree and equivalence EQ framework) Bayesian Network algorithms were applied to the dataset. K-fold validation of all four algorithms revealed that equivalence (EQ) Bayesian Network algorithm had the highest contingency table fit of 78.57%. Additional Bayesian network models are being applied on this dataset and results from the best fit network model will be presented during the conference. Further, the best fit Bayesian Network model is being incorporated in a multi-level agent based model that simulates hog farmer adoption of biosecurity practices under alternate information and incentive regimes.

Victor Landaeta, Cristian Candia-Castro-Vallejos, Carlos Rodriguez-Sickert, César Hidalgo, Jorge Fábrega and Camilo Rodríguez-Beltrán

Does classroom cooperation promote learning?

SPEAKER: Victor Landaeta

ABSTRACT. Does classroom cooperation promote learning? The literature on social learning has shown that people are more likely to learn from those who are seen as prestigious, talented, or that share demographic attributes with learners. Yet, the connection between cooperation and learning is relatively understudied. Here, we explore the connection between student performance and classroom cooperation by mapping six classrooms networks using a non-anonymous dyadic cooperative game. In our game, a variation of the prisoner's dilemma, in every round students are endowed with tokens that they can share or keep (cooperate or defect). The total number of tokens that a student gets is equal to the number of tokens they kept plus twice the number of tokens they received. Hence, the group maximizes the total number of tokens earned when everyone cooperates, but students maximize their tokens when they defect and everyone else cooperates. We use this game to map a weighted network of cooperation for each classroom, with weights equal to the amount of tokens received by each student in each dyadic game. Finally, we compare the centrality of each student with their classroom grades (GPA) and find a positive and statistically significant relationship between network centrality, measured as the sum of tokens received, and a student's academic performance. These results suggest a link between cooperation and learning and open new avenues for the role of networks in education.

Alexander Barron and Johan Bollen

Developing a Moral NLP tool kit

SPEAKER: Alexander Barron

ABSTRACT. How do people make moral judgements? Morality shapes our social lives, how we collaborate and communicate, and how we develop a sense of individual and collective identity. Moral Foundations Theory (MFT)\cite{Haidt:2007wg} proposes that moral judgements are made along along five dimensions: harm vs.~care, subversion vs.~authority, outgroup vs.~ingroup, degradation vs.~sanctity, and cheating vs.~fairness. The divergence of moral structures and collective identity between various human social groups is assumed to be rooted in these foundations, each group placing a different weight per foundation than other groups. MFT has enjoyed broad empirical validation, and has even produced an extensive lexicon of terms that either ``affirm'' or ``violate'' each foundation\cite{Haidt:2009gn,Graham:2009er}. The construction of lexicons in psycho-metrics and natural language processing (NLP) is underpinned by the so-called ``lexical hypothesis'', which holds that the most important issues in daily human life and communication will be encoded directly into language\cite{Goldberg:1981wp}. Since morality features prominently in human lives, by the lexical hypothesis we should find its traces in human language. However, the MFT lexicon has not been extensively confirmed against natural language data; nor has it been translated into NLP methods. Here we show a 2-step process to (a) validate the MFT lexicon against large-scale language data and (b) leverage it towards a well-vetted tool for the assessment of moral judgements in natural language.

First, we validate the structure of MFT against multiple word embeddings, refining the lexicon and ensuring self-consistency. As an example, we show that opposing word pairs per foundation in the MFT lexicon are associated with linear substructures within an embedding. Our figure shows this for the harm vs. care foundation. After our validation, in the second objective we develop a set of NLP methods to score large-scale text data along each of MFT's dimensions. The effectiveness of this approach is shown in an analysis that evaluates the differential MFT ratings of Twitter users who identify as belonging to opposite ends of the political spectrum. Our work opens the possibility of rating the moral content of social media data to study how collective identity develops and evolves in terms of collective self-esteem and within/between-group moral judgements.

Enrique Caceres Nieto and Ivan Vladimir Meza Ruiz

Steps Towards a Computational Visualizer of Legal Globalization as a Complex Adaptive Network

SPEAKER: Enrique Caceres Nieto

ABSTRACT. 1. Goals of the talk The aim of this talk is to present some of the results obtained in the development of a system to visualize the self-organizing processes that are taking place in legal globalization; specifically in the set of legal systems which are part of the Inter-American System of Human Rights. The second objective is to show it is possible a new transdisciplinary approach combining mathematics and legal theory 2. Antecedents This talk is the result of the efforts made to integrate complexity theory, law, contemporary cognitive sciences, and mathematics in what we call "Complex Legal Constructivism". This research is funded by CONACYT as part of its Frontiers of Science program. 3. Problem One of the main problems of legal globalization is that traditional sources of law derived from national constitutions do not work anymore. The appearance of diverse factors in the constitutional environment are changing the dynamics of legal systems. Some of these factors are new information technologies, the intensification of international trade, new globalized organizations not created by national legal system norms or international law, such as intergovernmental organizations, trans-governmental cooperation networks, non-governmental organizations, transnational networks of private actors, multinational corporations, globalized organized crime networks, etc. In this context no one is capable of knowing the connectivity happening at the global level and therefore, the possibility of intersubjective control of the whole system is more and more difficult. 4. The experiment
Even with a ”global” legal globalization, it is possible to talk of sub legal globalizations. One of this corresponds to the Inter-American system that includes all the countries that have signed the American Convention of Human Rights and accepted the competence of the Interamerican Court of Human Rights (Mexico included). Based on discrete mathematics, specifically graph theory, a hyper textual theory of law has been developed to identify some words as semantic markers of normative connectivity between rulings of national judges and the norms contained in the American Convention of Human Rights, which form the basis for second level decisions made by the Inter-American Court. From a corpus of both national and Inter-American Court decisions, our goal is to construct a system capable of identifying and establishing connections among semantic markers (considered as network nodes) to obtain an image of a complex network. This visual image could help know different properties of the Ius Commune Latin-American. For instance, the degree of specific nodes corresponding to certain articles of the American Convention (AC) would tell us something interesting about the different legal cases in the region; which AC norms are the hubs with the most important roles in the system´s dynamics; changes in network morphology might represent changes in social problems, etc.

Sabine Jeschonnek and Volker Jeschonnek

The Great Recession (2007 – 2009) and GDP fluctuations of US States

SPEAKER: Sabine Jeschonnek

ABSTRACT. We investigate the interplay between the GDP fluctuations of the US states, looking for common behavior during crises or booms, for ``leader'' and ``follower states'', and for possible early signs of a recession in the data. It is interesting to see how the smaller building blocks of the US economy add up to form the whole. Our study is similar in style to studies of rich countries [1], Chinese provinces [2], and Latin American countries [3].

We analyze Gross Domestic Product (GDP) data downloaded from the U.S. Bureau of Economic Analysis (BEA). Our data consists of the quarterly real GDP for each U.S. state and Washington D.C. These data are available from 2005. We calculate the fluctuations of the GDP over different time frames, starting at three quarters up to over a year, and calculate Pearson correlation coefficients and economic distances for each pair of states. From these, we construct a network of the states using the threshold method. We also consider the complete weighted network.

When plotting the rank distribution of economic distances in a Zipf-style plot, we notice that at the start of the Great Recession (December 2007 – June 2009), the economic distances shrink – the state economies become more similar. We observe a similar phenomenon for the near-recession in 2012, when the GDP was almost stagnant.

We consider the network structure, various centrality measures and correlation coefficients. While some network clusters have a clear geographic correlation, the largest cluster contains states that are geographically very distant. We note that the degree distributions do not form a power law, and they seem to change during the recession.

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Giulia Poce, Giulio Cimini, Andrea Gabrielli, Andrea Zaccaria, Giuditta Baldacci, Marco Polito, Mariangela Rizzo and Silvia Sabatini

What do central counterparties default funds really cover? A network-based stress test answer

SPEAKER: Giulio Cimini

ABSTRACT. In the last years, increasing efforts have been put into the development of effective stress tests for financial institutions. Here we propose a stress test methodology for central counterparties based on a network characterization of clearing members, whose links correspond to direct credits and debits between them. This network constitutes the ground for the propagation of financial distress: equity losses caused by an initial shock with both exogenous and endogenous components reverberate within the network and are amplified through credit and liquidity contagion channels. Indeed, the default of one or more clearing members has the potential to impact other members as well: as highlighted by ESMA, a significant part of the protection central counterparty are equipped with is given by the resources provided by non-defaulting clearing members, which are in turn at risk of facing significant second-round losses. Indeed, our method allows to quantify these potential equity losses (the vulnerabilities) of clearing members resulting from the dynamics of shock reverberation between clearing members themselves. We can thus assess the adequacy of the central counterparty's default fund---which, according to EMIR Regulation, is gauged to cover losses resulting from the default of the two most exposed clearing members (the so-called “cover 2” requirement). The stress test methodology we propose is made up of the following operative steps: 1. use of a Merton-like model to obtain daily balance sheet information of clearing members; 2. reconstruct the network of bilateral exposures between clearing members; 3. apply a set of initial shocks to the market (idiosyncratic, macroeconomic and on margins posted); 4. reverberate of the initial distress through credit and liquidity shocks, and quantify the overall equity losses. We apply the proposed framework to the Fixed Income asset class of CC&G, the central counterparty operating in Italy whose main cleared securities are Italian Government Bonds. If we simulate an initial shock corresponding to the cover 2 case, after an unlimited reverberation of shocks the system falls into a stationary configuration which is comparable to the one obtained with a more uniform distribution of initial shocks. However, if we stop the propagation after the first reverberation, the cover 2 shock appears more severe, triggering a greater number of additional defaults. On the one hand, this proves that---and least under “extreme but plausible” market conditions---the cover 2 is a good proxy of a systemic shock but that, on the other hand, a network-based stress test can be deemed a more refined tool for calibrating central counterparties default funds.

Alexander Becker, Marcel Wollschläger, Irena Vodenska and H. Eugene Stanley

Economic and Political Effects on Currency Clustering Dynamics

SPEAKER: Alexander Becker

ABSTRACT. We propose a new measure that we call the symbolic performance to better understand the structure of foreign exchange markets. Instead of considering currency pairs, we isolate a time series for each currency which describes its position in the market, independent of base currency. We apply the k-means clustering algorithm to analyze how the roles of currencies change over time, from reference status or average appreciations and depreciations with respect to other currencies to large appreciations and depreciations. We show how different central bank interventions and political and economic developments, such as the cap enforced by the Swiss National Bank or the Brexit vote, affect the position of a currency in the currency network. Additionally we demonstrate how the symbolic performance encodes the correlation and dependence of currencies, allowing to quantify the influence one currency has over another.

Claudius Gräbner and Torsten Heinrich

The Dance of Godzilla and the Earthquake: On the Sectoral and Structural Foundations of Macroeconomic Fluctuations

SPEAKER: Claudius Gräbner

ABSTRACT. Our investigation takes as vantage points two recent empirical findings: firstly, there are significant co-movements between the business cycles of different countries (e.g. Johnson, 2014). Secondly, because firm sizes are heavy tailed, aggregate fluctuations in a given country can be traced back to output fluctuations of the largest firms (e.g. Carvalho and Grassi, 2015).

Against this backdrop we employ methods from network science and time series analysis to understand the extent to which business cycle co-movement between different countries can be traced back to the firm level and the network of multinational firm relationships. More precisely, we suppose that the co-movement of business cycles between countries can be explained partly by the fact that the large firms which determine busyness-cycle movements in both countries are linked through their multinational activities (such as trade, activity in the same value-added chain, or joint R&D activities). Furthermore, we relate these results with the theory of economic complexity and the product space (Hidalgo et al. 2007, Hidalgo & Hausman 2009, Tacchella et al. 2012): controlling for the sectoral composition of the economies we expect countries with higher complexity to be less vulnerable to economic volatility, both internally – induced by any of the predominant firms - and externally. Thus, countries with low complexity can be expected to show greater co-movements with more advanced countries. This relationship would carry important policy implications with regard to international development collaboration.

To quantify the effect of the firm level on the business cycle co-movements we proceed as follows: Firstly, we quantify the business cycle co-movements by analyzing the dependency structure of the first moments of countries time series of GDP, profits of the largest firms, and changes in the business activities of the largest firms. Secondly, we study the inter-firm networks and the connectedness between large firms in countries with strong business cycle co-movement. Thirdly, investigate the possibility that information on firm-relatedness and firm-level fluctuations can predict the business cycles for each of the other countries. Finally, we study the relationship between product complexity cand business cycle co-movement. The resulting model will then be compared in terms of its predictive power with the importance of alternative sources of business-cycle co-movement, in particular, the degree of sectoral similarity between the countries and the amount of bilateral trade.

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Tiziana Assenza, *Alberto Cardaci* and *Domenico Delli Gatti*

Cognitive biases, perceived wealth and household debt accumulation

SPEAKER: *Alberto Cardaci*

ABSTRACT. Recent findings in behavioural economics and social cognitive psychology show that differences in perceptions can modify individual behaviour in ways that have potentially relevant macroeconomic consequences. This is due to the presence of cognitive biases which lead individuals to make decisions that are inconsistent with the actual amount of available resources (Morewedge et al., 2007; Soman, 2001; Sussman and Shafir, 2012). In line with these findings, we introduce the construct of perceived wealth which identifies a cognitive bias that creates a distorted perception of individual net worth, leading to consumption, saving and borrowing decisions that are not consistent with the actual level of wealth. Eventually, we build a simple macro agent-based model (ABM) in order to study the macroeconomic consequences of individual consumption and borrowing decisions based perceived wealth – measured by the product of deposits and the net-worth-to-liability (NWL) ratio – rather than actual net worth. Our results show that perceived wealth may trigger a process of overconsumption and massive debt accumulation which jeopardise macroeconomic stability. In addition, in presence of the cognitive bias, individuals are also likely to overestimate their ability to pay back consumption loans in the future. As such, individual consumption and borrowing decisions become a potential source of instability for financial markets, as banks may accumulate non-performing loans that affect credit availability for future borrowers. Hence, perceived wealth can explain the emergence of booms and busts characterised by consumption euphoria that eventually results in a debt crisis and a credit crunch.

Elsa Arcaute

The hierarchical landscape of industries in the UK

SPEAKER: *Elsa Arcaute*

ABSTRACT. Co-location of firms is a well-recognised strategy to take advantage of agglomeration economies. Using data at a micro-level, we explore whether there's a hierarchical structure underlying the clustering of firms in London and whether its composition changed after the 2008 crisis. We take particular interest at knowledge-based industries and look into the role of diversity and the historical context for the observed patterns.

Roberto Murcio, *Michael Batty*, *Clémentine Cottineau* and *Elsa Arcaute*

Urban Systems diversity measures

SPEAKER: *Roberto Murcio*

ABSTRACT. Digest the complex temporal dynamics of hierarchical communities is hard to attain in a way that captures the changes in rank and size of its members. Particularly, in urban systems, scaling laws and rank clocks approaches have proved to capture much of this dynamic at macro and micro scales respectively, correlating the variation of urban attributes with city size. Nevertheless, the former highly dependents on a coherent city definition and the later lose the actual population in the analysis. Fully aware that these problems are perhaps intractable, here we argue that adding simple diversity measures to the analysis could give some insights about the self-organization process that these urban hierarchical structures experience over time. Taking some ideas from linguistics and biology we looked at the behaviour of the rank itself (measured as the number of different cities occupying one rank over time) and relate it with the mean clock rank shifts and the cities total turnover from one year to another, to compose a rational picture of the complex temporal evolution of the urban system in terms of its population size. We selected 10 urban systems (UK, France, Italy, Spain, Mexico, USA, Colombia, Canada, Japan, Ex-Soviet Union) as a case of study and apply these diversity measures over a 100 years period (1900 to 2010) divided into 12 points roughly corresponding with national official Census.Our findings emphasize the differences between European systems and their Asian and American counterparts, reinforcing the notion that there is no ultimate rank-size universality to be found in cities. For example, the corpus of cities that are present in lower ranks at all years sampled, it is much larger for European systems that for the American ones, detecting the fundamental differences in terms of foundations dates between the two continents. American systems have "more" variety at middle ranges reflecting a stronger interaction between their cities through these last 110 years. Finally, we tested our measures using an alternative definition of cities for the UK, to explore its robustnesses.

Stanislav Sobolevsky, Sergey Malinchik, Philipp Kats, Cheng Qian, Satish Ukkusuri, Kaan Ozbay, Constantine Kontokosta and Mark Hoffman

Networks of urban vulnerability

SPEAKER: Stanislav Sobolevsky

ABSTRACT. City is a complex system, composed of a multitude of interacting actors of different types. And while complexity is one of the main reasons for city's efficiency, it is also one of its major vulnerabilities. Urban systems are largely dependent on the functionality of their key components and one or several local failures can often cause substantial disruption to the entire system. In that relation understanding vulnerabilities of urban systems is critical for urban planning, transportation and public safety.

Vulnerability of the road networks for example is a well-studied area which saw a lot of advances including recent ones – in particular, approaches are developed to identify potential impact of disruptions happening to a certain node or link of the network [Ukkusuri, S. V., & Holguín-Veras, J. (2007). In Network Science, Nonlinear Science and Infrastructure Systems, Li, J. and Ozbay, K. (2012). Journal of the Transportation Research Board(2284)].

Disruptions can happen for a variety of reasons including infrastructural failures, planned interventions, natural or technogenic disasters or even terrorist attacks. But in most cases they create negative impact on urban mobility resulting in delays for urban population to reach their locations of interest. Major disruptions can even cause people to cancel their plans and change their destinations, but those scenarios are beyond the scope of the present study for now.

However, under certain conditions it can happen that a simultaneous disruption of two or more locations across the city (causing transportation system failures) can have a cumulative impact (delay) on urban mobility larger than the sum of their individual impacts taken separately, creating an effect one can call a disruptive synergy. One can represent this effect by constructing a vulnerability network with nodes representing urban locations, while edges are weighted according to the surplus of the projected cumulative delay to the expected urban mobility caused by a simultaneous disruption of this pair of nodes over the sum of their separate impacts.

In the present work we construct and study the vulnerability networks for NYC and several other major US cities. For that purpose, we leverage the information on available urban multi-modal transportation options on one hand and the expected mobility estimates on the other, based on the Longitudinal Employer-Household Dynamics (LEHD) and geo-tagged Twitter data. The last, despite its limitations is seen as a proxy for human mobility [Hawelka, B., et al (2014). Cartography and GIS, 41(3), Kurkcu, et al, 95th TRB Annual Conference, #16-3901] supplementing static LEHD data with temporal variations of the transportation demand.

In this analysis we ask a question: to what extent urban vulnerability networks for different cities exhibit common statistical and physical patterns and to what extent are those patterns city-specific? We also apply the vulnerability networks to discovering the structure of the city from a vulnerability standpoint, defining communities of locations, representing particular potential threat if disrupted together and compare those communities to the known patterns in urban infrastructure identifying new insights for urban and public safety stakeholders.

Mehdi Bida, *Céline Rozenblat* and *Elfie Swerts*

Modeling hierarchy and specialization of a system of cities as a result of the dynamics of firms' interactions

SPEAKER: *Mehdi Bida*

ABSTRACT. The two main characteristics of systems of cities are the size distribution and the specialization of the cities. These characteristics have extensively been studied by geographers (Christaller, 1933; Berry, 1964; Pred, 1977; Bourne, 1984; Pumain, 1982; Batty, 2005; Pumain et al., 2006), and more recently by physicists (Makse et al., 1995; Schweitzer, & Steinbrink, 1998; Bettencourt et al., 2007). All this literature underlines the remarkable constancy in space and time of Zipf's law of distribution of city sizes (Zipf, 1941). Alongside the urban hierarchy, the degree of cities' economic specialization follows an opposite trend to the size. It has been shown that the sole account of the diffusion of innovations across the network that cities form, is necessary and sufficient to reproduce the observed characteristics of urban systems (Bura et al., 1996; Pumain, Sanders, 2013). However, the developed models always considered the entire city as the unit in the urban system like in the Simpop model (Pumain et al., 2017).

In our approach, we propose a model where the cities forming the urban system are the results of micro-agents' interactions. This model also aims reproducing hierarchy and specialization of urban systems, but with a complete bottom-up approach from the micro-agents, to the meso level of each single city until the macro level of system of cities. We use an agent-based model where agents are firms that make evolve their cooperation network for innovation in a geographical space. Innovations stem from a firm, or a group of firms that cooperate and propagate across them according to their geographical distance and their position in the agents' network of cooperation. We will underline to what extent this basic model will be able to reproduce the urban system hierarchy. In a second step we will add a supplementary economic dimension that consists in different economic sectors. The new economic space combined with the geographical one will modulate the interaction patterns. In this configuration of the model, we will identify the necessary conditions to reproduce both hierarchy and specialization of urban systems.

Charlotte James, *Luca Pappalardo*, *Alina Sirbu* and *Filippo Simini*

Data-driven model of researchers' migration

SPEAKER: *Charlotte James*

ABSTRACT. In the academic community there is a widely accepted belief that movement between institutions is beneficial to, possibly even essential for, a successful career. From doctorate to post-doc, lecturer to professor, many individuals relocate at some point in their career. Despite its common occurrence, it remains unclear how a researcher looking to relocate selects their next institution and at which point in time they decide to make this move.

Here we present an analysis of the APS publication database which consists of over 400,000 papers, reconstructing career trajectories of scientists to determine the driving forces behind their decisions to change institutions. The driving forces we consider include relative performance of both the researcher and the institutions and duration of employment, amongst others. We apply methods originating from machine learning, including decision tree regressions and random forest classifiers, in order to determine which factor is most influential in a researcher's decision to move relocate.

Using this insight, we construct a mathematical model to describe the migration of researchers between institutions. The model may be used to determine both the probability that a researcher will migrate (i.e., change institution) and the probability to relocate to a given institution (i.e., the possible destinations). The insight gained from this work provides us with a deeper understanding of the factors that influence the migration decisions of researchers along side a general modelling approach to describe migration dynamics.

Irving Omar Morales Agiss, Emmanuel Landa Hernandez and Liliana Sosa

Network properties of mexican cities

SPEAKER: Irving Omar Morales Agiss

ABSTRACT. Cities are complex systems par excellence. Human beings live in cities of various kinds, which are shaped according to very specific and local processes, for example the topology of the land where they were built or the culture of the society that inhabits it. However there are universal properties that all human cities share. This talk discusses some of these universal properties in the context of Mexican cities. We analyze 3500 Mexican cities in the context of complex networks. Our study encompasses cities of a broad range in terms of population, from cities with 2500 inhabitants to megacities with millions of inhabitants such as Mexico city. In a system like the city, different communities emerge with their own identities; This is due to multiple factors, among them, the physical infrastructure of the city; Being part of this the structure the city streets. We represent the urban trace of each of the studied cities as a complex network and then we analyze the statistics of the properties of these networks, their effects on human mobility and how they change as a function of population. Representing the city as a complex network allows segmenting the network into communities or subnets according to the connectivity properties of the network itself. These communities in the network correspond to areas of the city with similar connectivity. Structures that are topologically coherent with each other. These regions are compared directly with zones of the city obtained through other strategies, in particular in terms of socio-demographical variables, such as social development, security, poverty, etc.

Samuel Scarpino, Munik Shrestha, Erika Edwards, Lucy Greenberg and Jeffrey Horbar

The Interhospital Transfer Network for Very Low Birth Weight Infants in the United States

SPEAKER: Samuel Scarpino

ABSTRACT. Background- Very low birth weight, VLBW, infants are frequently transferred among hospitals, yet the structure of transfers and how structural variation affects care is not well understood.
Objective- To identify structural relationships in the interhospital transfer network for VLBW infants in the United States and determine how structural variation relates to function, i.e. care.
Methods- We used data from the Vermont Oxford Network, VON, to construct the interhospital transfer network. The transfer network was partitioned into communities using modularity maximization via message passing. Centrality was quantified using message passing and hierarchy was determined using spectral entropy. Significance was determined by hierarchical Bayesian modeling and permutation.
Results- In 2015, VON hospitals in the US cared for 44,859 VLBW infants. The interhospital transfer network included 2,126 hospitals with 10,185 infant transfers among the hospitals. The figure shows two views of the transfer network. The communities differed in terms of both the degree of hierarchy and pattern of transfers. These structural differences accounted for among-community variation in the frequency of hospital acquired infections and successful infant discharge.
Conclusions- The interhospital transfer network for VLBW infants in the US consists of structurally variable communities. This variation affects care, in terms of the percentage of successful discharges and hospital acquired infections, and function, in terms of the frequency of infant transfers. This study is the first to demonstrate that the structure of the interhospital transfer network for VLBW infants in the US varies and that this variation may affect care.

Luís F Seoane and *Ricard Sole*

Information theory, predictability, and the emergence of complex life

SPEAKER: *Luís F Seoane*

ABSTRACT. Darwinian dynamics emphasize fast replication and large progeny in a process devoid of final cause. To satisfy these constraints, it pays off being small and relatively simple, such as bacteria; while large, complex, costly structures can often be penalized. And yet, different levels of cognitive (and other forms of) complexity have been achieved by living systems – which poses an evolutionary conundrum. Stephen Jay Gould [1] argued that simple life forms still largely dominate the biosphere, and that the 'incidental' complexity that we observe is the result of a random drift biased towards larger complexity only because a lower boundary exists: nothing much simpler than bacteria can replicate autonomously, hence any random fluctuation is likely to yield more complex replicators. He insisted that explicit selection of complexity does not take place [1]. An alternative solution is that cognitive complexity might allow living systems to extract enough information from their environment, so that they can cope with the costs associated with the expensive processing structures. Under some such circumstances complexity could be explicitly selected for by natural selection.

Inspired by Maynard-Smith [2], we modeled evolutionary dynamics as a message passed down across generations through a noisy channel (the environment) [3]. In [2], genes carry meaningful bits of information that must be protected against the action of the environment. Against this view, we realize how messages that better cope with the environment naturally replicate faster. Hence a better characterization is that of the environment pumping meaningful bits of information into the genome. This can be rewritten as a prediction task in which so-called bit-guessers [3] attempt to reduce the uncertainty of the environment. Based on these insights we develop a minimal mathematical model that allows us to address the tradeoff between complexity and replication. Thanks to it we can prove that complex living systems can be selected for beyond a random drift, and we can quantify under what circumstances this will happen. The complexity of the environment is the key driver in these dynamics, but other actors can also be integrated into the model – as we discuss in our work [3]. The model also proved extremely versatile to address other biological scenarios so we expect this to be the first in a series of contributions around the same topic.

[1] Gould SJ, 2011. Full house. Harvard, MA: Harvard University Press. [2] Maynard-Smith J, 2000. The concept of information in biology. Philos. Sci., 67(2), 177-194. [3] Seoane LF and Solé R, 2017. Information theory, predictability, and the emergence of complex life. Under review, J. R. Soc. Interface.

Ivan Kryven

Numerical Take On Multidimensional Chemical Master Equation: Modelling Biological Switches

SPEAKER: *Ivan Kryven*

ABSTRACT. When discussing master equations that govern population dynamics the term 'high-dimensional' is rather routine than exceptional. In this case, we mean 'population' in the broadest sense: whether these are molecules, cells, bacterias, colloids, people, or connected components in a random network, it is natural to represent the system state as a multidimensional probability (or mass) density function. This reflects a statistical view on the system as a population of samples with deviating vector-valued properties. In this talk, I will focus on the case when, even though the distribution that solves the master equation is multivariate, it is supported only on a 'small' manifold comparing to the whole state space. Here, the support is defined as a region where the probabilities are larger than a pre-defined threshold. Such manifold may have a non-trivial shape, and even may change its topology as the distribution progresses in time. The radial basis functions are employed to approximate the distribution in the interior of the manifold. In the same time, the shape of the manifold is tracked by the level set method, so that the approximation basis can be adapted to the change of the distribution support. The talk is fortified with examples inspired by problems from cell differentiation paradigm that feature metastable behaviour.

[1] Kryven, Ivan, Susanna Röblitz, Christof Schütte. "Solution of the chemical master equation by radial basis functions approximation with interface tracking." BMC systems biology 9.1 (2015): 67.

Esther Ibáñez-Marcelo, Angkoon Phinyomark, Paul Expert, Robin Cahart-Harris, Francesco Vaccarino and Giovanni Petri

Global topological conservation versus local reorganization of the psychedelic brain

SPEAKER: Esther Ibáñez-Marcelo

ABSTRACT. We analyse the homological structure of functional connectivity of the human brain under the effect of two different psychedelic drugs, psilocybin [1] and LSD [2] via persistent homology [3], a technique in topological data analysis, able to capture multiscale high-order patterns. Previous work showed that subjects injected with psilocybin showed a remarkably different functional topology as compared with subjects that received placebo [4]. The differences were in both the overall modulation of connectivity and in the localization of the homological features in the brain. Global information about topology is summarised by persistence diagrams which describe the lifespan of functional cycles, corresponding to areas of localized weaker connectivity bounded by strongly interacting cycles. Local information is instead encoded in a set of surrogate networks, called persistent homology scaffolds, which bring the information about functional cycles back to the brain network level, effectively yielding its topological skeleton [4].

In this contribution, we first replicate the psilocybin results under a different preprocessing pipeline, showing that the homological properties detected are robust under different processing pipelines and that psilocybin causes a strong reorganization of the local correlational structure. Then, by leveraging recent results on distance kernels for persistence diagrams [5], we compare the topology of functional brain networks for subjects under psilocybin and subjects under LSD and we find that, at the topological level, psilocybin produces functional alterations that are more uniform across subjects as compared with those produced by LSD. We then focus on the localization of these functional alterations (as expressed by homological scaffolds) and find that the scaffolds for subjects under LSD and placebo share a large fraction of edges (~ 50%) with the difference that stems from a strong reduction of the scaffolds' edge weights of the LSD scaffold and correlates with the self-reported intensity of the psychedelic experience; in the psilocybin case instead, scaffolds under drug or placebo share a very small edge fraction (~5%) and also on those, there is no relationship between edge weights in the two conditions. Considering the global (persistence diagram distances) and local (scaffold weights modulations), we find strong evidence for a different topological effect of the two drugs: LSD causes small effects of the topological structure that are inconsistent across subjects, effectively showing a psilocybin instead produces a substantial network rearrangement which is more consistent across subjects.

Harshitha S. Kotian, Shalini Harkar, Ayushi Mishra, Shubham Joge, Varsha Singh and Manoj Varma

Social Intelligence in Pseudomonas aeruginosa

SPEAKER: Harshitha S. Kotian

ABSTRACT. Pseudomonas aeruginosa (PA) is one of the several species of bacteria which exhibits swarming motility, defined as the ability of a collection of bacterial cells to rapidly spread across a solid surface such as agar supplemented with nutrients. Bacterial swarming is a phenomenon which involves collective decision making, for instance, to estimate whether a critical population size has been reached or if the conditions are favourable for swarming. Swarming bacteria display spatial patterns characteristic to their species ranging from smooth circular patterns to finger like patterns formed by PA. The swarming patterns extend over a length scale (tens of centimeters) which is 4-5 orders of magnitude larger than the typical size of a single bacterium (about a micrometer). Given the extremely large number of individuals in a bacterial swarm (more than 10^7 cells), and the fact that individual bacteria are likely to encounter a highly stochastic environment in terms of local concentrations of nutrients and signalling molecules, bacterial swarms provide an excellent system to probe biological complexity. The relative ease of performing temporal and spatial multi-scale imaging enables detailed documentation of the emergence of robust collective behaviour from stochastic individual behaviour in the case of bacterial swarming. It is more difficult to piece together such data in other systems studied in the context of biological complexity such as reaction networks. We will describe interesting instances of robust collective control exhibited by PA swarms. Specifically, we focus on the ability of a PA swarm to sense its neighbourhood and to modulate its movement based on the sensory cues. Multiple PA colonies swarming on the same agar plate can sense an approaching colony from as far as a centimeter. The response of a swarming PA tendril (a finger like projection) to an approaching PA tendril suggests the dynamic emergence of a colony level altruism along with reorganisation of the bacteria within the swarm. The swarm reorganisation process begins with a unique swarm tendril retraction without any significant distortion of the swarm finger shape as might be expected from jamming associated with the direction reversal of a large population of motile agents. Quite Surprisingly, our experiments present strong evidence for the ability of a swarming PA tendril to sense non-biological obstacles made of inert polymers such as PDMS (Poly DiMethyl Siloxane). We propose a computational model of motion control in PA swarms based on the sensing of concentration gradients of nutrients and signalling molecules. While the current computational model is a coarse grained fluid dynamical model, we are exploring the development of a microscopic single cell based model to better understand the strategies employed by the swarm to overcome stochasticity at the single bacteria level. In summary, bacterial swarms present a rich system to study complexity in a biological setting. Understanding the rules governing the behaviour of bacteria at the single cell level and studying how such rules lead to emergence of robust collective behaviour observed in experiments holds good promise in developing successful strategies to deal with complexity associated with large systems.

Santa Elena Tellez Flores and Fernando Ramírez Alatriste

Diagnosis of epilepsy from the reconstruction of the attractor of EEG

SPEAKER: Santa Elena Tellez Flores

ABSTRACT. In this work, we performed an ANOVA analysis of the embedding dimension and the delay time, which form part of the measurements intervening in the reconstruction of the attractor of non linear time series corresponding to electroencephalogram including alpha signals of both healthy and epileptic patients. The measurements corresponding to healthy patients were divided into two groups: one in which the EEG was considered with the eyes opened (type Z) and another with the eyes closed (type O); a second group of measurements corresponding to an intracranial EEG included two types of epileptic patients: the first one is a free of crisis (type N) patient whose measurements were obtained from the hippocampus zone and in the second one the measurements were obtained from the epileptogenic part. As with similar studies, we have focused in the correlation dimension, but additionally, we have also included the delay time to study their possible correlation. We found that for both kinds of patient, there are significative differences, with p = 0;05 in the embedding dimension and the delay time. We conclude that, in the presence of the disease, the dynamics of the signals has less degrees of freedom than in its absence. The results could allow considering the creation of software for medical routine use; this could be helpful in the diagnosis of the disease, as it would indicate the place in which epileptic crisis start, through the embedding dimension.

Omar Patricio Juárez Álvarez and Alessio Franci

Neuromodulation in crustacean circadian rhythm: a theoretical analysis

SPEAKER: Omar Patricio Juárez Álvarez

ABSTRACT. Circadian rhythms are universal biological clocks that synchronize cell and organism behaviors with natural rhythms. Their main role is probably to regulate the sleep-wake cycle. Although a “master clock”, a single physiological structure responsible for generating circadian rhythms, has yet to be found, specific organs and systems are responsible for robustly maintaining circadian activity in different organisms, for example, the suprachiasmatic nuclei (SCN) in the human hypothalamus, the pineal gland in birds, and the eyestalk in crustaceans. Robust maintenance of circadian rhythms rely on endogenous release of hormones and neurotransmitters, the resonance of several ultradian (shorter than a day) rhythms, the synchronization with exterior cycles such as food and light, and other properties particular to the organism, e.g. age [Fanjul-Moles1992, Escobar1999]. Thus, complexity ensues. Recently, cellular excitability and its modulation have also been identified as key players in the genesis and regulation of circadian rhythms [Nitabach2002].

In the case of crustaceans, such as the crayfish members of the Procambarus genus, the eyestalk serves not only as a sense organ, but also coordinates rhythms involved in the individual’s locomotor system. The X organ-sinus gland system, located in the eyestalk, is of particular interest because it houses 150 – 200 neurosecretory cells that release various hormones, some of which are crucial to regulating blood sugar levels and molting [Garcia1998]. Recordings of X organ neurons during the circadian cycle show rich transitions in their electrical activity. Within an 11 hour time-lapse they have been shown to exhibit tonic spiking, repolarizing blocks, low-amplitude oscillations, bursting and silence [Garcia1998]. These changes are mediated by a plethora of neuromodulators, like γ-aminobutyric acid (GABA), Met-enkephalin (Met-enk) and 5-hydroxytriptamine (5-HT), and regulate the type and amount of neurotransmitters and hormones released during the day by the X organ-sinus gland system.

We employ conductance based modelling and novel non-linear sensitivity analysis techniques [Drion2015] to explore the maximal conductance space and formulate predictions about the neuromodulatory mechanisms underlying the spiking mode transitions observed in the X organ during the circadian cycle. We use a state-of-the-art neuronal conductance-based model of a stomatogastric ganglion (STG) neuron in Cancer borealis [Liu1998]. This model is able to robustly reproduce all the activity patterns observed in the X organ and has been widely used for neuromodulation studies [Marder2014]. Our analysis leads to clear predictions about the possible paths in the maximal conductance space that realize the circadian neuromodulation in the X organ.

Christopher Stephens, Raul Sierra Alcocer and Constantino Gonazlez Salazar

SPECIES: A platform for modeling spatial data and identifying ecological interactions

SPEAKER: Christopher Stephens

ABSTRACT. The data revolution of the last couple of decades has given rise to vast amounts of new data, as well as making old data available for analysis in new ways. Much of the data is spatio-temporal, giving information about where things - species, people, businesses, diseases etc. - are, relative to one another in space and time. These spatio-temporal positions, in turn, are highly dependent on the interactions between objects. In physics, such information has yielded most of the knowledge we currently have about the interactions between physical objects. The most illustrative example is that of the gravitational interaction, associated with Brahe, Kepler and Newton, which was perhaps one of the first examples of data science. A data base of the positions of planetary bodies (Brahe) was analysed and phenomenological regularities observed (Kepler) which led to the supposition of an interaction (Newton). Unlike physics, where the number of fundamental interactions is small and there is a very high degree of universality, in Complex Adaptive Systems we know much less about the interactions between organisms. Indeed, there are just too many to ever try to observe and characterize directly. We are therefore led to examine to what degree ecological interactions may be detected and characterized from data associated with where and when organisms are. The platform SPECIES (Sistema Para la Exploracion de Informacion Espacial - http://species.conabio.gob.mx) is an interactive on-line tool for creating predictive models at the level of ecological niche and community that include data, both abiotic and biotic, from arbitrary and distinct spatio-temporal resolutions. By constructing Complex Inference Networks, it can, and has been, used to discover, identify and characterize ecological interactions. As examples, we consider emerging diseases, showing how the system can be used to identify vector-host interactions, identifying the most important potential disease hosts for a given disease. Indeed, in the case of the disease Leishmaniasis, the predictions have been validated by recent field work leading to the prediction and confirmation of 23 new species of host in Mexico, a 300% increase relative to what was known before. We will discuss the theoretical underpinnings of the system as well as considering various concrete applications: data validation, emerging diseases, risk analysis, biodiversity, habitat destruction etc.

Sergi Valverde, Jose Montoya, Lucas Joppa and Ricard Solé

Evolution of mutualistic networks by speciation-divergence dynamics

SPEAKER: Sergi Valverde

ABSTRACT. Mutualistic networks have been shown to involve complex patterns of interactions among animal and plant species. The architecture of these webs seems to pervade some of their robust and fragile behaviour. Recent work indicates that there is a strong correlation between the patterning of animal-plant interactions and their phylogenetic organisation. Here we show that such pattern and other reported regularities from mutualistic webs can be properly explained by means of a very simple model of speciation and divergence. This model also predicts a co-extinction dynamics under species loss consistent with the presence of an evolutionary signal. Our results suggest that there is no need to assume that the ecological scale plays a major role in shaping mutualistic webs. Instead, the evolutionary unfolding of these webs would lead to the observed invariant properties.

Clàudia Payrató-Borràs, Javier García-Algarra, Javier Galeano and José J. Ramasco

Robustness of plant-pollinator mutualistic networks against phenological mismatches

SPEAKER: Clàudia Payrató-Borràs

ABSTRACT. Mutualistic interactions play an important role within many natural systems, with abundant examples ranging from the economical context to the biological world. Such mutualism occurs when two different species or agents engage in a relation that benefits both, instead of competing like in the case of predation. The paradigmatic subjects of study are, in fact, ecological networks, whose structural and dynamical features have been linked, thanks to a recently growing endeavour, to observations of ecosystems' biodiversity and stability. In this context, the extent to which the so-called mutualistic networks might be affected by global climate change remains as a crucial question, specially for plant-pollinator communities that seem to be particularly sensitive to climate alterations. Empirical studies report an advance in their flowering and birth cycles (known as phenological shifts) as a response to environmental warming, which occasionally results on losses of temporal overlap between interacting species and by extension on an atrophy of the mutualistic functions.

In our work we determine the repercussions of such deterioration of pollination services in a scenario in which the occurrence's probability of phenological shifts can be tuned. By borrowing tools from population dynamics and statistical mechanics, we introduce a model accounting for such effects on networks. We apply it to a real system, based on the phenological and relational data collected by Burkle et al [1], as well as to artificial networks. We observe that, as the noise in the initial dates of activity increases, the number of surviving species gradually descends until reaching a critical regime in which it sharply drops, indicating a massive disruption of the remaining subnetwork. Such results suggest the existence of a non-equilibrium phase transition from an alive to an absorbing state where all species go extinct. Interestingly, we encounter that the quantity of phenological noise necessary to destroy the entire network entails a vanishing seasonality, pointing out that the system as a whole is extremely robust. Moreover, we find that pre-critical configurations are higly resilient, displaying a considerable inertia which surely slows down the process of extinction. At the critical regime, though, the resilience steeply declines and the rate of extinctions accelerates. Together with the disappearance of high generalist species and the subsequent severe loss of nestedness, the existence of this final collapse alludes to a sort of cascading effect. Besides, our method permitted to identify the most vulnerable species, integrating the combined effect of the structure of interactions and their phenology distribution. It also allowed us to assess the role that the core of generalist plays in enhancing the inertia against extinction. Prospective work should go on the direction of asserting the generality of these conclusions regarding other network's sizes, as well as on deciding whether the nature of the phase transition is continuous or not.

[1] Burkle, Laura A., John C. Marlin, and Tiffany M. Knight. "Plant-pollinator interactions over 120 years: loss of species, co-occurrence, and function." Science 339.6127 (2013): 1611-1615.

Gisele Miranda, Jan Baetens, Odemir Bruno and Bernard De Baets

Interference between connectedness and species dynamics in in silico ecosystems governed by non-hierarchical competition

SPEAKER: Jan Baetens

ABSTRACT. Competition is one of the mechanisms that supports biodiversity in ecosystems. Previous works have shown that cyclic dominance among species can promote their coexistence and as such contributes to the maintenance of biodiversity. A classic example is the rock-paper-scissors (RPS) game, where three species interact in a non-hierarchical way, i.e., each species has one predator, and, at the same time, it preys on another species. Many food webs display such a behavior, like certain bacterial species, coral reefs, and vertebrates, amongst others. Besides, some human decision-making processes are guided by similar interactions. Variants of the RPS game for more than three species can also be found in literature, supporting the study of richer communities. Characteristics to be taken into account when modeling such evolutionary systems are community evenness and the individuals' mobility. The first is related to the distribution of the species, which is often assumed to be uniform despite evidence of the contrary from real-world ecosystems. Secondly, mobility plays a crucial role in many ecosystems. For instance, it has been found that the coexistence of species is mediated by their dispersal and that there is a critical threshold mobility above which biodiversity is lost.

In computer simulations, square lattices are typically used when simulating the interactions among species, which strongly limits the individuals' degrees of freedom. To a much lesser extent, graphs have been considered. Yet, other studies have led to the insight that the dynamics of a system can be affected by its underlying topology, making use of network models that are closer to real-world topologies. In the present work, we investigate how the structural properties of a set of graphs obtained from different network models (random, small-world, scale-free, geographic and regular) influence the dynamics of the RPS game. For that purpose, we generated 100 graphs per network model and per average vertex density for which we selected four values, namely 4, 6, 8 and 10. Then, the RPS dynamics was evolved for 2000 generations and we investigated how the coexistence of species was affected by tracking the time until the first extinction, the evenness and richness of the community, and the community's patchiness. In agreement with previous works, the following processes were simulated on these graphs: 1) selection according to the non-hierarchical competition structure, 2) reproduction and 3) migration. These interactions were stochastic, meaning that at every iteration one individual and one of its neighbors are randomly chosen, after which only one of the processes occurs, which one is dictated by their respective reaction rates. Based on this extensive simulation study and corroborating preliminary studies, we conclude that not only the mobility of the species has an important impact on the evolved dynamics, but the connectedness of the species as well.

Maxime Lenormand and Olivier Argagnon

Biogeographical network analysis of plant species distribution in the French Mediterranean area

SPEAKER: Maxime Lenormand

ABSTRACT. The study of biotic taxa distribution on a territory represents a key step in the understanding, analysis and conservation of ecosystems, but often hindered by a level of diversity and complexity that may appear overwhelming at first glance. To better understand and visualize the biogeographical structure of a territory, it is therefore necessary to divide this territory into meaningful and coherent geographical regions, minimizing the heterogeneity in taxonomic composition within regions while maximizing the differences between them. While the delineation of biogeographical regions has been based for a long time on expert knowledge of qualitative data collection, the increasing availability of species-level distribution data and the recent technological advances have allowed for the development of more rigorous frameworks. While limited consideration is given to network approaches in biogeography, the generic nature of networks and the level of complexity that they can capture at different scale, make it a powerful tool for investing the interactions among species occurring on a territory. In this work, we used a network approach to identify and characterize biogeographical regions in southern France, based on a large database containing information on millions of vegetation plant samples corresponding to more than 3,500 plant species. This methodology is performed following five steps, from the biogeographical bipartite network construction, to the identification of biogeographical regions and the analysis of their interactions based on plant species contribution indicators.

Juan Carlos Rocha Gordo, *Katja Malmborg* and *Line Gordon*

Mapping Social Ecological Systems Archetypes

SPEAKER: *Juan Carlos Rocha Gordo*

ABSTRACT. Achieving sustainable development goals requires targeting and monitoring sustainable solutions tailored to different social and ecological contexts. Elinor Ostrom stressed that there is no panaceas or universal solutions to environmental problems, and developed a social-ecological systems' (SES) framework -a nested multi tier set of variables- to help diagnose problems, identify complex interactions, and solutions tailored to each SES arena. However, to our knowledge, the SES framework has only been applied to over a hundred cases, and typically reflect the analysis of local case studies with relatively small coverage in space and time. While case studies are context rich and necessary, their conclusions might not reach policy making instances. Here we develop a data driven method for upscaling Ostrom's SES framework and applied to a context where we expect data is scarce, incomplete, but also where sustainable solutions are badly needed. The purpose of upscaling the framework is to create a tool that facilitates decision making on data scarce environments such as developing countries. We mapped SES by applying the SES framework to poverty alleviation and food security issues in the Volta River basin in Ghana and Burkina Faso. We found archetypical configurations of SES in space given data availability, we study their change over time, and discuss where agricultural innovations such as water reservoirs might have a stronger impact at increasing food security and therefore alleviating poverty and hunger. We conclude outlining how the method can be used in other SES comparative studies.

Emilio A. Rodríguez-Izquierdo, *Luis A. Bojórquez-Tapia*, *Pablo Padilla-Longoria* and *J. Mario Siqueiros-García*

Developing an early warning signal of a critical ecological threshold for gray whale breeding lagoons in Mexico

SPEAKER: *Emilio A. Rodríguez-Izquierdo*

ABSTRACT. Use of early warning signals to prevent crossing undesired thresholds of social-ecological systems (SESs) is key to avoid unsustainable pathways. To date, most of the research in SES's thresholds has been done after such thresholds were crossed and hence that research becomes irrelevant for preventing undesirable consequences. Consequently, it is crucial to develop approaches that can enable both policy-makers and society to act in time and prevent undesired changes in SSEs. However, deep uncertainty about the interactions and feedbacks between the human and nature domains is pervasive to SSEs. Thus, there is limited knowledge about when and how rapidly SES's thresholds will be crossed.

One way to address deep uncertainty is through computational modeling that allows for an exploration of multiple scenarios so that an early warning signal of a SES's threshold to a catastrophic change can be identified. In that sense, SES modeling does not seek to predict the most likely future but rather to foster a more strategic vision of the future on the decision-making process. Through the case study of the gray whale breeding coastal lagoons in Baja California, Mexico, we illustrate the development of a SES computational model. The gray whale is protected by national and international law. Nonetheless, the Mexican government lacks the technical information to justify the regulation of the number of boats carrying out whale watching activities. Our model aims to produce an early warning signal to be used in the development of regulations for gray whale watching activities.

The SES computational model entailed the elicitation of scenarios regarding the carrying capacity of whale watching boats. We developed a system dynamics model assuming a logistic growth of the gray whale population with a "harvesting" factor equivalent to the sublethal effect of whale watching activities. These activities, in turn, were coupled to a logistic model of tourism to complete the socio-economic loop of the overall system. We carried out a set of computational experiments through Monte Carlo simulations. These experiments allowed us to identify a critical ecological threshold by examining the relationship between the variance of gray whale abundance (the state variable) and the variance of number of whale watching boats (the forcing variable). Thus, the early warning signal corresponded to the highest value of the quotient between the state and the forcing variables.

Jorge Sanchéz, *Carlos Gershenson* and *Nelson Fernández*

Hydro-geographic Complexity and Teleconnections Analysis: The Puerto Rico Stream Flow Regimens Case.

SPEAKER: *Nelson Fernández*

ABSTRACT. In general, hydrological dynamics consider time series analysis approach. Teleconnections detection uses cross-correlation analysis between the stream flow series and other indicators such as SO or NAO index (SOI and NAOI). However, hydrological dynamics can also be described regarding information content and observing the microstates of series. Recently, measures of emergence, self-organization, complexity and relative complexity based on information theory have been developed, and their usefulness in hydrological studies can be evaluated (Fernández, et al., 2014).

In this context, we carried out two types of analysis. The former was a time series analysis to analyze the flow patterns in 19 streams of Puerto Rico considering their location. That means we carried out an hydrological and hydro-geographic analysis. The second one was a complexity analysis concerning the regularity and change of stream flow and SOI. A comparison between the complexity of rivers and SOI were also performed to determine the relative complexity, or response of stream flows to SO phenomenon.

Comparing results of the time series analysis and complexity analysis, we argued that emergence, self-organization and complexity measurement approach is an alternative way to characterize the states of rivers at multiple scales. Future work could also verify the utility of our measures including ecological aspects of migratory species that are affected by the discharge.

Katya Perez Guzman and *Carlos Perez*

The structural drivers behind neoextractivism: a discussion about edge centralities

SPEAKER: *Carlos Perez*

ABSTRACT. Neo-extractivism has been the main economic model of Latin America in the last decade, and for a major part of its modern history. The almost exclusive concentration in exports of raw materials from agriculture and mining industries, with little added value, has promoted broad research literature around such phenomena: from the related worsening of terms of trade in the scope of the regional dependency theories of ECLAC to the more recent ones of natural resource curse and Dutch Disease of North American and European literature, both of which pose extractivism as a syndrome of economic and policy ailments that permeate Latin American economic development. Recently, the definition of such concept has gone beyond mere export concentration to include the promotion of commodities exports by government (hence the prefix “neo”) and includes the ailments usually associated with such practice: environmental degradation, unequal distribution of income and international commerce imbalances. This last connotation, implicit in all the aforementioned literature, has a structural implication which characterizes global trade: a country which concentrates on exporting raw materials is highly likely to be at a disadvantage when compared to other countries in the world, with other production specializations. This structural characteristic of global trade, when diligently and scientifically scrutinized, can give light to imbalances in today’s commercial network, and thus give lead for policy prescriptions that can make this system a better one for all. A network analysis of the world trade network, specifically focused on the differences between countries that specialize on raw materials from agriculture or mining against those who don’t, is an apt methodology for such inquiry. However, in network theory the common unit of analysis is the node (the country in case of global trade), whereas for extractivism the edge is of utmost importance (the flow of goods between countries). This article, thus, develops the framework for an innovative measure of edge centrality that can capture the relevant information of such natural resource and economic flows. The straightforward application of such measure is to determine the level of “extractivism” of a country, relative to the global trade network. Current questions such as whether Mexico is more or less extractive than Brazil, could be answered using such edge centrality measure by capturing different features of what extractivism implies, and thus, would be a new analytical asset for the critical objective of sustainable (and egalitarian) economic development in Latin American countries.

Juan Toledo-Roy, *Alejandro Frank* and *Ana Leonor Rivera*

Indications of a critical transition in global climate timeseries

SPEAKER: *Juan Toledo-Roy*

ABSTRACT. Climate change is one of the most pressing matters that humanity faces in the twenty-first century. The global land and ocean temperature average is the most direct measurable evidence of this change and has been the centerpiece of climate change discussion and research. Although these climate time series have been studied extensively, our work pretends to analyze the modern data record --mainly that spanning the twentieth century-- in the context of dynamical complex systems and phase transitions. The driving question is to determine whether the global temperature record exhibits some of the characteristic telltale signs of many dynamical systems when they are near important dynamical transitions such as critical points of phase transitions (the Ising model for ferromagnetism being a classical example). In this work we have analyzed the global temperature data (both global averages and surface distribution) published by the Berkeley Earth Group using traditional tools of timeseries analysis. We have found suggestive changes in the correlation properties in the power spectra, in the autocorrelation function and in the evolution of the statistical properties of the spatial distribution of decadal temperature records as time progresses from 1880 to 2010. In order to gain a better understanding of the possible significance of this result, we have engaged in the theoretical study of a well-understood model of planetary homeostasis: Lovelock's Daisyworld. By understanding the dynamical differences exhibited by the timeseries of Daisyworld both in the self-regulated and non-regulated regimes, we hope to draw connections that hint that climate change may be altering the regulatory stability of the global climatic system of the Earth and that we may be approaching a critical tipping point.

Paola Vanessa Olguín and *Markus Müller*

Stable structures and dynamic aspects of sleep EEG

SPEAKER: *Paola Vanessa Olguín*

ABSTRACT. Electroencephalographic scalp recordings (EEG) are noise contaminated and highly non-stationary. Therefore one might expect, that an averages of an interrelation measure like the Pearson coefficient, which may take positive and negative values with the same probability, should (almost) vanish when estimated over long data segments. However, the average zero-lag cross correlation matrix estimated over the sleep stages of healthy subjects result in a pronounced, characteristic correlation pattern. This pattern seems to be a generic feature of the brain dynamics, because it is independent of the physiological state and even if calculated for different subjects we find an amazing similarity between the average correlation structures. Hence, dynamical aspects of the brain dynamics should be studied as deviations from this stable pattern. In the present study we confirm this hypothesis via the analysis of sleep-EEG recordings and discuss our results within the framework of established theories about the “sleeping brain”.

Joshua Garland, Tyler R. Jones, Elizabeth Bradley, Jakob Runge and James W. C. White

Climate Information Production Recorded in Water Isotopes from Deep Polar Ice Cores

SPEAKER: Joshua Garland

ABSTRACT. The Earth's climate system is a nonstationary complex system with intricate spatiotemporal dynamics, complicated external forcing and appears to be changing rapidly. One promising way to explore this is by framing what is currently happening to the climate in context of its past history---e.g., the detailed histories that are laid down in ice cores. From the water isotope records in these cores, it is possible to reconstruct climatological factors like temperature and accumulation rates dating back to the last glacial period, and beyond.

For our initial study we used the two highest-resolution records available, one from Northern Greenland (NGRIP) and one from West Antarctica (WAIS). The NGRIP core, drilled in 1999-2003, covers 128,000 years at 5cm resolution. The WAIS core, completed in the past few years, covers a shorter timespan (68,000 years), but at 0.5cm sampling.

From these data, we would like to answer questions like: Do these records contain any information about the past, present or future climate? If so, what information can we reliably extract? Do extreme events like super volcanic eruptions or abrupt temperature transitions (e.g., Dansgaard-Oerschger events), have detectable signatures?

As a first pass at answering these questions, we calculated weighted permutation entropy (WPE) in a sliding window across these records. This measured the average rate at which new information---unrelated to anything in the past---is produced by the climate.

Our preliminary results suggest that analytical techniques, as well as thermodynamic, climactic, and glaciological effects, impact the information production of the climate system. One such early finding suggests that WPE can detect differences in hydrogen and oxygen isotope records that are likely related to kinetic fractionation in the hydrologic cycle, including evaporation of source waters, diffusion in the firn column, and solid diffusion during geothermal heating. The second-order thermodynamic differences between these isotopes are known in theory, but detecting these effects in data has been elusive until now. Additionally, studying information production over time in these records has allowed us to detect extreme events that were not visually apparent in the raw data, such as instrumentation failure and super volcanic eruptions.

Because of the physical and chemical processes that affect the ice, such as compression and deformation, the relationship between the depth in the core and the age of the material at that depth is nonlinear. Since the precise nature of those effects is unknown, it is a real challenge to deduce an age-depth model; this process involves a combination of layer counting, synchronization with tiepoints (e.g., eruptions), modeling, and interpolation. The intertwined mechanics of age, measurement resolution, accumulation variation and the art of age-depth models have created interesting challenges for us, which we will discuss in our talk.

Going forward, we believe that similar applications of information-theoretic methods to paleoclimate records may prove to be a powerful forensic tool for unraveling the mysteries of our ancient climate system. In turn, this may provide deep insights into the current climate system—such as quantifying the timing and impact of human civilization on the climate.

Panos Argyrakis, Michael Maragakis and Konstantinos Angelou

Temporal evolution of the giant component in Patent Citation Network

SPEAKER: Panos Argyrakis

ABSTRACT. Patent Citation Network is the network that is formed from the references of a patent to other patents. The nodes of the network are the patents and the links between the nodes exist if a patent cites another patent. All links are directed as they point only to one direction and the network is acyclic as the references are only to prior patents. The network of all patents in the European Patent Office (EPO) and the Patent Cooperation Treaty (PCT) for the period 1978-2016 was formed. It includes 14,031,393 patents and 22,107,570 links. The majority of patents have only a few citations, while there are not many highly cited or citing patents. Percolation method was applied to the network [1], to figure out the number of days that it takes after a patent is announced for the giant component to form. Starting from day 1 of the data, the result is that it takes approximately 1200 days. The same procedure was followed for various starting dates, at later points in time, in the interval 1978-2016. The outcome is that the giant component is formed in a shorter time period as we progress in time. While at the beginning of the data (1978) it takes more than 1000 days, around year ~1983, we find that it takes only ~500 days. After that year, there is a gradual decrease in the number of days required for the giant component to form. In the last decade (~2010 and later) it only takes one to two months. Some possible causes for these drastic changes in the time required could be the increase in interdisciplinarity in science, and thus in patents, as well as the use of internet and the ease that it provides in communication and exchange of ideas. [1] D. Stauffer and A. Aharony, Introduction to Percolation Theory (Taylor and Francis Ltd, London, United Kingdom, 1994).

Jorge Adrián Perera-Burgos, Rosa María Leal-Bautista and Manuel Coronado

Continuous-Time Random Walk simulations of tracer transport with radial drift in 2D fracture networks

SPEAKER: Jorge Adrián Perera-Burgos

ABSTRACT. The transport of particles in 2D fracture networks is simulated by a Continuous Time Random Walk approach (CTRW), in which random walks with prescribed statistics are considered. The characteristics of the jump vector are related to the statistical properties of the fractures in the porous medium, specifically orientation, and fracture segment length, which are given in terms of probability distribution functions (PDF). The velocity of the tracer is incorporate by means of a conditional probability function which consider that a jump of size r takes a time t, i.e. we are assuming a coupled CTRW. In general the velocity need not be a constant. Varying some functional forms chosen for the PDF, and their respective parameters, several transport behaviors are observed. By this way the classical Brownian motion can be recovered and further Levy walks and in general anomalous transport can be analyzed. In the simulations the possible presence of a radial drift that makes particles to have a preferential jump orientation in radial direction with respect to an origin is included. This drift can depend on the distance to the origin. The introduction of a radial drift in CTRW simulations is new, and resembles the effect of a continuous fluid injection at a given point in the fracture network. This fluid carries the tracer particles giving place to an advective motion, which adds to the dispersive stochastic random walk motion. The total random walk properties that are calculated in these simulations are: particle trajectories, particle concentration profile and radial PDF, tracer breakthrough curves at diverse radii, and the temporal evolution of the first and second moments of the radial PDF's. Results for diverse situations of interest in geosciences are presented.

Andrea Zaccaria, Lorenzo Napolitano, Emanuele Pugliese and Luciano Pietronero

Firms' Complexity: Technological Scope, Coherence and Performance

SPEAKER: Andrea Zaccaria

ABSTRACT. The aim of this work is to shed light on the relationship between firms' performance and their technological portfolios using tools borrowed from the complexity science. In particular, we ask whether the accumulation of knowledge and capabilities related to a coherent set of technologies leads firms to experience advantages in terms of productive efficiency. To this end, we analyzed both the balance sheets and the patenting activity of about 70 thousand firms that have filed at least one patent over the period 2004-2013. From this database it is possible to define a monopartite network of technological codes, that can be used to assess the firms' configuration, defined as the set of technologies in which the given firm is active. We then introduce firms' coherent diversification, a quantitative assessment that does not evaluate a technological portfolio based only the number of fields it encompasses, but also weighs each of its constituent fields of technology on the basis of their coherence with respect to the firm's global knowledge base, as illustrated by Figure 1. Such a measure implicitly favors companies with a diversification structure comprising blocks of closely related fields over firms with the same breadth of scope but a more scattered diversification structure. We find that our measure of the coherent diversification of firms is quantitatively related to their economic performance and, in particular, we prove on a statistical basis that it explains labor productivity better than standard diversification. This is an empirical evidence that this measure of the coherent diversification of technological portfolios captures relevant information about the productive structure of the firms. As a consequence, it can be used not only to investigate possible synergies within firms but also to recommend viable partners for merging and acquisitions.

Duc Thi Luu, Mauro Napoletano, Andrea Roventini, Giorgio Fagiolo and Paolo Sgrignoli

Shock Diffusion in the European Production Network

SPEAKER: Duc Thi Luu

ABSTRACT. Global economic system is a highly interlinked network, comprised of heterogeneous industries in different countries. In such a complex system, the production of any industrial sector has two distinct effects on the remaining industrial sectors: On the one hand by increasing/decreasing production it will demand more/less inputs from other sectors (i.e. "upstream" propagation), on the other hand it will be able to supply more/less output to the sectors that use its production as input to their own production process (i.e. "downstream" propagation).

This work studies shock diffusion in the input-output production network of the Economic and Monetary Union (EMU). Our goal is to answer the following questions: (i) if a shock hits an industry or a country, what are the consequences on the aggregate output of the whole EMU as well as the output of each other country?; and (i) how does the network structure among industries affect shock diffusion and the possible emergence of crises at a national and international level?

At the sector level, we find that a shock initially triggered in different industries ignite cascades with different aggregate "downstream" severity and "upstream" severity. In addition, based on the individual and global damages that would result from the failure of each sector, we can rank its economic importance as well as precisely identify the most important sectors (i.e. hubs) facilitating shock propagation in the EMU's input-output network.

At the country level, we find that, first, some countries like DEU, FRA, ITA, EPS, NLD, and BEL are the key propagators to other countries. Second, the impacts of a shock initially triggered in each country on the other countries are highly heterogeneous, revealing that the way the shock is propagated crucially depends on more intensive bilateral trade linkages as well as on more tightly connected nature of some clusters among sectors in some countries.

Furthermore, we show that when both upstream and downstream propagation channels are taken into account in cascading failures, large shocks to some key propagators can lead to a huge loss in the aggregate output of the whole EMU.

Our findings shed light on the way shocks are propagated in the EMU's input-output network. The results provide useful information for designing more effective strategies to mitigate cascades in this network.

Pierpaolo Andriani, Mariano Mastrogiorgio and Renata Kaminska

Exaptation: a crucial mechanism for the open-endedness of biological and technological evolution

SPEAKER: Pierpaolo Andriani

ABSTRACT. Vladar et al. (2017) have recently suggested that open-endedness in biological evolution can only be envisaged if evolution can add new functional dimensions to the phase-space of species and suggest that exaptation enables the emergence of such new functional dimensions. Is this also true in technological innovation? It seems undisputable that technological evolution has been both open-ended and extremely rapid, especially since the Industrial Revolution. We posit that discoveries due to exaptation may have played a role in such dynamics. To assess the role of exaptation in technological innovation and in the open-endedness of technological evolution, we measured the radiation of emergent uses for a sample of FDA-approved drugs based on new molecular entities (1998-2000 sample, for a total of 83 drugs). First, we identified all their FDA-approved uses, and the emergent uses later discovered by clinicians as listed in the 2013 version of the Micromedex Drugdex compendium. Second, we associated each FDA-approved and emergent use to the respective disease(s) as classified in the ICD9-CM (WHO's International Classification of Diseases, version 9-CM). Third, we compared each emergent use with the FDA-approved one to understand whether the emergent use represents a new functionality hence an exaptation. Our results showed that: o Slightly more than 40% of emergent uses appear to be exaptations. o About 70% of these involve a first-order bifurcation and thus are significantly removed from the original use. o The distribution of emergent uses and exaptations across drugs is a long-tailed distribution of the power-law type. o A fraction of uses shows a radical impact, as measured by their capability of treating previously untreated diseases or providing substantial improvement over existing treatments. Almost all radical uses are characterized by a large distance from the original adaptive use and are exaptive. o All the radical uses for which it was possible to reconstruct the history of the discovery indicate that the discovery was unanticipated and resulted from the serendipitous observation of a new function. o Also, it seems that these radical uses rely on different molecular pathway and (sometimes) phenomena than the approved use. o As an illustration see the pattern of radiation of thalidomide (figure 1). All uses are exaptive, seven of them are radical and rely on different pathways than the approved use. A few uses revealed unsuspected phenomena. o Overall, the observation that: a) radical uses are exaptive and functionally distant from the approved uses; b) their discovery is mostly due to serendipitous events; c) they seem to rely on new pathway/phenomenon and d) their discovery may lead to systematic research meant to uncover the science behind the discovery suggests that exaptation seems to represent a mechanism for discovery of the 'adjacent possible' that adds further dimension to the complexity of the existing phase-space of technological evolution. We speculate that such discoveries occur when the exposure of current artifacts to very distant contexts activates 'affordances' in the artifact that reveal new mechanisms of actions and occasionally unknown phenomena.

Figure 1: functional diversification of thalidomide.

Kunbei Zhang, *Aernout Schmidt* and *Gerrit-Jan Zwenne*

Data Protection Law and Data Controllers' Behaviors in Digital Trade: An Analysis Based on a Standing-Ovation Model

SPEAKER: *Kunbei Zhang*

ABSTRACT. Our paper deals with digital trading, i.e. selling and purchasing services via the internet, and it impact on the legal frameworks that aim to protect individuals personal data and that have been developed in the last decade, notably in the European Union. As the description implies, personal data about individuals and their commercially relevant habits and preferences are important building blocks of digital trade. The increase in digital trade volume is consequently having a significant impact on personal-data protection that has been under debate in several territories for years. Many relevant questions about the enforcement and about the effectiveness of data-protection law have emerged. How do domestic enforcement departments make sure of the compliance with data protection law, when online transactions may instantaneously transmit information around the world? Where and how are the data located if data rarely stay in one location? How are personal-data themselves traded between personal-data users? What kinds of relationships with the data processors do national data protection authorities have? And what defines the effectiveness of data protection law if divergent approaches to data privacy and protection, particularly as regards the United States and the European Union (EU), reportedly impose substantial costs and uncertainty on companies? These questions keep on challenging the current data-protection law regimes. We argue that current data-protection practice, as based on a positivist legal-theory perspective, treats the effectiveness issue too narrowly and too statically. Drawing on complexity theory, we find agent-based modeling fit to simulate and explain (i) the core (inter) actions among participating stakeholders, (ii) to emulate the combined working mechanisms of the legal practice, and (iii) to support calibration of the model's parametric adaptations. We contend that the ability to emulate and calibrate toy versions of the processes by which the interactions between enforcement departments, social-media service providers and commercial profile-data users is essential for understanding and - if necessary – adapt them. In this paper, we will offer the results of our investigations. First we employ and adapt Miller and Page's standing ovation model to try and explain how in the network of personal data users a race to the bottom qua protection level can emerge in commercial practices where data protection is concerned. We subsequently investigate whether the "workflow" of configured competition-, bargaining- and altruistic-punishment encounters (as harvested from an earlier project on describing the co-evolution of the legal fair-use principle and the complex practice of music-file sharing from 1960-2017 and as discussed at the TILTing 2017 conference) can be adapted so that it can help analyze and possibly even stop the rot. We conclude with an example model that provides an existential proof of the possibility.

Tarik Roukny and *Marco D'Errico*

Compressing Networked Markets

SPEAKER: *Tarik Roukny*

ABSTRACT. Unlike centrally organized markets, markets where participants trade on a bilateral basis can generate large networks of contractual obligations. These markets are known to be opaque as market information is often very limited to most agents. In addition, they are also extremely large in size: the aggregate volumes of total bilateral obligations can amount to several trillion dollars. The size, coupled with the lack of transparency of these markets has become an important concern for policy makers.

In this paper, we show both theoretically and empirically that the size and complexity of markets can be reduced without affecting individual trade balances. First, we find that the networked nature of these markets generates an excess of obligations: a significant share of the total market volume can be deemed redundant. Second, we show conditions under which such excess can be removed while preserving individual net positions. We refer to this netting operation as compression and identify feasibility and efficiency criteria, highlighting intermediation as the key element for excess levels. We show that a trade-off exists between the amount of excess that can be eliminated from markets and the conservation of trading relationships. Third, we apply our framework to a unique and comprehensive transaction-level dataset on a largest types of financial market: markets for derivatives. We document large levels of excess across all markets and time. Furthermore, we show that compression - when applied at a global level - can reduce a considerable fraction of total notional even under relationship conservative approaches.

While some markets have already adopted compression in order to reduce their risk and size, these results show, for the first time, the efficiency and trade-offs of compression when systematically applied at a larger scale. Finally, our framework provides ways for regulators and policymakers to curb the impact of financial crises and improve the efficiency of markets by reducing the total aggregate size of markets and reconfiguring the web of obligations.

Fernando Buendía

Network Externalities Revisited

SPEAKER: *Fernando Buendía*

ABSTRACT. The theory of network externalities, even though it is relatively new (it appeared in the mid-1980s), is now a well-established field of analysis in the economic literature and an important reference in numerous legal areas including antitrust, intellectual property and corporate law. Its fundamental idea is that each new participant in a network derives private benefits, but also brings about external benefits (network externalities) on existing users. Besides, because of network externalities, markets may “fail” by tipping the market in favor of the inferior technology and produce excess inertia and technological monopolies. Presently, network externalities have been studied from two different theoretical perspectives: the game-theoretical approach and the Pólya processes conceptualization, and despite their important findings these approaches are based in very artificial maneuvers and ad hoc assumptions that reduce their explanatory capacity. In this paper I show that they rely excessively on the assumption that consumers will adopt the technology that enough number of individuals have already adopted, thus expectations are given and fixed in advance and, as a consequence, uncertainty is eliminated implicitly from their models. To reduce the negative effects of these ad hoc conditions on the explanatory power of these models, this paper attaches to the standard Pólya process a network-based arbitrary function and proves that this kind of function is more realistic for it allows describing the dynamics of the adoption process in a more accurate way and introducing an adequate level of uncertainty to the model of markets subject to network externalities. In this paper, I also discuss that the revision to Pólya process-based network externalities models brought about by this network-based arbitrary function can be helpful to distinguish winner-take-all situations that result from increasing returns produced by network externalities from the those situations where the outcomes conform to a power law and are produced by other sources of increasing returns. Consequently, I argue, these results are not only relevant for economics, but also for management and more specifically for strategy whose theories have to be revised accordingly. This paper has five additional sections. In the following section analyzes briefly the disadvantages of the game-theoretical models of technological adoption subject to network externalities. Section three provides an overview of the application of Pólya processes to technological competition in markets characterized by network externalities. Section four shows that these models are based on very artificial assumptions that reduce substantially their explanatory power. In section five a solution to this problem is provided. This paper finishes with some conclusions.

Maximino Aldanas and *Saul Huitzil-Juárez*

Modeling the role of the microbiome in evolution

SPEAKER: *Maximino Aldanas*

ABSTRACT. It is known that animals and plants host a myriad or bacterial species which live with them, both on their skin and also inside them. All the bacteria living with an organism constitute its “microbiome”, and the system composed by the host organism and its microbiome is known as a “holobiont”. It has been assumed that through evolution a symbiotic relationship has been established between the host and its microbiome, and this is why all superior organisms have a microbiome in the first place. Although experimental evidence of this symbiotic relationship has been found for specific cases, it is still unclear what advantages the microbiome confers to the host, and vice versa. In this talk I present a model of network evolution in which networks representing the host co-evolve with networks representing its microbiome. The main difference between the host and the microbiome networks is in the mutation rates, being the former smaller than the latter. When the host network is trained to perform a task, the training is achieved faster and more efficiently in the presence of the microbiome networks than in their absence. Furthermore, when the host network has to perform several tasks, in can only do so when different types (or species) of bacterial networks are present. The results presented here suggest general principles of species co-evolution that allows us to understand why all superior organisms, from insects to humans, have evolved very diverse and complicated microbiomes.

Kim Christensen, Kishan Manani and Nicholas Peters

Complexity science approach to modelling atrial fibrillation

SPEAKER: Kim Christensen

ABSTRACT. The 21st century will be characterised by the need to master chronic diseases as the population ages, and among the greatest challenges is the disrupted cardiac electro-mechanics of the diseased heart that leads to atrial fibrillation (AF), which is increasing in prevalence and is the single biggest cause of stroke. Because of its common occurrence, and because there is a developing treatment that involves targeting complex signals within the heart, any progress in characterising the complexity of heart activity in atrial fibrillation is likely to have a large and immediate beneficial effect. Ablation, destroying regions of the atria, is applied largely empirically and can be curative but with a disappointing clinical success rate. Moreover, the progression of AF with age, from short self-terminating episodes to persistence, varies between individuals and is poorly understood. An inability to understand the origin of AF and predict variation in AF progression has resulted in less patient-specific therapy.

We design a simple model of activation wave front propagation on an anisotropic structure mimicking the branching network of heart muscle cells [1]. This integration of phenomenological dynamics and pertinent structure shows how AF emerges spontaneously when the transverse cell-to-cell coupling decreases, as occurs with age (e.g., due to fibrosis or gap junctional remodelling), beyond a threshold value. We identify critical regions responsible for the initiation and maintenance of AF, the ablation of which terminates AF. Hence, we explicitly relate the microstructural features of heart muscle tissue (myocardial architecture) with the emergent temporal clinical patterns of AF. The simplicity of the model allows us to calculate analytically the risk of arrhythmia and express the threshold value of transversal cell-to-cell coupling as a function of the model parameters. This threshold value decreases with increasing refractory period by reducing the number of critical regions which can initiate and sustain microreentrant circuits, consistent with clinical observations.

Furthermore, the model reveals how variation in AF behaviour arises naturally from microstructural differences between individuals: the stochastic nature of progressive transversal uncoupling of muscle strands with age results in variability in AF episode onset time, frequency, duration, burden, and progression between individuals [2]. Again, this is consistent with clinical observations. The uncoupling of muscle strands can cause critical architectural patterns in the myocardium that anchor microreentrant wave fronts and thereby trigger AF. It is the number of local critical patterns of uncoupling as opposed to global uncoupling that determines AF progression. This insight may eventually lead to patient-specific therapy when it becomes possible to observe the cellular structure of a patient's heart.

[1] K. Christensen, K.A. Manani and N.S. Peters, Simple model for identifying critical regions in atrial fibrillation, Phys. Rev. Lett. 114, 028104 (2015).

[2] K.A. Manani, K. Christensen and N.S. Peters, Myocardial architecture and patient variability in clinical patterns of atrial fibrillation, Phys. Rev. E 94, 042401 (2016).

Bertha Vázquez Rodríguez, Andrea Avena Koenigsberg, Olaf Sporns and Hernán Larralde

Information transfer enhanced by noise on a human connectome model

SPEAKER: Bertha Vázquez Rodríguez

ABSTRACT. Stochastic resonance (SR) is a phenomenon in which noise enhances the response of a nonlinear system to an input signal. The nervous system, and particularly the brain, has to integrate extrinsic and intrinsic information in a noisy environment, suggesting that it is a good candidate to exhibit SR. Here, we aim to identify the optimal levels of noise that ensure the best transmission of a signal through a discrete dynamic model implemented on the human connectome [1]. We find a noise level (different from zero), that enhances the similarity between an input signal that is introduced through a seed node, and the activity of all other nodes in the system (Fig. 1). Furthermore, the optimal noise level is not unique. Instead, we find that when the model parameters are such that the system enters a critical regime, noise is able to enhance the similarity between input signals and signals that have propagated through the network, with higher similarities detected for particular seed and output node pairs. Given the simplicity of the model presented here, future research could aim at finding the differences in the dynamical properties of the networks extracted from diseased brains. If the transmission of information in damaged networks is different, the noise effect could be explored as a way to improve neural communication in these systems.

Giovanni Petri, Sebastian Musslick, Kayhan Ozcimder, Biswadip Dey, Nesreen Ahmed and Jonathan Cohen

Universal limits to parallel processing capability of neural systems

SPEAKER: Giovanni Petri

ABSTRACT. One of most fundamental puzzles that any general theory of cognition must address is our limited capability for multitasking of control-dependent processes: why in some cases the human mind is capable of a remarkable degree of parallelism (e.g., locomotion, navigation, speech, and bimanual gesticulation), while in others it is radically limited (e.g., conducting mental arithmetic and planning a grocery list at the same time). Multiple-resource theories of cognition identify shared neural resources between tasks as the primary parallel capacity limitation: if two encoded tasks rely on the same resource (e.g. representations encoded in a neural network) then their task pathways will interfere when executed simultaneously. However, to date, such theories have been expressed only qualitatively. Here we provide the first analytical approach to capturing the limitations on multitasking ability in general neural networks. We first show that the the maximum number of tasks a neural network can successfully perform in parallel corresponds to the maximum independent set (MIS) of its task interference graph. Then we give a tight estimate of the MIS density based on the task-degree distribution alone, and show analytically that it is independent from graph size, it decreases with average degree and grows with increasing network degree heterogeneity (Figure 1 left). We compare these results with the average parallel task density of random task subsets with size equal to the MIS': we find in fact that, for any fixed network average degree and heterogeneity, the average parallel capacity decreases strongly with increasing network size. This provides a formally rigorous solution to the multitasking puzzle: while linear network size provides an increase in capacity for a specific task set (the MIS), it simultaneously imposes increasing constraints on parallel capacity of generic task subsets (Figure 1 right). In short, even a small overlap between tasks strongly limits overall parallel capacity to a degree that substantially outpaces gains by increasing network size.

Jiří Bíla and *Martin Novák*

Emergent situations in ecosystems and their detection

SPEAKER: Jiří Bíla

ABSTRACT. In the paper will be introduced a novel method for the detection of emergent situations in ecosystems. The ecosystem is considered as a complex system with many interacting elements. The paper continues in recent published works ?1, 2, 3? where the detection of an emergent situation was done by indication of violence of so called structural invariants of the system. In this paper is used only one type of structural invariant - Matroid and Matroid Bases (M, BM). A calculus for the emergent situation appearance computation is introduced. The application of the presented approach and computation method is demonstrated for the violation of so called Short Water Cycle (SWC) with some consequences of such a situation (dry landscape, invasions of parasites in forests). The Short Water Cycle (SWC) refers to the behavior of the local ecosystem, in which the volume of water that comes into the ecosystem is evaporated and falls back into this system. When SWC is violated, the evaporated water rises quickly in the transport zone and does not have time to condense before it is transported outside the ecosystem to the distant mountains, where it condenses spontaneously in the rising air streams. (Due to the enormous volumes of vapor that are transported, the condensation is very dynamic and sometimes leads to torrential downpours).Violation of SWC is demonstrated by situations in National Park Sumava in South Bohemia. (The reason was a small volume of ground water in the soil and drying the trees. Then followed the invasion of wood parasites and absolute devastation of landscape.) The proposed method of the detection is universal, can be used for retro analysis (e.g., also for violation of SWC in region Yucatan in Mexico many years ago). (There are also introduced in the paper another emergent situations that could be interpreted positively.)

Very important in complex system description are two factors: level of the description and the basic group (compartment) of complex system elements. There are used two descriptive sets: the first - symptoms represented by external observational variables (e.g., biodiversity, maximum temperature, …) and the second - drivers (e.g., high velocity in transport layer, decrease of area of landscape vegetation, …). The calculus for the emergent situation in a complex system (that is introduced in the paper) associates two variables for emergent situation – The power of emergent phenomenon and the complexity of emergent phenomenon. By quantified actualized symptoms is computed the power of emergent phenomenon and from the power is computed complexity of emergent phenomenon that determines the “size” of compartment. The further computations leads to detection of a Possible Appearance of an Emergent Situation (PAES).

Dries Maes, Estelle Petitclerc, Fanny Vanrykel and Marc Bourgeois

Adaptive policies, guided by knowledge generation, in order to avoid private monopolies in an emerging technological sector

SPEAKER: Dries Maes

ABSTRACT. Deep geothermal energy appears to be currently on the edge of a take-off and offers the potential to supply a major share of the Belgian renewable energy requirements. For the authorities, deep geothermal energy production is a standard showcase of an emerging innovative technology. Pioneer installations require significant financial support from public funds to be profitable. This can be justified by considering the important learning effects that quickly improve the profitability of the individual geothermal projects, and allows the sector to emerge in the medium to long term. In this respect the geothermal development is very similar to the development of solar technologies in last century, or the growth of the co-generation sector at the start of this century. However, geothermal energy intrinsically starts from the utilization of a the deep underground, which can be considered a public resource. Also geothermal projects need large scales and exhibit high levels of investment risks, compared to other innovative energy solutions. Considering the particular characteristics of geothermal energy, and their impact on the economic viability of the projects, the sector development may be more difficult than for other technologies. In the medium term, it can be expected that early investment will allow public and private actors to learn about crucial information on the deep underground. However, the same learning effects increase the probability of a regional private monopoly in geothermal energy. This monopoly can emerge in an open market with public support, if no legal requirements for data exchange and open innovation are imposed. In this paper, we review the situation of geothermal energy in Belgium, the technology characteristics and the different public support instruments that are applicable. We build an evolutionary model to simulate the future development of the sector under different policy scenarios, and to estimate the probability of emerging private monopolies in the sector. The dynamics of the sector emergence require interdisciplinary models. A large part of the development potential is determined by the geological and technical characteristics of each new project. An economic level of analysis is added, because investments are determined by availability of capital, risk assessments and expectations of market evolutions. Finally, the complexity of the sector evolution is caused in reality by the knowledge creation during each geothermal activity, and the impact of policy measures on the speed and capitation of newly generated knowledge. The model therefore includes also the endogenous knowledge creation and exchange between private partners, as well as the learning effect for policy makers that make adaptive policy scenarios possible. The results show that protected private geological knowledge can lead to private monopolization of a public resource. It implies that policy makers have to include safeguards early on during the emergence. The underground can be managed as a public resource, and judicial options are necessary to impose the exchange of geological data. This obligation is best coupled with other policy measures to ensure the optimal investment climate and fast sector growth, while avoiding early monopolization.

Oliver López-Corona, Elvia Ramírez-Carrillo, Juan Toledo, Luis Osorio, Julian Equihua, Vanessa Pérez-Cirera and Fernando de León González

Assessing sustainability in North America's ecosystems using criticality and Information theory

SPEAKER: Oliver López-Corona

ABSTRACT. Sustainability has become a key concern in every economical or political discussion for good reasons. Concern about whether current trajectories of human demography and socioeconomic activity can continue in the face of such environmental impacts has led to calls for “sustainability.” Never the less, sustainability is often used in a very qualitative sense and then a quantitative measure of it through a system-level index is greatly needed. In this work we use an informational approach to quantifying some aspects of ecosystem sustainability, in particular their health and stability.

We propose a novel conceptualization of ecosystem health as criticality, following well established ideas in human health. In this framework for example, a hearth is healthy if the power spectrum of the fluctuations of electrical activity is scale invariant (S~f^beta) and it scales as a pink noise (beta ~ -1). In this work as a simil of hearth activity we used ecosystem respiration data from AMERIFLUX data base, a network of more that one hundred monitoring sites in most ecosystems types of North America.

After selecting only time series without gaps and after removing periodicities, a traditional spectral analysis was performed by computing the Fast Fourier Transform of the fluctuations time series and computing spectral indices by fitting power-laws to the spectrum. Two fits are obtained. The first is a direct single power-law fit to evaluate if it follows a pink noise type. The second fit model is piecewise-defined double power-law composed by a low-frequency power-law followed by a high-frequency to prube scale invariance. A time series is scale invariant if comparing with a BIC infomational index the single power-law model is better that a two power-law model.

In terms of stability using the same fluctuations time series, we followed in one hand a Fisher Information approach developed by Frieden, Cabezas and others that has proved as robust method to assess the stability of a system over time. On the other hand we used statcomp library in R to measure permutational entropy and complexity in terms of Michaelian ideas about ecosystem stability and out of equilibrium thermodynamics.

We validate our results by comparing to Landscape Condition from the Nature Serve Network, that commonly refers to the state of the physical, chemical, and biological characteristics of natural ecosystems, and their interacting processes.

In this way we assess sustainability (health and stability) in North America's ecosystems finding a complex set of patterns that we analysed using traditional statistics and classification trees using the C4.5 algorithm in WEKA. In general we found that ecosystems types out of criticality are elder forest or has been altered by human activity or events of wildfires for example. Sites with pink noise (beta ~ -1) behavior are statistically in better Landscape Condition that those sites with white (beta ~ 0) or brown (beta ~ -2) noise type. In the same way, stability is greater for sites with pink noise type. Some heuristics for desicion making are propoused

Takayuki Mizuno, *Takaaki Ohnishi* and *Tsutomu Watanabe*

How to guard company's supply-chain risks by global inter-firm relationships

SPEAKER: *Takayuki Mizuno*

ABSTRACT. In this paper, after examining the structure of global inter-firm networks, we discuss the implications of global linkages at the firm level for the proliferation of 'conflict minerals' or 'dirty products' through global buyer-supplier linkages and apply these implications to solve similar issues for supply-chain risks. We first investigate the structure of global inter-firm relationships using a unique dataset that contains the information of customer-supplier relationships for 423,024 major incorporated firms. Global customer-supplier network has scale-free properties. We show through community structure analysis that firms cross national borders and form communities in the same industry. There are also firms that act as bridges between these communities, so that throughout the world each firm is connected with an average of six business partners. By enhancing this feature of links between firms, it can be used as a countermeasure for risks related to conflict minerals and slave labor issues. Conflict minerals are natural minerals (gold, tin, tungsten, etc.) that are extracted from conflict zones and sold to perpetuate fighting. The most prominent example is the natural minerals extracted in the Democratic Republic of the Congo (DRC) by armed groups and funneled through a variety of intermediaries before being purchased by multinational electronics firms in industrial countries. There is wide discussion on how to mitigate the worldwide spread of conflict minerals. By utilizing a simple diffusion model and empirical results where firms comprise a community with those firms that belong to the same industry but different home countries, we show numerically that regulations on the purchases conflict minerals by limited number of G8 firms belonging to some specific industries would substantially reduce their worldwide use. When these firms refuse to buy conflict minerals from their suppliers, the supply chains of many intermediaries which are positioned upstream suffer. We also deal with slave labor issues. The global indirect connections with illegal firms through lawful trades of each country are also attracting attention. For example, nobody wants to import clothes made by the garment manufacturer that exploited sweatshop laborers that make cheap clothing possible, although the trade with this garment manufacturer is lawful in its home country. We use the Dow Jones Risk & Compliance dataset that covers about 40,000 firms who may have had adverse/negative media coverage related to specific topics, "Regulatory, Competitive/ Financial, Environment/Production, Social/Labour". The firms associated with adverse media are concentrated on the specific communities in global inter-firm network. We can efficiently guard wholesome firms from such supply-chain risks by cutting these communities based on edge betweenness centrality from the firms associated with adverse media. Our results improve supply-chain transparency and contribute to the sustainability of firms.

Fabio Bento

Complex adaptive processes in the oil and gas industry: a network perspective to knowledge management and the challenges of a retiring workforce

SPEAKER: *Fabio Bento*

ABSTRACT. Changes in workplace demographics have raised a concern with the impacts of mass retirement to knowledge management in the oil and gas industry. Some recent reports estimate that the industry may lose up to 50% of its workforce in a matter of five years. From a knowledge management perspective, such phenomenon is perceived in terms of a knowledge loss crisis. The typical industry response to this challenge has consisted of strategies aiming at codifying and storing knowledge in databases and reports. However, such common managerial responses show important limitations in terms of grasping tacit and network-based dimensions of knowledge in rather complex oil production operations. In this conceptual article, I suggest a complex system approach to this organizational problem by discussing the potential of social network analysis in enlightening the emergence of new patterns of interaction and knowledge in the oil and gas industry. Complex adaptive processes demand looking into organizations not only in terms of formal organizations charts, but as units of adaptation characterized by emergent patterns. The focus on relational data that embeds organizational network analysis has an important potential in uncovering the dynamics of integration operations that have permeated organizational changes in the oil and gas industry. The concept of integration is more than the implementation of new technologies, but a significant change in the business model of most companies focusing on the interdependence among staff in different operational processes This is a major shift from a traditional business model in which processes were modelled in a sequential manner and understood with little focus on interactions with other processes. Organizational network analysis has been used to understand flows of information and identify the role of different agents in processes of communication. However, understanding adaptive process due to knowledge crisis demands operationalizing the temporal dimension complexity. First, we need to incorporate the temporal dimension of central concepts such as emergence and self-organization. Second, we need to go beyond the concern with system robustness in most organizational network analysis but also developing an understanding of systems resilience. The conceptualization of network analysis from the perspective of complex adaptive processes has the potential of understanding how systems behave in response to the retirement of central actors and losses in networked-based expertise. Bearing that in mind, the conceptualization of knowledge loss crisis in organizations seen as units of adaptation may contribute to our understanding of integrated operations and perform the basis for new knowledge management initiatives in the industry.

Thomas Maillart

Exogenous vs. Endogenous Critical Cascades, Community Building & Productive Bursts in Open Collaboration

SPEAKER: Thomas Maillart

ABSTRACT. Many social phenomena arise from human interactions, such as imitation and cooperation. Among them, collective action involves groups of individuals animated by the prospect of achieving a common goal. Although the conditions under which successful collective action arises are well-documented [1], mechanisms of interactions and triggering, as well as their long-term implications for the success of collective projects remain unclear. Using version control data of 50 open collaboration projects, we show that activity of contributors exhibit endogenous versus exogenous critical dynamics [2, 3] in their contribution timelines (Figure 1A) [4]. These dynamics of contributions map into self- and multi-excited Hawkes conditional Poisson processes [5, 6], with exogenous input activity and endogenous triggering with long-memory (the memory kernel yields from human task prioritization and economics of time as a non storable resource, and is typically found exponential, stretched exponential or power law [7]). For number of open collaboration projects, we have found that triggering is at or close to criticality, and may involve both individual or mutual excitation [8]. Critical cascades of contributions hence explain how number open collaboration projects remain active over long periods, even though they exhibit overall marginally decreasing inflow of new contributors. Critical cascades also explain why open collaboration projects exhibit super-linear productive bursts, which concentrate the majority of contributions in very short time windows [9]. Such special moments [10] may include setting deadlines for software release, kicking of new sub-projects, or simply convening regular co-located meetings. With some exceptions, these special moments are actively organized for the sake of maintaining or enhancing the spirit of community, for fast-paced colliding of new ideas, to make strategic choices about the project. Hence, while short-lasted – typically a few days, they often play a fundamental role for the long-term continuation and survival of an open collaboration project. A specific study of co-located special moments is carried on for two communities of data scientists (astrophysicists and neuroscientists), for which we have gathered detailed information of their physical meetings and we know that they are geared towards advancing data science projects hosted on an online repository platform (i.e., GitHub). We find that co-located meetings have a long-term positive impact on community building and contributions. Yet, each co-located event has its own impact on the community, as measured by the number of contribution cascades initiated on personal and shared code repositories (resp. ci and cs; see Figure 1C). Co-located events with a clear jump of activity exhibit decays of activity that are best fitted by power laws $\sim t^{-\alpha}$ with $\alpha \approx 0.7 \pm 0.1$ for events c, d and e (both for individual and collective contribution cascades). Additionally, collective cascades (i.e., contributions by 2 or more individuals) follow a power law distribution of size, while individual cascades follow a log-normal distribution (Figure 1B). This last result underlies the importance of co-located events for community building, which in turn foster collaboration, and critical cascades of self-propelled contributions.

Saeed Moghayer

Indifference-attractor bifurcation in discrete-time complex ecological-economic optimal control problems

SPEAKER: *Saeed Moghayer*

ABSTRACT. We study the genesis of indifference thresholds for a class of single- state discrete time optimal control problems, as a system parameter changes. The class under consideration contains a wide range of ecological-economic models, like the discrete time version of the lake pollution models introduced by Maler et al. (2003), which models complex nonlinear responses of (shallow) lakes to the increase of the stock of phosphorus in the water. This model is used here as an illustration example. We consider state-costate — or phase— orbits that are associated to optimal state orbits, making use of the fact that these have to be on the stable manifolds of saddle fixed points of the phase system. In particular, we show that if the phase system goes through a so-called heteroclinic bifurcation scenario, an indifference threshold and a locally optimal steady state are generated in an indifference-attractor bifurcation and we the analyze the consequences for the optimal solutions. In the case of the lake model, the resulting bifurcation diagram summarizes the joint effect of the robustness of the lake and the economic importance of the lake in the form of the optimal policy. The diagram is partitioned into four parameter regions: unique steady state, low pollution, high pollution, and dependent on the initial state. Moreover, we analyze the effect of the change of 'stiffness' or responsiveness of the lake. We find that in the pollution management of strongly responsive ecosystems, it is more likely that the optimal policy is 'green'.

Emmanuel Calderon Espinosa, *Joan Benach* and *Carles Muntaner*

Approaching the Impact of Neoliberal Policies' on Health Equity and Wellbeing from a Complex Systems Perspective: The Case of Mexican Industrial Cities

SPEAKER: *Emmanuel Calderon Espinosa*

ABSTRACT. During the last 35 years Mexico's industrial cities experienced an accelerated transformation of migration and urbanization patterns, environmental deterioration and a growing precarious labor market, among other factors. Many of them have reconfigured their economy by becoming industrial manufacturing centers connected to global production chains. Through critical realism and network theory we develop a theory-informed conceptual framework to guide the mapping of the most important determinants of population health and wellbeing in urban agglomerations in Mexico between 1980 and 2016. Cities are taken as the space of conflict in which historical, political, economic and cultural dimensions converge, and where territorial social pacts materialize, shaping the management of public goods at local level. The conceptual model shows a systemic representation that simultaneously considers social, spatial, temporal elements and the most relevant social actors, grouping them into four categories: a) Factions of capital b) Institutional state c) Civil society and d) Labor force. This synthesis tool aims to achieve a better understanding of the systemic processes behind the implementation of neoliberal policies and how these affects the political, economic, and cultural determinants of health equity and wellbeing and provides some insights in how to organize the complexity involved in studying the health effects. It could therefore constitute a meaningful stimulus to trigger further empirical research and as a basis for the development of future scenarios on health inequalities research inspired by complex-systems approaches.

Javier Borge-Holthoefer, Manuel Mariani, Claudio Tessone and Albert Solé-Ribalta

Re-thinking nested and modular networks in ecological and socio-technical complex systems

SPEAKER: Javier Borge-Holthoefer

ABSTRACT. The identification of macroscale connectivity patterns in complex networks has been central to the development of the field. Besides an interest in the methodological challenges, these patterns matter to the community inasmuch they result from a complex structure-dynamics interactions. It is in this context --network architecture as emergent phenomena-- that nestedness and modularity arise as prominent macrostructural signatures to study. Nestedness was originally developed in ecology, to characterise the spatial distribution of biotas in continental and isolated landscapes, and to describe species-to-species relations. In structural terms, a nested pattern is observed when specialists (nodes with low connectivity) interact with proper nested subsets of those species interacting with generalists (nodes with high connectivity); see Fig.~ \ref{figure1}A (left). A modular network structure (Fig.~\ref{figure1}A (middle)) implies the existence of well-connected subgroups, which can be identified given the right heuristics to do so.

Nestedness has imposed itself as a landmark feature in mutualistic settings with an emphasis in natural ecosystems, and has also triggered a large amount of research spanning fieldwork, modelling and simulation. Modularity constitutes a sub-area itself in complex networks, with an unmatched number of references regarding algorithms and heuristics, network dynamics, alternative measures, and, of course, the diverse empirical contexts in which it plays a role.

In the last years we have become increasingly aware that nestedness is not exclusive to plant-animal interaction assemblages. Rather, it appears often in systems where positive interactions play a certain role. Perhaps this fact, and the remarkable evidence that modularity is observed in many systems, has spurred research on the (possible) co-existence of both features. Here we will focus on particular settings in which modularity and nestedness are observed together, and discuss some possible explanations and methodological problems. Then, we will present a brand new formulation of the problem where nestedness and modularity can coexist in the form of nested blocks within the network (NeMo structures: Fig.~ \ref{figure1}A, right). Using a proper formulation of the problem, we first exploit synthetic networks as a testbed for our approach. Once validated, we proceed to analyse hundreds of real networks to evidence by example that this type of structures exist in both uni- and bi-partite networks (Fig.~\ref{figure1}B,C), and discuss possible directions from here.

Adilson Motter

Advantage of Diversity in Network Dynamics: Convergence Because of (not Despite) Differences

SPEAKER: Adilson Motter

ABSTRACT. It is widely held that individual entities are more likely to exhibit the same or similar behavior if they are equal to each other--imagine animals using the same gait, lasers pulsing together, birds singing the same notes, and agents reaching consensus. In this presentation, I will show that this assumption is in fact false in networks of interacting entities. This surprising observation is rooted in a new network phenomenon we term “asymmetry-induced symmetry” (AIS), in which the state of the system can be symmetric only when the system itself is not. Using spontaneous synchronization as a model process, I will discuss scenarios where the state in which all nodes exhibit identical dynamics (a state of maximum symmetry) can only be realized when the nodes themselves are not identical. AIS can be seen as the converse of the well-studied phenomenon of symmetry breaking, where the state has less symmetry than the system. AIS has far-reaching implications for processes that involve converging to uniform states; in particular, it offers a mechanism for yet-to-be-explained convergent forms of pattern formation, in which an asymmetric structure develops into a symmetric one. AIS also has implications for consensus dynamics, where it gives rise to scenarios in which interacting agents only reach consensus when they are sufficiently different from each other.

Peter Fennell and James Gleeson

Multistate dynamical processes on networks: Theoretical frameworks and epidemic thresholds

SPEAKER: Peter Fennell

ABSTRACT. Multistate dynamical processes on networks – where nodes can be in one of a finite number of states – are widely used as modelling frameworks in the epidemiological, physical and socio-technical sciences. In epidemiological settings, for example, complex multistate models are employed to forecast the evolution of real diseases, offering more realistic and accurate predictive tools than the simpler Susceptible-Infected-Susceptible and Susceptible-Infected-Recovered models.

In this work, we present a general formulation of Markovian multistate dynamical processes on complex networks that is representative of a broad range of models in the complex systems domain. In this formalism, the dynamics are specified by probabilistic rate functions Fm(a → b), indicating the rate at which a node in state a changes to state b depending on the states of its neighbours, encoded in the vector m. With this formalism, we construct theoretical frameworks of varying complexity and accuracy. Such frameworks allow for the analysis of multistate dynamics processes on networks, and the effect that the degree distribution of the network has on the evolution and equilibrium behaviour of the dynamics. We illustrate the power of our approach with novel analysis of a recently proposed model of co-operative diseases, gaining a deep understanding of the stability of the disease-free and endemic states of the model and the effect of network structure on these equilibrium states. Finally, we present detailed analysis of the special case of linear rate functions; such rate functions correspond to independent pairwise interactions, covering a broad range of epidemiological and spreading models. Employing our developed theoretical framework, we derive an expression for the position of the epidemic threshold of the dynamics, a manifold in parameter space that separates a disease-free equilibrium state from one which is endemic. This remarkable result is highly powerful because of its generality for arbitrary multistate linear rate functions, and is a major step in understanding the effects of highly complex spreading mechanisms on viral outbreaks.

Anna Sapienza, Laetitia Gauvin and Ciro Cattuto

A tensor decomposition-based method to estimate the spreading process outcomes for temporal networks with incomplete information

SPEAKER: Laetitia Gauvin

ABSTRACT. Dealing with missing data in networks is a long-standing problem with important applications. For temporal networks, where missing data result in missing links, a major challenge is to extract information relevant to recover a faithful outcome of spreading processes occurring on them. To this aim, we leverage the fact that temporal networks (here, human proximity networks) can be naturally represented as 3-dimensional tensors whose slices correspond to the adjacency matrices of the network at a given time. This enables us to devise an approach based on tensor decomposition (NTF) – a dimensionality reduction technique from multi-linear algebra – to recover some properties, related to the nodes, whose some of the links are missing, and exploit these properties to build a surrogate of the network with the aim of reproducing a faithful spreading dynamics. The key idea is to learn a low-dimensional representation of the partial network and adapt it to take into account temporal and structural heterogeneity properties we know to be crucial for spreading processes occurring on networks. To test our approach we take into account three human proximity networks of different sizes and measured in different contexts. We simulate a loss of data for 10, 20 and 40% of the network nodes by removing their links for half the time span of the dataset taken continuously. Using our method on the resulting partial networks, we build a surrogate version for each of the networks. We compare the outcome of a Susceptible-Infected-Recovered (SIR) process on the original networks (non altered by a loss of data) and on the surrogate networks. We observe that the epidemic sizes obtained with the surrogate networks are in good agreement with those measured on the original networks. Finally, we propose a natural extension of our framework, to take into account additional data sources, when available. Here, we have access to the approximate location of individuals of the networks in time. The extension relies on joint tensor factorization (JNTF), that decomposes several tensors at a time. The rationale behind is that the information of the tensor representing node locations in time can help to recover their missing information in the node proximity tensor. This approach enables to face drastic cases where either all nodes miss some links or some nodes completely lose their links in the proximity network. We consider the two following scenarios to evaluate the method: a) 100% of nodes loses 50% of their links at random b) 50% of nodes loses all their links. We apply our method based on the joint factorization the partial proximity network and the node location network, to build a surrogate version of the proximity network. We simulate SIR processes on the partial, original and surrogate networks. The epidemics sizes measured on the surrogate network build through the JNTF method provide a good estimation with respect to the original case. To summarize, we propose a framework, based on tensor decomposition, to face missing data in temporal networks to estimate the outcome of spreading processes in various context.

Jana Huisman and Olivia Woolley

Structural instabilities in network driven complex contagion

SPEAKER: Olivia Woolley

ABSTRACT. When will an idea or behavior successfully spread through a population? Many different theoretical models of ``complex contagion'' processes have been proposed and studied to answer this question. Similarly, an ever increasing amount of network data is available to empirically study and to predict the outcome of such processes. However, although we understand how some of the global and local characteristics of network structure affect the global outcome of these spreading processes, little is understood about the general stability of even the simplest complex contagion models under small perturbations to network structure. Here we study perturbations to a network that leave the global and local structure statistically unchanged but have large effects on global spread. Specifically, we consider contagion according to a fractional threshold, which is one of the best-understood complex contagion mechanisms.

Community structure and modularity have been shown to play an important role in shaping the global outcome of contagion. Under fractional threshold contagion, communities foster spread originating within the community through reinforcement effects, but also obstruct the spread that originates outside. Prior work finds that there is a window of intermediate inter-modular connectivity that sustains optimal global spread [1]. These findings consider randomly structured inter-modular connectivity. However, real-world networks commonly exhibit a hierarchical structure where high-degree (central) nodes are more likely to provide inter-modular connectivity than low degree (peripheral) nodes. Interestingly, we find that adding a very small number of inter-modular connections between peripheral nodes in different modules quickly enables global spreading. On the other hand, a much larger number of connections between central nodes in different communities are needed to generate global spread. We derive general conditions for the structure of modules and inter-modular connectivity that exhibit this strong sensitivity to the degree-degree structure of inter-modular links.

Social networks typically have marked community structure, degree heterogeneity and stratification and connections between peripheral individuals in different communities are rare. In other words, they frequently exhibit the structural characteristics that sustain the structural instability we have identified. Thus, our findings have many important implications for spread in social systems. For example, consider the case where we want to stimulate the spread of a behavior. If links can be added, the most efficient way to ensure global spread is to add connectivity between peripheral nodes in different modules. Interestingly, this implies peripheral nodes can have a huge global impact where central nodes cannot. Another interesting application concerns evaluating the predictive power of contagion models simulated on measured networks. When the conditions for structural instability are satisfied, predictions made are highly sensitive to small measurement errors perturbing the network structure. This has a clear consequence on the limits of predictability of complex contagion in many real world systems, especially given that in many systems peripheral nodes are the hardest to observe, and links between peripheral nodes even harder.

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Joan T. Matamalas, *Alex Arenas* and *Sergio Gómez*

Epidemic conductance in complex networks

SPEAKER: *Joan T. Matamalas*

ABSTRACT. The problem of modeling the spread of a disease among individuals has been studied in deep over many years. The development of compartmental models, that divide the individuals among a set of possible states, has given rise to a new collection of technics that enables, for instance, the analysis of the epidemic threshold or the study of the impact of a prophylactic campaign. After the initial epidemiological studies on well-mixed populations, it has been recognized that complex networks constitute a better description for the substrate on top of which the epidemic spreading takes place. Among the many available epidemic models, the Susceptible-Infected-Susceptible (SIS) has become a cornerstone in the study of epidemic spreading in complex networks. From the initial analysis of SIS using heterogeneous mean field approximations to determine the epidemic threshold [1], to the recent ones in which the probability of being infected is determined at the level of node [2], there have been uncountable advances on this topic [3].

In this work we analyze the SIS model in complex networks at the level of edges. In particular, we propose the definition of the epidemic conductance as the probability that a link is in condition of spreading the epidemics. We show how to obtain equations for the conductance of all the links, which can be solved by iteration in a similar way to the Microscopic Markov Chain Approach (MMCA) in [2]. These equations provide a more accurate description of the global epidemic incidence and the epidemic threshold than previous methodologies.

The relevance of the epidemic conductance is proved in a set of experiments, in which we show that removing the edges of maximum conductance leads to a much faster way of leaving the endemic state than by taking out the most infected nodes. This shows the importance of analyzing epidemics at the level of links, and the need to consider them in any protocol to try to limit the incidence of epidemics.

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Aamena Alshamsi, *Flavio L. Pinheiro* and *César Hidalgo*

When to target hubs? Strategic Diffusion in Complex Networks

SPEAKER: *Aamena Alshamsi*

ABSTRACT. What is the most effective way to spread a behavior on a network? The recent literature on network diffusion has focused mostly on models of simple contagion–where contagion can result from contact with a single “infected” individual–and complex contagion–where contagion requires contact with multiple “infected” sources. While in the case of simple contagion, strategies focused on central nodes are known to be effective, the strategies that are most effective in the case of complex contagion are relatively unknown. Here, we study the strategies that optimize the diffusion of a behavior on a network in the case of complex contagion by comparing algorithms that choose which nodes to target at each step. We find that, contrary to the case of simple contagion where targeting central nodes is an effective strategy, in the case of complex contagion minimizing the total diffusion time requires the use of dynamic strategies that target less connected nodes in the beginning and hubs at a critical intermediate time. That is, the strategic question in the case of complex contagion is when to target hubs. We solve the model analytically for simple network structures and also use numerical simulations to show that these dynamic strategies outperform simpler strategies that could be hypothesized to be effective, like always choosing the node with the highest probability of infection. These findings shed light on the dynamic strategies that optimize network diffusion in the case of complex contagion.

Jorge Jose

Precision and Computational Psychiatry in Neurodevelopment

SPEAKER: *Jorge Jose*

ABSTRACT. Despite great advances in neuroscience and genetic studies, our understanding of the biological sources of psychiatric disorders is still quite limited. An important reason for this is not having objective psychiatric clinical tests, in particular in the case of neurodevelopment, involving the structural growth and functional maturation of the central nervous system. Humans develop a variety of brain functions through this process such as learning ability, memory, and psychomotor skills. Abnormalities during this process, either due to genetic or environmental factors, can lead to a series of neurodevelopment disorders (NDD), including autism spectrum disorder (ASD), intellectual disability (ID), etc. A crucial challenge facing the field now is the lack of scientific or biological explanations in the current psychiatric diagnostic/classification systems. We have found a quantitative biomarker applicable to neurodevelopment disorders by carefully studying the statistical properties of how people move. No two people move in exactly the same way. It turns out that people that suffer from cognitive deficiencies have noticeable heterogeneous movement impairments when compared with typical development (TD). Recent advances of high-resolution wearable electromagnetic sensing devices enables continuous motion recordings at milliseconds time scales, away from detection of the naked eye. Using this technology, we have extracted information leading to unraveling quantitative neurodevelopment biomarkers. In this talk I will first set up the general problem in particular for the non-specialists. Then I'll discuss, briefly our neurodevelopment results, that falls into the emerging field of Precision Quantitative Psychiatry. By studying the statistical properties of hand movement's we discovered a new data-type which allowed us to catalog the continuity property of the body dynamics. Using correlation functions, nearest neighbor speed-spike statistics plus other statistical metrics, typical of studies of complex systems, we were able to quantitatively characterize each person cognitive abilities. We applied our metrics to individuals with ASD. Our quantitative statistical analysis led to a parameter phase space that provides an automatic ASD severity classification comparing it, a posteriori, with over 90% precision, to their diagnosed verbal speaking abilities. We also found, unexpectedly, many similarities in the parent's biomarkers with those of their ASD diagnosed progeny.

Leonardo Zapata-Fonseca, Dobromir Dotov, Ruben Fossion, Tom Froese, Leonhard Schilbach and Bert Timmermans

Complexity matching in minimal embodied interaction between patients with High Functioning Autism and controls

SPEAKER: Leonardo Zapata-Fonseca

ABSTRACT. Social interaction is impaired in High-Functioning Autism (HFA). This impairment is less pronounced in simplified technologically mediated circumstances such as when interacting with humanoid robots. This study aims to investigate quantitatively the real-time dyadic interaction between HFA patients and healthy participants in a minimal virtual reality environment known as the perceptual crossing experiment (PCE). An independent control group of healthy participants was also included. In the PCE pairs of blindfolded participants were embodied as avatars in a one-dimensional virtual space and moved their avatars with a mouse computer. A tactile vibration stimulus was delivered when the avatar crossed another object in the space. Each participant could encounter three objects: a static decoy, the avatar of her partner, and a shadow of her partner's avatar. Hence, the only event when both partners received feedback simultaneously was when they crossed each other. The task was to mark these encounters by clicking but not those with the decoy or partner's shadow. Here we treated each participant's movement in the virtual space as a point process by defining as salient events the zero-crossings in acceleration. An index of multi-scale similarity between partners was computed by applying complexity matching (CM), which compares two power-law distributions and represents the maximization of information exchange between complex networks. CM can be obtained for point-processes by comparing Allan Factor (AF) distributions, where AF quantifies the variation of event occurrences across different time scales. Using surrogate analysis where the observed CM was compared to the CM of shuffled partners we found evidence for multi-scale coordination in both HFA-controls and controls-controls pairs. Moreover, CM was not significantly different between these two groups. There are two ways of explaining our findings. On the one hand, machine-mediated interactions might help in reducing the cognitive, sensory, and affective load coming from other dimensions in typical social interaction. Thus, autistic people might engage in the task very similar to healthy participants, consistent with previous research. On the other hand, the constraints of the virtual environment could enhance repetitive movement patterns, a well-documented autistic trait, making it easier for the healthy participants to adapt their trajectories to the patients, and ultimately achieve complex coordination without relying on social co-regulation of movement. Importantly, it could be that in both groups the healthy participants are doing all the adaptation and coordination. However, this is to be determined on the basis of extra analysis. This research highlights the multi-scale and distributed character of dyadic interaction, which marks it as a complex system. Additionally, it is consistent with recent investigations on CM and dyadic interactions. Remarkably, the PCE, although minimal, has proven to be an experimental setup capable of eliciting meaningful interactions and forms of alignment found in real-life social interactions. Furthermore, this paradigm allows researchers to systematically and quantitatively assess dyadic interaction in real-time, a feature which is crucial for understanding and studying online social interaction. Therefore, this work supports the implementation of human-computer interfaces and real-time paradigms in the context of psychopathologies when regarded as social interaction disorders.

Gabriel Ramos-Fernandez, Denis Boyer, Andrew J. King, Filippo Aureli, Julia Lehmann and Thore Bergman

Using information theory to measure social flexibility and its consequences for social cognition

SPEAKER: Gabriel Ramos-Fernandez

ABSTRACT. Human and nonhuman animals often show flexible grouping patterns, in which temporary aggregations or subgroups come together and split, changing their size and composition in short time scales. While this flexibility confers clear advantages in exploring and exploiting heterogenous environments, it also increases the uncertainty faced by group members, who have to deal with social relationships using partial information in a frequently changing social environment. Here we develop and validate a method to measure the flexibility in composition of these subgroups using Shannon's entropy, which captures the degree of predictability of the composition of a given subgroup over time. We formulate null expectations of entropy that consider subgroup size variation and sample size, against which the observed entropy can be compared. Using the theory of set partitioning, we also develop a method to estimate the number of subgroups that the group is likely to be divided into, based on the composition and size of the observed subgroups. We use these methods to analyze the composition of spider monkey, chimpanzee and gelada baboon subgroups. The three species are known for their high variation in subgroup size, but only the first two show highly flexible subgroup compositions, whereas geladas split their groups along more predictable lines. Our results serve to quantify the differences in social flexibility between these three species, which are consistent with the differences based on qualitative characterizations of their grouping dynamics. When measured at an individual level and for different interactions, our results can also be interpreted as the degree of social uncertainty faced by individual members of a given group. We discuss the implications of these results for the evolution of social complexity and cognition.

Sabine Pfleger and Astrid Ruiz Surget

May the Force be with You An enactive approach to conceptual indeterminacy situations: the case of Mexican Spanish ¡Échale ganas!

SPEAKER: Sabine Pfleger

ABSTRACT. Many of the situations we deal with on a daily basis do not allow for an accurate prediction of their outcome and pose a potential loss of control of action, which in turn may lead to undesirable negative emotional states for the agents. And yet, we have learned to live with a constant conceptual indeterminacy, where previous experiential as well as rational knowledge are not enough to simulate or run symbolically an event and its possible implications. Situations with high degrees of uncertainty, such as an upcoming exam, a meeting with the boss, or a work presentation, to name a few, are perceived as an antagonistic force that impinges decisively on the emotional state of an agent and potentially inhibits its range of action. In social interaction, this antagonistic force may be minimized or controlled with the help of a second agent boosting a more assertive behavior and actions. In this talk we will weave together three different cognitive processes; forces, metaphoric thinking, and conceptual integration that evidence the complex interactional force dynamics that is present in linguistic instantiations such as the Mexican Spanish ¡Échale ganas!. The expression and its underlying enactive metaphoric structure help to promote the needed shared cognition between agents enabling them to strengthen agonist power, while stabilizing negative emotions when facing a conceptually indeterminate event. Our analysis supports the idea that an important part of our interaction depends on joining conceptual forces via languaging to minimize antagonistic actional forces, especially when the environment fails to provide us with all the information needed for a thoughtful analysis of the outcome of an uncertain event.

Jesus Espinal-Enriquez, Cristobal Fresno, Guillermo de Anda-Jáuregui and Enrique Hernandez-Lemus

Loss of inter-chromosomal regulation in breast cancer

SPEAKER: Jesus Espinal-Enriquez

ABSTRACT. Breast cancer is a complex heterogeneous disease. Common hallmark features of cancer can be found. Their origin may be traced back to their intricate relationships governing regulatory programs during the development of this disease. To unveil distinctive features of the transcriptional regulation program in breast cancer, a pipeline for RNA-seq analysis in 780 breast cancer and 101 healthy breast samples, at gene expression and network level, was implemented. Inter-chromosomal relationships between genes resulted strikingly scarce in a cancer network, in comparison to its healthy counterpart. We suggest that inter-chromosomal regulation loss may be a novel feature in breast cancer. Additional evidence was obtained by independent validation in microarray and Hi-C data as well as supplementary computational analyses. Functional analysis showed upregulation in processes related to cell cycle and division; while migration, adhesion and cell-to-cell communication, were downregulated. Both the BRCA1 DNA repairing signalling and the Estrogen-mediated G1/S phase entry pathways were found upregulated. In addition, a synergistic underexpression of the gamma-protocadherin complex, located at Chr5q31 is also shown. This region has previously been reported to be hypermethylated in breast cancer. These findings altogether provide further evidence for the central role of transcriptional regulatory programs in shaping malignant phenotypes.

Rok Cestnik and Michael Rosenblum

Reconstructing networks of pulse-coupled oscillators from non-invasive observations

SPEAKER: Rok Cestnik

ABSTRACT. Reconstruction of a network structure from observations is an important problem relevant for many different areas such as neuroscience, physiology, climatology, genetics, ecology, etc. A group of established reconstruction techniques relies on analysis of the system response to a specially designed perturbation, i.e., on invasive measurements. However, often invasive measurement is not an option, e.g., in problems related to climatology, physiological studies, and medical diagnosis. In such cases one is restricted to analysis of observations of the free-running system.

In this work we develop a method of reconstruction relying only on observation of the free-running system. We address the case when the signals are spiky, namely, that the measurements between the spiking events are dominated by noise and only determination of the times of spikes is reliable. Hence, the data we analyze are spike trains and estimation of time-continuous phase is not feasible.

The reconstruction routine is of iterative nature. First, since we do not have any knowledge of the system yet, we evaluate the phase response curve (PRC) in the mean-field approximation, i.e., all-to-all equal coupling. Next, using the PRC estimate, we obtain an approximation of the network, which is then in turn used to obtain a better approximation of the PRC, and so on, continuing this procedure until the error of the reconstruction falls bellow a chosen value. Assuming that the outputs of all nodes are known and that the coupling between the elements is sufficiently weak to justify the phase dynamics description, we recover the connectivity of the network and properties of all its nodes. We perform thorough statistical analysis to quantify the robustness of our method.

Finally, we test our method on a network of 20 Morris-Lecar oscillators, to see how it behaves for a realistic neuronal model.

Himanshu Kaul, Chris Brightling and Rod Smallwood

Clinically-relevant computational model to design and optimise interventions to treat asthma.

SPEAKER: Himanshu Kaul

ABSTRACT. Background: The mechanisms underpinning the pathogenesis of asthma remain poorly understood. Given the complexity and heterogeneity observed at the organ level, characterising asthma requires computational approaches that offer tightly controlled variables and boundary conditions. Such models can offer mechanistic insights into drug pharmacodynamics and guide drug optimisation.
Objective: We aimed to develop a clinically-relevant computational model of airway remodelling capable of predicting the impact of therapeutic interventions targeting asthma at patient level. We hypothesised that capturing interactions between the epithelial, mesenchymal, and inflammatory elements within airways will capture airway remodelling, with the crucial implication that abnormal variations in model parameters will result in the hallmarks asthma.
Methods: The Flexible Large-scale Agent-based Modelling Environment (FLAME) was employed to model the airway. Cylindrical model of a Strahler Order 3 airway was developed, and featured epithelial (columnar and basal), mesenchymal (fibroblasts and muscle), and inflammatory (mast and eosinophil) agents. Rules captured interactions between these cells. Parametric analyses were conducted by altering model variables independently and collectively. Model validation was achieved by comparing model output – epithelial integrity, eosinophils/mm2 sub-mucosa, and muscle/mm2 wall area – against clinical data. The following markers reflected the hallmarks of asthma: <50% intact epithelium, >10 eosinophils, and >10% muscle mass. Significance was assessed using two-way ANOVA and Bonferroni multiple comparison. Each simulation was run equivalent to 6 months of physical time.
Results: Of the 25 boundary conditions studied only 4 captured all three hallmarks of asthma. Of these 4, the most parsimonious set of boundary conditions was selected as the virtual patient (42.8% epithelium; 22 eosinophils/mm2 sub-mucosa; and 26.5% muscle mass). The virtual patient was intervened with two therapeutic strategies: (i) eosinophil apoptosis, and (ii) reduced recruitment of inflammatory cells. The pro-apoptosis intervention reduced eosinophil activity by 54.1%, which agreed with the impact of mepolizumab (55% reduction in eosinophil activity). The anti-recruitment intervention reduced eosinophil activity by 81.4%, which agreed with the reduction in eosinophil activity following intervention with fevipiprant (79.6%). When employed to predict loss in muscle mass, the pro-apoptosis simulation showed a maximum relative reduction of ~35% for the highest ‘dose’. For the same ‘dose’ the anti-recruitment model reported a muscle loss of ~70%.
Conclusions: The model accurately predicted the impact of mepolizumab and fevipiprant on airway eosinophilia, and suggested that the intervention with a therapeutic that reduces eosinophil recruitment (over inducing eosinophil apoptosis) will be more successful in reducing muscle mass. This demonstrates the clinical and design significance of the model, and suggests the model as a useful tool to guiding drug development in respiratory medicine.
This study was funded by AirPROM.

Guillermo de Anda Jáuregui, Kai Guo, Brett McGregor and Junguk Hur

Changes in pathway connectivity induced by disease and therapeutic treatment: the case of diabetic neuropathy and pioglitazone

SPEAKER: Guillermo de Anda Jáuregui

ABSTRACT. Most biological functions are the result of coordinated interactions in groups of molecules, known as pathways. Typically, pathways are not isolated and can interact with other pathways through shared molecules, a phenomenon known as pathway crosstalk. Altered physiological states such as disease can lead to perturbations in these pathways. These perturbations not only affect the pathways themselves, but also the communication existing between them, which may be associated with the pathological features observed in disease. Therapeutic agents may correct this pathway deregulation, but at the same time they can also affect untargeted pathways, and cause further changes in the connectivity of pathways. We examined how an anti-diabetic agent pioglitazone alters the connectivity among functional pathways observed in a murine model of type 2 diabetes mellitus (T2DM). Pioglitazone, a peroxisome proliferator-activated receptor gamma (PPARG) agonist, is an insulin-sensitizing agent used for treating T2DM with various effects such as lipid/glucose lowering and anti-inflammation. We used RNA-Seq data in sciatic nerve tissues from our previous study, which included diabetic (db/db) either with or without pioglitazone treatment, and non-diabetic (db/+) mice as control. Normalized expression counts were used to quantify transcriptional deregulation at the pathway level in diabetic mice, either in the presence or absence of pioglitazone treatment, using a cutoff-free enrichment algorithm. Alterations in communication between pathways were evaluated through the enrichment analysis of the crosstalking sections of deregulated pathways, which was used to construct pathway perturbation networks. We identified significant perturbations in 91 pathways from the Reactome database in diabetic mice without pharmacological treatment. These pathways formed a network with 229 connections, which included a major subnetwork consisting of 61 pathways that are centered on neuronal system and transmission across chemical synapses, GABA and rhodopsin-like receptors, GPCR signaling, trans-membrane transport and ion channels. The pioglitazone treatment induced perturbations in 107 pathways, forming a network with 258 connections. Notably, a pathway associated to lipid and lipoprotein metabolism gained a higher degree-centrality in this pioglitazone-treated network, and pathways related to hemostasis and platelet activation emerged as “bridges” between neurological, signaling, developmental and metabolic pathways. In this work, we explored how pioglitazone modulates the communications between significant functional pathways altered in the context of diabetic neuropathy and induces rewirings that may indicate the importance of lipid metabolism and hemostasis pathways in the therapeutic action of pioglitazone in diabetic neuropathy.

Ana Leonor Rivera, Bruno Estañol, Juan Claudio Toledo-Roy, Ruben Fossion and Alejandro Frank

Blood pressure and heart rate variability: in search of early warnings of diabetes mellitus.

SPEAKER: Ana Leonor Rivera

ABSTRACT. The autonomic nervous system modulates the cardiac cycle through central (e.g. vasomotor and respiratory centers) and peripheral (e.g. arterial pressure and respiratory movements) oscillators. Parasympathetic modulation decreases the heart rate and cardiac contractility, whereas activity of the sympathetic branch opposes these effects and regulates peripheral vasoconstriction [1-4]. Autonomic nervous system has been found to break down under pathologic conditions like Diabetes Mellitus (DM) type II [5-9]. Thus, the correlation between blood pressure and heart rate can be used evaluate vagal and sympathetic activity, providing a non-invasive method for understanding autonomic control. An effective way to modulate blood pressure and heart rate is breathing rhythmically at 0.1 Hz. It is known that for control subjects, the respiratory resonant frequency of 0.1 Hz can induce periodic modulations in the cardiac rhythm with a frequency that depends on each person around 0.1 Hz [9]. Pathological conditions like DM breaks such modulation [8]. Our objective is to evaluate the vagal and sympathetic activity damage on diabetic patients using non-invasive measurements. For that, in this work, we compare for control subjects and DM patients, the correlations between systolic blood pressure (SBP) and interbeat intervals (IBI) records simultaneously taken by a portapress® [10] under rhythmic breathing at 1 Hz during 5 minutes. We found that the moments of the SBP and IBI fluctuations are statistically different between control and DM, thus it can be used as early-warnings auxiliary for diagnoses [7]. Moreover, there is a loss of the respiratory modulation of the heart rate as diabetes evolves [8].

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Francisco Reyes-Mora, Elisa Domínguez-Hüttinger, Elena Alvarez-Buylla, Juan Carlos Martínez-García and Mathieu Hautefeuille

Modelling the complex regulatory interplay between Epithelial-Mesenchymal Transitions and the Microenvironment and its Disegulation in Health and Disease

SPEAKER: Francisco Reyes-Mora

ABSTRACT. Epithelium to mesenchymal transition (EMT), is complex phenomenon of cellular transdifferentiation through which an epithelial cell looses its characteristic phenotypic epithelial markers and becomes a mesenchymal cell which has the an ability to invade other tissues and which is resistant to chemotherapy. Under homeostatic conditions, EMT participates in wound healing, development and organogenesis. However EMT is also involved in the characteristic tissue remodelling of pathological chronic degenerative processes such as fibrosis and carcinomas, accounting for 51% of worldwide deaths. It remains to be investigated how EMT-driven tissue remodelling, needed for the maintainance of tissue homeostasis, becomes aberrant and a driving force of pathologies such as cancer and fibrosis. The EMT is controlled by the complex interactions between Transcription Factors, operating within individual cells in the tissue, and changes in the surrounding micro-environment, given by the composition of the extracellular matrix (ECM, which determines the stiffness of the tissue), and the levels of pro-inflammatory cytokines such as TGFb. In turn, the mesenchymal cells produce ECM components and cytokines, forming a positive feedback loop between the phenotypes of the cells and the properties of the surrounding tissue. While in equilibrium this complex feedback control structure preserves homoeostasis, we hypothesized that when the system is perturbed by genetic or environmental risk factors known to predispose to fibrotic or oncogenic conditions, the equilibrium between positive and negative feedback loops is impaired, which can lead to the onset and progression of pathology. Here, we use a systems biology approach in which we represent this complex multi-scale feedback control structure with a mathematical model. Using control theoretical approaches, we analyse this model to identify the different perturbations that can drive aberrant tissue remodelling processes. With this analysis, we were able to identify the different risk factor combinations that drive the transition from a homoeostatic to pathological tissue repair process in hepatocytes. Model simulations and analysis of the proposed core gene regulatory network attains only three steady–states, corresponding to the epithelial, mesenchymal and an intermediate senescent phenotypes observed during the EMT. We could also quantitatively characterise the different microenvironmental signals, in terms of the minimal input amplitudes and frequencies required to break the stability of the system and, forcing the transition from an epithelial to a mesenchymal state. Simulations of our multi-scale model show that an increased strength of in the positive feedback loop between the phenotypic decision-taking and the microenvironment cues can lead to an abrupt transition from a homeostatic to a pathological tissue with an over-accumulation of mesenchymal cells. In conclusion our analysis demonstrates how a system biology approach for the identification of underlying mechanisms in the onset and progression of complex diseases.

Elisa Omodei

Computational support for humanitarian response

SPEAKER: Elisa Omodei

ABSTRACT. In recent years, the availability of detailed data on human behavior has lead to great advances in the understanding and modeling of phenomena such as natural disasters and epidemic outbreaks, which constantly affect the lives of the most vulnerable. At UNICEF Office of Innovation we are collecting, combining and analyzing data from private sector and open sources to generate insights so that UNICEF country offices and other stakeholders can take better informed decisions to respond to the needs of children worldwide.

Sergio Arregui, Joaquín Sanz, Dessislava Marinova, María José Iglesias, Sofía Samper, Carlos Martín and Yamir Moreno

A data-driven model for the assessment of age-dependent patterns of Tuberculosis burden and impact evaluation of novel vaccines.

SPEAKER: Sergio Arregui

ABSTRACT. The control of Tuberculosis (TB) is one of the largest endeavors undertaken by public health authorities. Recently, the development of global strategies for diagnosis and treatment optimization have led to TB burden decay worldwide to the point that the scientific community has dreamed with its eradication by 2035. Nonetheless, such goal is yet far away, and TB still constitutes a major Public Health problem, provoking 1.8 million deaths in 2015. Among all possible novel epidemiological interventions against TB, improved preventive vaccines hold the promise of offering substantial reductions of TB burden worldwide. Accordingly, several vaccine candidates are currently under development, each of which, depending on their immunogenic properties, might show differences in protection when applied to different age groups. In this context it would be required to develop a model for TB spreading capable of successfully describing the different age-dependent processes that affect the transmission and evolution of the disease. We present a TB epidemiological model which, capitalizing on publicly available data from different sources (World Health Organization (WHO), United Nations (UN) Population Division and published studies on contact-patterns surveys at an international scale), formalizes a data-driven description of most relevant coupling mechanisms between populations' age structure and TB dynamics. Our results shows that the global demographic shift projected by the UN for the next decades in certain regions is to be accompanied by a shift in the age-distribution of TB burden in some of the regions most affected by the disease. We show that for Africa and the East Mediterranean this could lead to revert the projected global decline of TB unless novel epidemiological measures are deployed. This phenomenon appears mainly as a consequence of a large increase of the infection prevalence in the eldest strata of the population. Also, a proper calibration of disease burden distribution across age groups and the incorporation of heterogeneous mixing patterns, yield to significantly different forecasts with respect to the state-of-the-art modelling framework. Regarding the comparison of different vaccination strategies, an adolescent-focused global immunization campaign appears to be more impactful than newborn vaccination in the short term. We demonstrated that TB indicators and vaccination strategies remarkably depend on how the disease dynamics is coupled to the demographic structure of the population. Capitalizing on a data-driven approach, we identified substantial biases in epidemiological forecasts that are rooted on an inadequate description of age-dependent mechanisms, among others. Our findings provide fundamental insights if novel age-focused epidemiological interventions, such as preventive vaccines, are to be considered and established.

Louis Macgregor, Peter Vickerman, Natasha Martin, Christinah Mukandavire, Ford Hickson and Peter Weatherburn

Effect of risk compensation on the impact of PrEP for HIV and HCV transmission in MSM

SPEAKER: Louis Macgregor

ABSTRACT. Background: Pre-exposure prophylaxis (PrEP) can confer nearly 90% protection against HIV acquisition amongst men who have sex with men (MSM). If scaled up to sufficient coverage, PrEP could significantly reduce HIV transmission within MSM. However, increases in risk amongst MSM on PrEP resulting from lower perceptions of HIV-risk (risk compensation) could negate some of the benefits of PrEP, and may alter the epidemics of other sexually transmitted infections (STIs) among MSM. We explore the impact of PrEP, and possible consequences in terms of reduced condom use amongst PrEP users and changes in sexual mixing patterns on the HIV and hepatitis C virus (HCV) epidemics among MSM.

Methods: We developed a joint MSM HIV/HCV transmission model parameterised with UK behavioural data, which captures biological (heightened HCV infectivity and reduced spontaneous clearance among HIV-positive MSM) and behavioural heterogeneities (preferential sexual mixing by HIV-status, differences in condom use and risk heterogeneity). Consistent with UK guidelines, we classified MSM not using a condom within the past 6 months or having a regular HIV positive partner as eligible for PrEP, which applies to 25.9% of MSM from our data set; the European MSM Internet Survey (EMIS). Of these we assumed 50% would take-up PrEP. We considered two risk compensations: (i) Lower condom use by PrEP users with their partners, from 68% to 13% (reflective of the chance MSM without a HIV diagnosis use a condom with partners during anal intercourse to the chance two HIV diagnosed MSM); (ii) PrEP users no longer preferring to mix with the same HIV status; (iii) both scenarios combined. We ran our model to an endemic HIV prevalence of 5% and HCV prevalence amongst HIV infected MSM of 10%, and then projected the impact of PrEP (efficacy 86%) over 20 years under different scenario assumptions.

Results: Our model projects that PrEP use reduces HIV prevalence from 5.0% to 3.8% over 20 years when no compensatory risk behaviours are modelled, see Figure 1. However, HCV became more concentrated within HIV-positive MSM due to a smaller self-mixing group (rising to 11.9%) and HCV prevalence increased from 1.0% to 1.1% overall in the MSM population. If condom use reduced among PrEP users, the beneficial effect of PrEP was negated by 19.2%, resulting in a HIV prevalence of 4.0% after 20 years and 7% greater prevalence of HCV infections in the MSM population overall. When PrEP users no longer preferred to mix with HIV-negative MSM, the impact of PrEP on HIV prevalence was the same but the overall burden of HCV was reduced by 9% and became less concentrated in HIV positive MSM (prevalence reduced from 10% to 9.7%).

Conclusion: The advent of PrEP may not only shape the future of the HIV epidemic but change the pattern of HCV infection due to resulting behaviour change. Increased screening of HCV among PrEP users is likely warranted.

Mariana Martínez-Sánchez, *Marcia Hiriart* and *Elena Alvarez-Buylla*

The CD4+ T cell regulatory network mediates inflammatory responses during acute hyperinsulinemia: a simulation study

SPEAKER: *Mariana Martínez-Sánchez*

ABSTRACT. Obesity is linked to insulin resistance, high insulin levels, chronic inflammation, and alterations in the behavior of CD4+ T cells. Despite the biomedical importance of this condition, the system-level mechanisms that alter CD4+ T cell differentiation and plasticity are not well understood. We model how hyperinsulinemia alters the dynamics of the CD4+ T regulatory network, and this, in turn, modulates cell differentiation and plasticity. Different polarizing micro-environments are simulated under basal and high levels of insulin to assess impacts on cell-fate attainment and robustness in response to transient perturbations. In the presence of high levels of insulin Th1 and Th17 become more stable to transient perturbations and their basin sizes are augmented, Tr1 cells become less stable or disappear, while TGFβ producing cells remain unaltered. Hence, the model provides a dynamic system-level explanation for the documented apparently paradoxical role of TGFβ in both inflammation and regulation of immune responses and the emergence of the adipose Treg phenotype. Furthermore, our simulations provide novel predictions on the impact of the micro-environment in the coexistence of the different cell types, proposing that in pro-Th1, pro-Th2 and pro-Th17 environments effector and regulatory cells can coexist, but that high levels of insulin severely affect regulatory cells, specially in a pro-Th17 environment. This work provides a system-level formal and dynamic framework to integrate further experimental data in the study of complex inflammatory diseases.

María Barrera, *Marcia Hiriart*, *Carlos Villarreal* and *Germinal Cocho*

A regulatory network perspective of chronic inflammation and diabetes 2

SPEAKER: *Carlos Villarreal*

ABSTRACT. We study a multilevel regulatory network of key inflammatory and metabolic cellular factors such as cytokines, transcription factors, cell receptors, hormones, etc., involved in inflammatory-related diseases. In the case of diabetes 2, we consider two connected networks for hepatocytes and beta pancreatic cells. The model is implemented in terms of continuos Boolean propositions satisfying the axioms of fuzzy logics. The stationary states of the dynamical system are consistent with patterns of health, metabolic syndrome, or diabetes disease. We determine the network nodes that mainly determine the transit between these states and their critical expression levels that induce these transitions.

Sergey Kovalchuk, Tesfamariam Abuhay, Anastasia Funkner, Oleg Metsker, Ekaterina Bolgova and Alexey Yakovlev

Towards a holistic modeling and simulation of complex healthcare process

SPEAKER: Sergey Kovalchuk

ABSTRACT. Healthcare system is characterized by multitude of aspects (health, economics, organization of the process, technological and informational support, social aspects, behavior, etc.), stakeholders (society, government, insurance companies, various kind of institutions and organizations), actor (patients, physicians, nurses, pharmacy, etc.). Moreover, the system is continuously changing, has the explicit and implicit relationship between its elements, as well as significant uncertainty due to limited observations, high variation in scenarios, subjective and local decision making. To investigate the systems on various scales (country, city, hospital, department) a whole system should be considered to manage the uncertainty and reactively modify the model of the system in respect to changing conditions. We propose an approach to holistic modeling of the healthcare process to identify the multi-scale processes in the healthcare systems, where limited or weak structured observations are available. Within our cases, the observations are mainly represented by electronic health records of in- and out-patients of selected hospital(s). In such conditions, we apply a combination of process mining, data mining, and text mining techniques to identify the structure of the process. The model of the complex process can be considered as an extended clinical pathway, describing multi-aspect, multi-scale dynamic complex process. The identified model of the system and complex processes cover the aspects mentioned earlier and serve as a basic framework to incorporate models of various aspects, parts, and sub-processes of the system. This includes models for simulation, data-driven prediction models, surrogate models for unknown aspects of the system, etc. For example, it incorporates agent-based modeling of activity within a hospital, models for prediction of length of stay or disease complications, etc. The model of the complex process can be used in various ways: comparison of different solutions, decision support (for different decision makers), optimization of hospital structure, etc. The key objective of the proposed approach is forming a framework for the model-based assessment of healthcare systems within a context of value-based approach, where the important role is played by resource usage and life quality improvement. We consider a modeling and simulation of complex health care process as a way to assess resources of the system which have high uncertainty, lack of observations, and undefined (or partly defined) structure. Moreover, incorporation of social, psychological, and behavioral aspects of the system enable quantitative assessment of personal life quality. Finally, identified and controllable (within a simulation) diversity of patient flow extends the basic approach with a new level of personalization on different levels of abstraction where even rare cases, events, and conditions are considered and analyzed. To validate the proposed approach, we consider a flow of patients with selected nosologies observed in 2010-2016 in Federal Almazov North-West Medical Research Center (Saint Petersburg, Russia), one of the leading cardiological research centers in Russia, and described with electronic health records. The selected nosology includes in-patients with acute coronary syndrome and planned stent implantation, out-patients with arterial hypertension. The solution considers a group of key hospital departments involved in the treatment as a system which has the issues mentioned earlier.

Caterina La Porta

Fluctuations in collective cell migration

SPEAKER: Caterina La Porta

ABSTRACT. Dense monolayers of living cells display intriguing relaxation dynamics, reminiscent of soft and glassy materials close to the jamming transition, and migrate collectively when space is available, as in wound healing or in cancer invasion. Here we show that collective cell migration occurs in bursts that are similar to those recorded in the propagation of cracks, fluid fronts in porous media and ferromagnetic domain walls. In analogy with these systems, the distribution of activity bursts displays scaling laws that are universal in different cell types and for cells moving on different substrates. The main features of the invasion dynamics are quantitatively captured by a model of interacting active particles moving in a disordered landscape. Our results illustrate that collective motion of living cells is analogous to the corresponding dynamics in driven, but inanimate, systems.

José Fernando Mendes

A unified approach to percolation processes on multiplex networks

SPEAKER: *José Fernando Mendes*

ABSTRACT. Many real complex systems cannot be represented by a single network, but due to multiple sub-systems and types of interactions, must be represented as a multiplex network. This is a set of nodes which exist in several layers, with each layer having its own kind of edges, represented by different colours. An important fundamental structural feature of networks is their resilience to damage, the percolation transition. Generalisation of these concepts to multiplex networks requires careful definition of what we mean by connected clusters. We consider two different definitions. One, a rigorous generalisation of the single-layer definition leads to a strong non-local rule, and results in a dramatic change in the response of the system to damage. The giant component collapses discontinuously in a hybrid transition characterised by avalanches of diverging mean size. We also consider another definition, which imposes weaker conditions on percolation and allows local calculation, and also leads to different sized giant components depending on whether we consider an activation or pruning process. This 'weak' process exhibits both continuous and discontinuous transitions.

Kaj Kolja Kleineberg

Structure and dynamics of multiplex networks: beyond degree correlations

SPEAKER: *Kaj Kolja Kleineberg*

ABSTRACT. The organization of constituent network layers to multiplex networks has recently attracted a lot of attention. Here, we show empirical evidence for the existence of relations between the layers of real multiplex networks that go beyond degree correlations. These relations consist of correlations in hidden metric spaces that underlie the observed topology. We discuss the impact and applications of these relations for trans-layer link prediction, community detection, navigation, game theory, and especially for the robustness of multiplex networks against random failures and targeted attacks. We show that these relations lead to fundamentally new behaviors, which emphasizes the importance to consider organizational principles of multiplex networks beyond degree correlations in future research.

Kaj Kolja Kleineberg, *Lubos Buzna*, *Fragkiskos Papadopoulos*, *Marian Boguna* and *M. Ángeles Serrano*

Geometric correlations mitigate the extreme vulnerability of multiplex networks against targeted attacks

SPEAKER: *Kaj Kolja Kleineberg*

ABSTRACT. We show that real multiplex networks are unexpectedly robust against targeted attacks on high degree nodes, and that hidden interlayer geometric correlations predict this robustness. Without geometric correlations, multiplexes exhibit an abrupt breakdown of mutual connectivity, even with interlayer degree correlations. With geometric correlations, we instead observe a multistep cascading process leading into a continuous transition, which apparently becomes fully continuous in the thermodynamic limit. Our results are important for the design of efficient protection strategies and of robust interacting networks in many domains.

Guilherme Ferraz de Arruda, Francisco A. Rodrigues, Emanuele Cozzo, Tiago P. Peixoto and Yamir Moreno

Disease Localization in Multilayer Networks

SPEAKER: Guilherme Ferraz de Arruda

ABSTRACT. We present a continuous formulation of epidemic spreading on multilayer networks using a tensorial representation, extending the models of monoplex networks to this context. We derive analytical expressions for the epidemic threshold of the susceptible-infected-susceptible (SIS) and susceptible-infected-recovered dynamics, as well as upper and lower bounds for the disease prevalence in the steady state for the SIS scenario. Using the quasistationary state method, we numerically show the existence of disease localization and the emergence of two or more susceptibility peaks, which are characterized analytically and numerically through the inverse participation ratio. At variance with what is observed in single-layer networks, we show that disease localization takes place on the layers and not on the nodes of a given layer. Furthermore, when mapping the critical dynamics to an eigenvalue problem, we observe a characteristic transition in the eigenvalue spectra of the supra-contact tensor as a function of the ratio of two spreading rates: If the rate at which the disease spreads within a layer is comparable to the spreading rate across layers, the individual spectra of each layer merge with the coupling between layers. Finally, we report on an interesting phenomenon, the barrier effect; i.e., for a three-layer configuration, when the layer with the lowest eigenvalue is located at the center of the line, it can effectively act as a barrier to the disease. The formalism introduced here provides a unifying mathematical approach to disease contagion in multiplex systems, opening new possibilities for the study of spreading processes.

Manuel Garcia Herranz

Data Science for the most vulnerable at UNICEF Innovation

SPEAKER: Manuel Garcia Herranz

ABSTRACT. In a world more connected and digitalized than ever, the steadily growing availability of data, along with the advances in fields such as Data Science, Complex Systems, Artificial Intelligence or Computational Sociology have profoundly change whole businesses such as marketing and advertising, revolutionizing related areas such as political campaigns or governance. How can we leverage these advances for the most vulnerable? How can we make sure that the existing data divide does not increase the gaps of inequality? How can we make the invisible visible and heard? How can we push for algorithmic and scientific advances to have equity and the most vulnerable at their core? How can we integrate these advances into the humanitarian and development systems?

Posters

Isaac Vazquez- Ocon, *Luis Arturo Rivas- Tovar*, *Eduardo Martinez-Mendoza* and *Fernando Lambarry-Vilchis*

Energy efficiency in Mexican electrical technology manufacturers

SPEAKER: *Isaac Vazquez- Ocon*

ABSTRACT. The objective of this study is to evaluate energy efficiency in Mexican electrical technology manufacturers. By 2015 78% of the Mexican energy production were based in high impact environmental technics (PROSEDEN, 2016). Energy demand by general population increases every day (SENER, 2015) so its crucial for producers of energy use products to manage the optimization and adoption of new technologies that decreased the general use of energy as a clever strategic plan of action to reduce energy demand and develop a bridge to energy efficiency. The Method used in the study is focused in some of the principal producers of electric technology landed in 10 focus groups. The study also approached two associations of energy use technologies and an observational study of the process methods in one of the principal refrigerating manufacturers facilities. The method is a Heuristic analysis by Atlas Ti program and the research is based on the analysis of complex systems. Theoretical framework is based in the theory of rationalized action model by Fishbein and Ajzen (1980), the Technology Acceptance Model (TAM) by Davis et. al (1989) and Yong- Rivas Model (2008) based on technology acceptance. For the complex system analysis of the information obtained by the research and interviews is presented a casual loop diagram following the methodology proposed by Vensim in 2016. The results as showed in figure 1 its the relation of the lead factors that conduct to energy efficiency in the studied subjects centered in four variables of study, Mexican and international legislation, regulatory body supervision, commercial policies and component integration which derivate in the principal subject of this work which is energy efficiency. The principal findings in this study are based on the knowledge energy efficiency is dependent of the international standards that derivate in official legislation imposed by local government that impulse the creation of more energy efficient products. Another finding is that there are three kind of efficient technologies disruptive saving efficient technologies, mature technologies like electric motors which increases significantly their energy saving rates and optimizing result technologies. It s also very relevant that one of the principal barriers to study energy efficiency is the aversive culture which is present in Mexican institutions which leads to a secrecy culture impregnated in private and governmental organizations. Lack of regulation that leads to problems in which is impossible to take metrics of energy efficiency like refrigeration chambers in matters like importation of products from other countries that export inefficient technologies at low cost affects the environment and local markets.

Marti Medina-Hernandez and *Tom Froese*

Cognitive significance of adaptive self-organization of Bali's ancient rice terraces

SPEAKER: *Marti Medina-Hernandez*

ABSTRACT. In their paper, Lansing et al. (2017) propose an evolutionary game to show that the spatial patterning of Balinese rice terraces is caused by the feedback between farmer's decisions and the ecology of paddies, creating a self-organized process that maximize harvest and explain the emergence of cooperation in a social complex system. Although the authors do not mention it explicitly, their adaptive self-organizing model is based on several cognitive assumptions from Game Theory, such as rational choice, utility maximization intentionality, and common knowledge. We propose to interpret the model's implications as a support of a dynamical-enactive approach which consist in explaining Balinese traditional philosophy of "Tri Hita Karana" and the ideology of Balinese people as the result of environmental constrains and daily activities. With this objective, this presentation will be divided into four parts. First, presenting Lansing et al.'s model essentials, focusing on how the model was constructed and the general implications according to authors. The intention in the second part is to reveal the model's underlying assumptions about cognition and show how, although they are rooted in Game Theory, they are also breaking with it. The following part delves into these divergences from Game Theory to argue that the assumptions can be related to a dynamical-enactive interpretation of cognition that actually supports their claims. Finally, the conclusion remarks some open questions and desirable efforts that can be made in the model to improve our understanding of cognition.

Lansing, J. Stephen; Thurner, Stefan; et. al. (2017) "Adaptive self-organization of Bali's ancient rice terraces", PNAS, Vol. 114, No. 25: 6504-6Lansing, J. Stephen; Thurner, Stefan; et. al. (2017) Adaptive self-organization of Bali's ancient rice terraces, PNAS, Vol. 114, No. 25: 6504-6509.509.

Leonardo Zapata-Fonseca, Dobromir Dotov, Ruben Fossion, Tom Froese, Leonhard Schilbach and Bert Timmermans

Quantifying multi-scale variability during dyadic embodied interaction: High-functioning autism as a case study.

SPEAKER: Leonardo Zapata-Fonseca

ABSTRACT. High-functioning autism (HFA) is one of the so-called social interaction disorders. In consequence, two-person experimental setups are required to objectively and systematically describe interaction's aspects that are impaired in these patients. Using a minimalistic paradigm known as the perceptual crossing experiment (PCE) we studied real-time interaction in combined pairs of healthy participants and HFA individuals, as well as in pairs of healthy participants. This constrained setup aims to isolate the interaction-aspect of reactivity (action contingency). However, it has also been applied for assessing complex forms of alignment found in real-life social interactions. In the PCE, pairs of blindfolded participants are embodied as avatars in a one-dimensional and looped virtual space and move their avatars with a mouse. A tactile vibration stimulus is delivered whenever the avatar crosses another object in the space. Each player can encounter three objects: a static decoy, the avatar of the other player, and a mobile "shadow" that copies the other player's avatar movements at a constant distance and that is not reactive in that the other does not receive any feedback when her "shadow" is encountered. Hence, the only event when both partners receive feedback simultaneously is when they cross each other's avatar. The task is to mark these encounters but not those with the decoy or partner's "shadow" via button press. We adopted a multi-scale time-series perspective and analysed the participants' movement trajectories during a PCE. We applied intra-daily variability (IV), a method that quantifies how much small-scale and large-scale components account for the variance of a time series. Additionally, IV excludes the trend of the signal by computing the derivative (X') of the original time series (X). Accordingly, the players' positions in the virtual space were differentiated yielding their velocity profiles. By applying IV we aimed to assess which scales (P) contribute the most to the variance of the time series: IV (P)=(Var (〖X'〗 _P)/(Var (X')). Clearly, IV is a relative measure that is normalized to the variance of X', so it made possible the comparison within and between samples. This preliminary analysis shows that individuals of the control-control pairs converge towards the same type of dynamics, i.e., their trajectories tend to be less variable between successive sessions and across all scales. In contrast, the controls of the HFA-control pairs remain rather stable without significantly increasing nor decreasing their variability according to sessions, and the variability of autistics' movements increases significantly for larger scales but decreases for smaller scales between successive sessions. Such behavior leads to an increase in the variability gap between participants, reflecting quite different strategies for solving the task not only within the HFA-control pairs but also between the two types of pairs. Our findings support previous work on the quantification of embodied interaction and show a characterization of the movement profiles of HFA patients. Consequently, this research places both the PCE and the multi-scale time-series analysis as suitable tools for objectively studying psychopathologies, with the potential implication of complementing the intrinsic subjectivity of clinical assessments in the realm of neuropsychiatry.

Tania Palacios-Romo and *Gabriel Ramos-Fernandez*

Simple local rules underlie collective foraging movements of spider monkeys.

SPEAKER: *Tania Palacios-Romo*

ABSTRACT. Collective decisions underlie group coordination and are the result of the choices made by each group member. Unlike cohesive animal groups, individuals living in groups with high fission-fusion dynamics can separate temporarily from their group when there is a divergence of interests. It is not clear how collective decisions are made in this kind of groups; collective coordination could emerge from simple rules and localized interactions, in turn giving rise to complex, adaptive properties at the group level. We evaluate the collective foraging decisions made during food-limited conditions (dry seasons of 2015 to 2017) of a group of spider monkeys (Ateles geoffroyi) in a tropical forest in the northeastern Yucatan peninsula, México. We used observations of two different contexts of collective foraging: focal subgroup observations during foraging movements to explore leadership processes and observations of novel food patches to identify knowledgeable and naïve individuals and their use of social information. We assessed how each individual's centrality in the social network, age (adult, subadult, juvenile), sex (female, male) and years living in the area (0-3, 3 to 10, ≥ 10) affected its collective movement initiation rate, as well the proportion of times that as a knowledgeable individual was followed by naïve ones to novel food patches. Additionally we examine the likelihood of being followed in both contexts as a function of these attributes and considering the kinship and the leader-follower association value. Leadership was partially shared between both sexes, residency and age classes, and individuals seemed to follow others that initiate collective movements without any intentional recruitment by the leaders. In both collective contexts, the most central individuals in the social network stood out as leaders (by the number of followers that they had), but adults and subadults initiated foraging collective movements more frequently. These characteristics, modulated by the social relationship between leaders and followers, influenced the decision of each individual to follow certain leaders. In the visiting dynamics to novel food patches, males and more central individuals were more likely to be followed by naïve individuals; neither the age class of the leader nor the social relationship between knowledgeable and naïve individuals was relevant in the individual choices. As in self-organized collective movements of other species with fission-fusion dynamics such as fish schools, crowds of humans and hyaena clans, our results suggest that collective foraging movements in our study group could emerge from simple local rules. Each individual could be following these behavioral rules according to its current ecological knowledge: when it is not possible or necessary to follow a knowledgeable group partner, an individual will decide to follow another according to their social affinity; similarly, when a naïve individual needs to find a new foraging patch, this individual will follow the group members with greater centrality and/or a male. Thus, the flexibility and coordination observed in adaptive, collective behavior such as fission-fusion dynamics could be the outcome of local, simple rules used by individuals to make foraging decisions.

Alfredo Alvarez, *Oscar Figueroa*, *Benjamin Figueroa* and *Jorge De La Torre*

Data mining: Using spatial analysis and socio-economic factors to solve the location problem in non-profit organizations.

SPEAKER: *Alfredo Alvarez*

ABSTRACT. Network localization problems occur when new public or private services in networks are planned. In other studies, methods have been developed to Clinics or hospitals location by means of optimal allocation models using geography and costs information. In this article, data mining techniques were used to determinate socioeconomic factors to characterize the different profiles of patients with ophthalmological conditions that have preferred the option of the 3rd sector over public or private options. The correlation of socioeconomic characteristics with each one of the ophthalmological diseases attended by FDHZ was determined through the Naive Bayes classifier. Data mining techniques and spatial analysis were combined to predict where there will be a greater probability of communities complying with the profiles. In this way a solution is proposed to the location problem for new non-profit headquarters of ophthalmological clinics, as well as to make a characterization of socioeconomic risk factors for three ophthalmological conditions. Data from the FDHZ, which has realized consult and ophthalmological services, through donations from 2006 to 2017, on patients who were operated on three categories (cataracts, pterygium and facovitrectomy) in Orizaba, Veracruz, Mexico, were used in this study.

Rodrigo Migueles, *Gastón Contreras*, *Adriana Vega*, *Enrico Gratton* and *Adán Guerrero*

Towards a model for centriole biogenesis regulation by Polo-like kinase 4 activity and first evidence for its dimerization in live cells

SPEAKER: *Rodrigo Migueles*

ABSTRACT. Cellular processes are often tightly regulated by a complex network of proteins, but in few cases, the core of a complex regulation loop is found within one single species. This is the case of centriole biogenesis regulation by the Polo-like kinase 4 (Plk4). Plk4 is considered the master regulator of centriole biogenesis, its over-expression leads to abnormal centrosome formation, resulting in defective chromosome segregation. Plk4 is subject to a positive-negative regulation loop that operates within Plk4 itself, as two regions of Plk4 are among its own phosphorylation targets. In both cases auto-phosphorylation occurs in a trans mechanism which suggests the formation of Plk4 dimers, one leads to Plk4's activation while the other labels the kinase for degradation. We built a two-compartment self-regulatory model for Plk4's activity based on Ordinary Differential Equations which considers an auto-phosphorylation process based on dimerization (Figure 1). The dimerization event involves association, phosphorylation and dissociation resulting in a monomeric active Plk4 population. The model allows the determination of the major species at the steady-state and predicts specifically the prevalence of particular dimeric species of Plk4, which are predicted to be restricted to the centrosome. Plk4 dimerization has never been reported in live cells. Here, we provide evidence for Plk4 dimerization in live human cell using single molecule confocal spectroscopy techniques. Our experimental findings corroborate the major Plk4 model predictions, namely Plk4 indeed forms dimers in the centrosome of living cells, which is consistent with the proper regulation of its activity at the centrosome.

Jorge Castillo, *Tamas David-Barrett*, *Carlos Rodriguez-Sickert* and *Isabel Behncke Izquierdo*

On the evolution of western modern art: Characterizing a paradigm shift in the production of painting artists.

SPEAKER: *Jorge Castillo*

ABSTRACT. In this paper we characterize a shift paradigm in modern western (european) painting art between the late 1800s and early 1900s, in which avant-garde movements and more abstract concepts developed in the broad of paintings. On one hand, this characterization of transition can be measured in terms of complexity measures in painters community, like number of artist and heterogeneity, focusing on art movements and art specilities by painter. On the other hand, we show that the cultural trait of art production can be proved extracting concepts of pictures via Image Content Analysis and thereafter applying Structural Topic Modeling in these concepts in order to see how the painters developed emergent ideas in their works in this revolutionary epoch. This work shows evidence for that the transitions in sociocultural evolution can be described in terms of complexity measures of systems and showing how certain cultural traits changes according to the change of another critical variables that motivates those changes.

Héctor Gómez-Escobar, Guillermo Ortiz-Garin, Adriana López and Tom Froese

Sensory substitution devices as a mean to assess dynamic systems approaches to cognition

SPEAKER: Héctor Gómez-Escobar

ABSTRACT. The dynamic systems approach to cognition has gained momentum in the last decades, with research from a wide scope of different disciplines [1]. Here we outline the theoretical reasons for conducting three experiments to empirically develop the perspective, currently under development in the 4E Cognition Group of the National Autonomous University of Mexico. We make use of the “Enactive Torch” (ET), a sensory substitution interface equipped to give real time data of human sensorimotor behavior [2]. The ET allows for the collection of time series of human movement and sensation by taking the input of an infrared sensor and converting it into a vibrational motor output delivered to the user’s hand, so that the presence of distal objects can be felt via the skin. That way, the ET makes it possible to control the distal sensory input of the user. The experiments we propose are: 1. Multi-scale time series collection: The long-term effects of sensory substitution devices have been studied as augmented perception, and certain effects on behavior have been identified [3]. Nevertheless, their usage as a gateway to understand multi-scale dynamics of human behavior are yet to be exploited. Although many features of behavior are well captured as a dynamical phenomenon [4], its long-term dynamics at the scale of months, or at multiple scales are still poorly understood. We propose to compare the learning rate obtained in short scale experiments, with the learning rates of iterated trials (separated by a fixed amount of days) of the same experimental setup, after training with the device in between trials. The study of scale-free properties could serve the purpose of finding long-term memory in motor activity associated to changes in perception, and to correlate it with perceptual efficiency in the sensorimotor tasks. 2. Sensorimotor complexity of perception: Although transfer entropy has been employed in robotics [5] and artificial life studies [6], the methods used to collect information in real time from sensors and actuators are rarely possible in humans. Analysis of the minimal complexity features for acquiring a perceptual skill as the emergent effect of sensorimotor contingencies, would need very complex data collection, but can be achieved via the ET. In this experiment, we devise a navigation task in which the participants need to use the ET to avoid obstacles, and apply information theoretical methods to study the emergent complexity of the sensorimotor dynamics needed to exploit distal perception [5,7]. 3. Intentional Behavior as a complex system: According to [8] intentional behavior can be characterized as a complex system. Nevertheless the effect of intentional movement under identical information exposure has not been studied with sensory substitution interfaces. In the third experiment, we expose two subjects to the same sensory array using the ET. One of them can move volitionally and the second follows the movement on passive mode. Then, we measure their success in a perceptual decision task.

Héctor Gómez-Escobar, *Leonardo Zapata-Fonseca* and *Tom Froese*

Time series analysis of human sensorimotor behavior using human-computer interfaces

SPEAKER: *Héctor Gómez-Escobar*

ABSTRACT. Sensorimotor theory conceives perception as an emergent effect of interaction dynamics between brain, body and environment, as opposed to passive computing [1]. This view holds that perception is an active behavior agents do to cope with their environment arising from sensorimotor coupling, and so action and perception in biological and artificial agents can be understood as part of the same dynamic process. Moreover, sensorimotor theory suggests that the quality of perceptual capacity is constituted by sensorimotor contingencies. That is, by lawful relations between motor behavior and associated sensory stimuli. Seeking to understand how to quantify the acquisition of a perceptual skill as the result of mastering a sensorimotor contingency has found widespread interest among cognitive scientists, and has led to information theoretical [2] and dynamic systems accounts of embodiment [3]. This however, implies the collection of data both from sensation and motor behavior, and has sparked interdisciplinary research in robotics [2], artificial life [3], philosophy of cognition [4] and psychology [5,6]. Psychology has followed unconventional research methods, namely, the use of sensory-substitution interfaces to study human behavior. Here we analyze the time series of arm movement and sensory output collected from human-machine interaction experiments to find empirical support for sensorimotor theory. For that purpose, we use a distal-haptic sensory substitution interface named “the Enactive Torch” (ET). The ET transforms the inputs from an infrared sensor into a motor output, such that a participant receives a vibration when pointing the ET to a distant object in proportion to that object’s distance. For our experiment, we devised a modified version of the maze navigation task used in [7]. Blindfolded participants were instructed to follow target sounds located in the corners of a closed space full of obstacles by using two ETs. The subjects were told they would “win” if they managed to pass five intervals without stopping nor touching anything, or the experiment would stop after 40 minutes of navigation. Task success was measured as the number of intervals that were passed without error. To analyze the time series, information theoretical methods were used to compute the transfer entropy between motor and sensory signals within and between both ET devices. This method is used to measure information flows in complex systems [8] and was proposed to quantify embodiment in a previous study using a quadruped robot [2]. We also use a measure complexity [9] in this case for the emergence of movement dynamics when they are modulated by sensory input, and their correlation to task proficiency. Our research highlights the complexity of human behavior as studied through time series, and the use of human-computer interfaces as a means to collect complete sensorimotor data from human subjects that are normally only available from experiments in robotics.

Takaaki Ohnishi, *Takayuki Mizuno* and *Tsutomu Watanabe*

Characteristic Spatial Interaction between Shops and Facilities in Japan

SPEAKER: *Takaaki Ohnishi*

ABSTRACT. We empirically investigate spatial distributions of shops and facilities (hereafter called establishments) observed in Japanese telephone directory (Yellow Pages) data on nationwide scale. This data contains comprehensive individual listings of about 7 million establishments (nearly all shops, firms, hospitals, schools, parks, etc). Name, address, latitude and longitude, phone number, and industrial sector of the establishment are also included. The industrial sector is divided into 39 categories. Each category is further divided into 735 subcategories. This allows us to study and discuss systematically geographic concentrations that are associated with various aspects of agglomeration. In order to measure the concentration of different types of subcategory, we use M index introduced by Marcon and Puech (2010). For each establishments of subcategory A, we count the total numuber of establishments (t) and the number of establishments of subcategory B (n), which are located within a distance r from it. We compute the ratio n/t to the global ratio N/T, where N and T are the total number of establishments and the number of establishments of subcategory B in the whole region, respectively. The M index between A and B is defined as the average value of this ratio over all establishments of subcategory A. If M value is larger than 1, there are more establishments of subcategories A and B within a distance r relative to the whole area. The spatial interaction between A and B can be defined as I=log(M), which is positive if there is attraction and negative otherwise. To identify characteristic location patterns of different types of establishment, we characterize subcategories by 735 dimensional vector whose elements consist of the values of I. Then we perform a cluster analysis with Ward's method using Euclidean distance and classify subcategories into groups. The obtained dendrogram illustrates the hierarchical structure and defines groups at different levels. We show that obtained groups are different from category classification and help to characterize spatial distributions of establishments, implying that we can extract important spatial information of urban structure from geographic interaction between different types of establishment.

Enrique F. Soto Astorga and *Tom Froese*

Embodied language and the endo/exo effect: Toward a big data analysis

SPEAKER: *Enrique F. Soto Astorga*

ABSTRACT. There is increasing evidence for the complex interactions between language and embodiment. One example is oral movements, which are related to digestive functions and speech. Ingestion and expectoration are the oldest oral functions to have emerged. Outwardness is associated with expectoration whilst inwardness is associated with ingestion. These movements can be placed on a sagittal plane ranging from the lips to the rear of the mouth where consonantal strictures can also be located as precise articulation points. Topolinski et al. (2014b) showed that participants in experiments preferred inward words (the “endo effect”) over outward words (the “exo effect”) when presented with positively-associated words, whilst the effects vanished when presented with negatively-associated words. This preference was modulated by oral affordance (e.g. lemonade is to-be-ingested whereas mouthwash is to-be-expectorated). Yet, when an object is situationally induced, it can elicit both effects, as it happened when participants were presented with bubblegum. We wish to construe a computational tool to analyze the contents of www.fishbase.org, which includes a large fish-related noun corpus in several hundred languages, and to label exemplar species as to-be-ingested or as to-be-expectorated even if reports of such exemplars’ suitability for use as food are lacking or nonexistent. For this purpose, we have begun codifying certain phonation repertoires and their sagittal plane of consonantal strictures, and then testing for inwardness or outwardness over a set of archetypal words associated with positive, neutral and negative attitude objects. German was the first language to be codified along with a small set of words (For instance: Milch, Papier, Gift). Once testing is over, results may have to be further analyzed based not only on the certain variations of dialects, but also on the phylogenetic aspect of the selected words. This effect may be seen as a novel instrument for the analysis of language, semantics and phonation regulation.

Ximena González-Grandón

Complex musical imagination in an ecological landscape: an epistemological framework for neuromusicology

SPEAKER: Ximena González-Grandón

ABSTRACT. The suggestion that cognition has to be explained in terms of the organism-environment system (with affordances for action), rather than by localizing functions to specific brain structures, has been solidly established. This is a result of the maturation and viability of enactivism as a legitimate alternative to traditional computationalist approaches. In this presentation we explain why an enactive neuroscience is needed to give a better explanation of the first-person experience of musical imagination. We argue for such a claim based on problems that have arisen in cognitive neuroscience with the functionalist (and uni-causal) project when structural connectivity strongly suggests that the function of the entire nervous system in interaction serves as dynamic, changing over time and working with complex causation. We explore this in the context of the problem of trying to determine the function of a brain area underlying musical imagination. We argue that neuroscientists need to look at the agent as characterized by a circular causality of global and local processes of self-regulation in an ecological and social environment, rather than following cognitive psychology in its analysis of isolated psychological functions. We point out how the dynamical conceptualization of causality, described as multidirectional across multiple scales of organization, may be a better explanatory unit. Also, an epistemological notion of first-person experience of musical imagination will be introduced, which can be defined as the insufficiency of a single descriptive modality to provide a complete description of this kind of complex system.

A second aim of our paper is to develop a particular definition of based on this enactive neuroscience perspective. Following this perspective (Thompson and Varela, 2001; Froese et al. 2014; Barandiaran, 2016), our argument centers on the idea of the inseparability of imagination and motor engagement in the nervous system (in interaction with a musical environment). We argue that Motor Musical Imagination is best understood in terms of imaginative affordances in the context of the agent's ongoing skillful engagement with the musical environment. MMI involves the whole living body of the organism, and is elicited by relevant possibilities for action in the environment that matter to the organism. We argue that the weight of evidence has now shifted in support of the view that MMI can be explained by appealing to principles of nonlinear dynamics, that introduce an emergent thought and an epistemic relational point of view. We review current research on structural and functional brain organization in music cognition, that defend a one-directional causal explanation, and we reject neuroreductionism in neuromusicology, arguing that the neurodynamical theories, that propose a two-direction or reciprocal relationship between embodied experience and MMI, provide a coherent framework for understanding this kind of first-person experience. Finally, we also identify a research agenda that naturally arises from our proposal. In this way we hope to provide an impetus for musical cognitive neuroscientists to pursue an enactive inspired research program.

Ahmad Taha, Tyler Summers, Nikolaos Gatsis and Sebastian Nugroho

Cherry-Picking Sensors and Actuators in Topologically-Evolving and Uncertain Dynamic Networks

SPEAKER: Ahmad Taha

ABSTRACT. A defining feature of dynamic networks is the prevalence of reliable realtime sensing and actuating devices---sensors sampling physical data in realtime and actuators driving networks to a specific state given the sampled data. For example, water quality sensors measure contamination levels in tanks and pipes in drink-water networks. This information is utilized to determine immediate control signals of actuators such as decontaminant injections or valves flushing out contaminated water. Other dynamic networks such as smart energy systems, transportation and gene regulatory networks operate in a similar fashion---they all obtain information from sensors thereby determining optimal signals of actuators to follow.

Systems-theoretic studies addressed a plethora of problems that explore optimal sensing and actuating algorithms. These classical studies, however, have two major limitations. First, the combinatorial selection of sensors and actuators (SaA) given the realtime physics and uncertainty is often ignored---all SaAs are activated which results in higher energy costs and oversampling. Second, the network topology is often static, that is, the selection of SaAs does not consider changing network structure. Physics-based studies have shown that network-level objectives can be met with fewer sensors and actuators, hence learning to activate specific sensors or actuators has plenty of merits. This work focuses on the interplay between the physical dynamics and the network evolution through the realtime SaA selection in uncertain dynamic networks.

With a large number of SaAs in uncertain complex networks, four research problems are investigated. (P1) How can the most influential SaAs be identified, and how does their selection change as network conditions evolve? (P2) Given a specific networklevel metric such as stability, minimal energy, or resiliency against attacks, how can SaAs be optimally selected in realtime? (P3) How does the network metric vary as the topology of the network evolves? (P4) How can key infrastructures such as drink-water networks and distributed energy systems benefit from the aforementioned theoretical advancements? The objective of this work is to initiate a model that addresses the above questions, while providing preliminary interpretations and answers to some of these challenging problems. The outcome is a new, hybrid network-dynamic mathematical model that formulates the above questions via tractable computational algorithms. First, we prove that the combinatorial problem of selecting SaAs can be relaxed into a tractable convex optimization routine. Second, we illustrate that robust selections can be obtained if the network evolution is bounded. Third, numerical simulations on random networks with unstable nodes show that the proposed solutions are able to bound the optimal combinatorial solution to the SaA selection problem in evolving networks. Finally, real-world applications of the model to power and water networks are discussed.

Jorge I. Campos and Tom Froese

Dynamical analysis of agents that were evolved for referential communication

SPEAKER: Jorge I. Campos

ABSTRACT. Referential communication is a complex form of social interaction whereby agents manage to coordinate behavior with respect to features that are not immediately present during their interaction. A famous example from nature is the bee waggle dance. Williams et al. (2008)[1] proposed an evolutionary robotics approach to create an agent-based model where referential communication emerges from the evolution and the dyadic interaction between the agents. With this approach as inspiration, we proposed a model which reduced the complexity to permit a full dynamical analysis, while still remaining complex enough so that the results provide a useful perspective on the processes that could be involved in natural referential communication. Also, we take the same structural copy of the artificial neural network (Continuous Time Recurrent Neural Network, Beer (1996)[2]) to control the sensorimotor system of each agent, in order to be more close to the natural example, where the bees can take on different roles during their lifetime. The task is for two embodied agents to interact in a “hive” area such that one of the agents (the receiver) is able to move to a specific “target”, the location of which is only known to the other agent (the sender). The task implicitly requires adopting the right role (sender vs. receiver), disambiguating between translational and communicative motion, and switching from communicative to target seeking behavior. Similar to the waggle dance, the best solution involved a correlation between duration of contact and distance to be traveled. The full dynamical analysis revealed surprising results: (1) There is only one fixed-point equilibrium attractor that is in different positions for each role. (2) The position of the attractor changes while the agents move in space and interact with each other. (3) Their behavior cannot be attributed to the agents in isolation. (4) The separate roles are clearly distinguishable from the time series data shown by the neural states of both agents while they are interacting with their environment and the other agent. Our model, therefore, reveals that referential communication can be studied as a complex system at the level of the sender-receiver interaction as a whole.

Yayoi Teramoto, Simon J.B. Butt and Tim P. Vogels

A computational model of developing neuronal circuits driven by activity-dependent plasticity

SPEAKER: Yayoi Teramoto

ABSTRACT. A developing brain can be thought of as a dynamical system in delicate balance. From birth to maturation, circuits of neurons in the cortex have to dramatically change how they are wired, while not interrupting the basic functions of the brain like sensing, and responding to stimuli. Figuring out how these changes take place is an active area of research in Neuroscience. Novel genetic manipulations and optical techniques allow the creation of detailed connectivity maps at different points in time, but it is nearly impossible to study the slow structural transitions from one developmental stage to the next experimentally. Here, we use computer models to test the hypothesis that these changes might be facilitated by neuronal activity-dependent mechanisms. In particular, we focus on an early thalamocortical circuit between neurons in the thalamus and two neuronal populations in the cortex (somatostatin-positive (SST+) interneurons in layer 5b and spiny stellate neurons (SSNs) in layer 4). This circuit is transient and shortly after the first week after birth, these connections disappear giving way for more mature brain circuitry.

We built a thalamocortical circuit model of 1700 integrate-and-fire neurons, comprising thalamic, SST+, and SSN cells to study the effect of varying activity levels in the network, the reversal potential of GABA (EGABA), and the two spike-timing dependent plasticity (STDP) rules on the network structure. Of the 21600 parameter combinations we tested, 21.7% allowed the network connectivity to evolve similarly to the experimental results, indicating the emergence of robust architectural features. The crucial parameters for successful network construction were the GABAergic reversal potential, and the parameter controlling the excitatory plasticity rule’s bias towards strengthening or weakening a connection weight. Interestingly, the initial structure and synaptic weights of cortical populations were a key factor to predict the fate of the network. Our results indicate that in addition to genetically encoded connectivity changes, activity-dependent mechanisms -- as well as the current structure of the network itself -- are substantially contributing factors in the creation of functional networks in the cortex. In a next step we can now predict the mechanistic effects of cell specific or network wide pharmacological or genetic manipulations such as knocking out genes, blocking specific transmitters or transecting a nerve. These can then guide experiments to further understand how these changes lead to deviations from normal brain development in structure and activity.

Adriana Reyna Lara and Karo Michaelian

Emergence of DNA replication by dissipation of UV-C light

SPEAKER: Adriana Reyna Lara

ABSTRACT. This work aims to establish a theoretical basis for a primitive mechanism of RNA and DNA enzymeless denaturing leading to replication during the Archean. This mechanism, called \ac{UVTAR} is associated with the dissipation of a generalized chemical potential, the solar photon potential. The dissipative structuring of molecules now known as the fundamental molecules of life can explain the emergence and proliferation of life in physical-chemical terms. This theoretical work consists in understanding the UV-C photon-DNA interaction process on time scales as short as fractions of picoseconds to nanoseconds and simulating with molecular dynamics, using empirical-potentials, the dissipation of excitation energy along the double helix of a 25 base pair DNA molecule due to the absorption of a photon (260 nm) in a single base pair. The absorbed energy of the photon breaks the hydrogen bonds that binds the complementary single strands of DNA, thus beginning the basic process of denaturing. In addition, the work considers all possible forms of energy transfer along the DNA, like the formation of excitons and charge transfer along the chain that could be important in fixing the initial conditions of the replicative-dissipative system based on the absorption of UV-C light. Experimental data exists favoring the proposed mechanism.

Daniel Alejandro Priego Espinosa, Adán Guerrero, Alberto Darszon, Gustavo Martínez-Mekler and Jorge Carneiro

Mathematical model for the temporal organisation and envelop of Ca2+-spike trains in sea urchin sperm flagellum

SPEAKER: Daniel Alejandro Priego Espinosa

ABSTRACT. Fertilisation is one of the most important events for sexually reproducing species. Organisms with external fertilisation, such as sea urchins, have been widely used as models for studying processes relevant to reproduction. The composition of the signalling network responsible for steering sea urchin spermatozoa in response to egg-released peptides, known as SAPs (Sperm Activating Peptides) remains largely unresolved. It is by now clear that upon stimulation by SAPs, several interconnected electrophysiological and biochemical events ensue within a sperm cell: increases in cyclic nucleotides (e.g. [cGMP]) and intracellular pH (pHi), as well as membrane potential changes caused by regulated ionic fluxes of K+, Na+ and Ca2+. The upshot of these events are fluctuations in intracellular Ca2+ concentration ([Ca2+]i) that control flagellar beating asymmetry, which in turn steers the cell. Here we used a differential equations model of the signalling network to ask which set of channels can explain the characteristic envelop and temporal organisation of [Ca2+]i-spike trains. The signalling network model comprises an upstream module that links the SAP activity to downstream cGMP and membrane potential, via the receptor activation, cGMP synthesis and decay, hyperpolarisation and repolarisation. The outputs of this module were fitted to kinetic data of cGMP activity and early response of membrane potential measured in bulk cell populations. Two candidate modules featuring voltage-dependent Ca-channels link these outputs to the downstream dynamics and can independently explain the characteristic decaying envelop and the progressive spacing of [Ca2+]i spikes. [Ca2+]i spike trains are explained by the concerted action of a classical CaV-like channel and BK in the first module, and by pH-dependent, [Ca2+]i-inhibited CatSper dynamics alone in the second module. The model predicts that these two modules interfere with each other to produce unreasonable dynamics, which suggests that one of the modules may predominate over the other in vivo. We further show that [Ca2+]i dynamics following sustained alkalinisation or the presence of low extracellular [Ca2+] would allow to identify if CatSper or a pH-independent CaV and BK modules predominate.

Mario Zarco and *Tom Froese*

Self-modeling in continuous-time Hopfield neural networks

SPEAKER: *Mario Zarco*

ABSTRACT. Discrete-time Hopfield neural networks, whose dynamic presents multiple fixed-point attractors, have been used widely in two cases: associative memory (Hopfield, 1982) based on learning a set of training patterns which are represented by attractors formed at updating the weights, and optimization (Hopfield & Tank, 1985) based on mapping a constraint satisfaction problem into the network topology such that the attractors represent solutions to that problem. In the last case, the network energy function has the same form as the function to be optimized, so that minima of the former is also minima of the latter. Although is has been proved that low-energy attractors tend to have large basins of attraction (Kryzhanovsky & Kryzhanovsky, 2008), networks usually get stuck in local minima. Watson, Buckley, and Mills (2011b) have demonstrated that discrete-time Hopfield networks can converge into globally optimal attractors by enlarging the best basins of attraction. The network combines reinforcing its own attractors by Hebbian learning, hence increasing their basins of attraction, and randomizing neuron states once the network have learnt its current configuration. Given the fact that global optimum has sub-patterns in common with many local optimum, reinforcing low-energy attractors through learning has the potential of simultaneously reinforcing lower-energy attractors even before the network converges onto the latters for the first time (Watson, Buckley, & Mills, 2011a). This so-called self-modeling process was restricted to be applied to symmetric weights matrices without self-recurrent connections so as to ensure the existence of only fixed-point attractors, and therefore the decrease of energy when the network is relaxed into a stable state. However, these conditions narrow the space of possible complex systems that could be represented by the network. In this work, we face the challenges involved in relaxing the constraints of this self-optimizing process by using continuous-time Hopfield neural networks with asymmetric weights matrix and self-recurrent connections. Continuous-time Hopfield neural networks can exhibit many different limit sets depending on their topology (Beer, 1995). Also, using a continuous activation function has important consequences in the network dynamic when Hebbian learning is applied. According to Zhu (2008), attractors are moved toward the corner of the phase space hypercube when the patterns learned by the network are being reinforced. Although the attractors are not longer neither binary nor stabilized in the same way as in discrete Hopfield networks, the associative memory allows the continuous Hopfield network to generalize over the learned patterns such that reinforcing local optima also reinforces superior optima regarding constrains satisfaction. Here we show that the self-modeling process can exploit the structure of the network in order to find globally optimal configurations, even if a positive correlation between the energy of attractors and the number of satisfied constraints was not found.

Ixchel Garduño Alvarado, Alejandro Frank, Juan Miranda Rios and Ruben Fossion

A novel method to assess Caenorhabditis elegans pharyngeal pumping time series through Digital Image Processing as a measure of functional decline in disease and ageing

SPEAKER: Ixchel Garduño Alvarado

ABSTRACT. A biological system is characterized by a set of different interdependent scales which interact non-linearly. It has been therefore proposed that the dynamics of physiological variables reflect the underlying modulation mechanisms. Among all physiological variables in humans, heart rate variability (HRV) is the most studied one and has been proved to serve as an independent predictor of heart rate for some chronic degenerative diseases. Our research team proposes Caenorhabditis elegans as an animal model to explore the relationship between the dynamics of physiological variables and the underlying modulation mechanisms. Hereby we aim to test the hypothesis that the variability of the pharyngeal pumping could be a relevant index of functional decline in disease and ageing in this organism. In C. elegans, feeding is achieved through pharyngeal muscular contractions (pharyngeal pumping) controlled by pacemaker neurons. Its pharynx has been compared to the human heart because of their similar electrical properties and development which are controlled by homolog genes. Furthermore, the C. elegans lifespan is only around two weeks; hence physiological alterations can be visualized over the course of aging. Age-related changes in tissue morphology and function, and a decline in C. elegans health are strongly correlated with a reduction in pharyngeal pumping rate (number of pumps/ total recording time) and thus with a decline in survival probability. Traditionally pharyngeal pumping has been assessed by eye and therefore the underlying variability has not been yet taken into account. For obtaining pharyngeal pumping time series, C. elegans individuals were filmed with a high speed camera coupled with a microscope. The videos were then segmented through Digital Image Processing (DIP). The change in the area comprising the pharyngeal grinder (contracted grinder is comprised by fewer pixels than when it is relaxed) was used to construct the time series. A crucial step in the statistical analysis of the time series is to separate the worm´s body movement (tendency) from the pharyngeal pumping (fluctuations). The novel statistical method Singular Spectrum Analysis (SSA) allows to divide self-consistently and data-adaptively tendency from fluctuations. In this work we established an experimental and theoretical method for measuring C. elegans pharyngeal pumping events with the aid of DIP and based on time series autosimilarity.

Martina Balestra, *Coye Cheshire* and *Oded Nov*

Lender Roles in Online Peer-to-Peer Lending Networks

SPEAKER: *Martina Balestra*

ABSTRACT. Online peer-to-peer (P2P) platforms of economic exchange enable users to take advantage of an excess capacity of resources (goods, capital, time, etc.) through free or fee-based sharing directly between individuals. P2P lending platforms such as Prosper, Lending Club, and Bitbond provide users who are in need of funds (borrowers) access to users who have idle capital and are interested in lending it (lenders). Like other types of decentralized platforms, online P2P lending markets offer participants a high degree of autonomy to participate as they wish: lenders can choose how much to lend, when, and to whom, according to a variety of relevant data that they themselves interpret. Yet despite the basic division between lenders and borrowers, little is known about lenders' distinct paths to participation. These paths are important because they are tied to lenders' investment decisions, and can have a significant impact on borrowers - many of whom are unable to find funding elsewhere if they are underbanked or unbanked. This study uses loan transaction logs from a P2P Bitcoin lending network, Bitbond (www.bitbond.com), to identify four structural-behavioral roles enacted by lenders. We then examine how these emergent roles reflect different investment strategies with implications for the lending community at large.

Data from 5,819 loan transactions were collected through Bitbond's API and website. This data was used to create a static, directed graph where source nodes represented lenders, target nodes represented borrowers, and edges represented the loans that flowed between them. In order to identify structural-behavioral roles, we first partitioned the network into modules using modularity optimization techniques. We then classified lender nodes into four structural-behavioral roles - Provincial Lenders, Connector Lenders, Non-Hub Lenders, Peripheral Lenders - according to their patterns of intra- and inter-module activity. Each plays a different structural role in the network; for example, Provincial Lenders are important to the coherence of their particular communities, whereas Non-Hub Lenders are important for network coherence.

We found that lenders in different roles tended to invest in different numbers of loans, of differing amounts, and of differing quality. For example, Non-Hub Lenders were relatively conservative: they made few, low-risk loans that were relative small, yet they had a high rate of repayment and lost relatively little on average. Provincial Lenders, on the other hand, made many, relatively large loans that had a moderate rate of success in terms of repayment, though they still lost a high amount on average. Taken together with what we know about lenders' structural roles within the network, these results can help us to understand the value of different types of lenders to a peer-exchange community, and how they may be engaged to improve the welfare and sustainability of the larger community. At a higher level, this study is an important first step in a research agenda for exploring P2P lending systems as socio-technical systems of networked exchange.

Jacek Grela

What drives transient behaviour in complex systems?

SPEAKER: *Jacek Grela*

ABSTRACT. We study transient behaviour in the dynamics of complex systems described by a set of non-linear ODE's. Transient phenomena are ubiquitous in nature whenever system is directional and become increasingly important in non-linear systems. Motivated by ecological (food-webs) and neural network dynamics where interactions are intrinsically non-symmetric we discuss robust properties of transients in these systems.

Destabilizing nature of transient trajectories is discussed and its connection with the eigenvalue-based linearization procedure. The complexity is realized as a random matrix drawn from a modified May-Wigner model. Based on the initial response of the system, we identify a novel stable-transient regime. We calculate exact abundances of typical and extreme transient trajectories finding both Gaussian and Tracy-Widom distributions known in extreme value statistics. We identify degrees of freedom driving transient behaviour as connected to the eigenvectors and encoded in a non-orthogonality matrix T 0 . We accordingly extend the May-Wigner model to contain a phase with typical transient trajectories present. An exact norm of the trajectory is obtained in the vanishing T 0 limit where it describes a normal matrix.

Ismael Quiroz, Arturo Pérez, Felipe Gallardo, Cesáreo Landeros, Joel Velasco and Griselda Badillo

Resilience: An emergent property for complex agroecosystems

SPEAKER: Ismael Quiroz

ABSTRACT. Based on the General System Theory (GST), agroecosystem (AES) is defined as a representation of interactions between abiotic, biotic, technology and culture elements related to crops where farmers define and take decisions on AES management based on his experiences and local knowledge. Resilience is an agroecosystem's attribute to recover or maintain its structure without losing its functions after being impacted and damaged by external phenomena. Therefore, there is a need to develop resilience systems as an alternative to diminish losing due to extreme events. The aim of this work was to analyze the concept of AES resilience as a property or attribute of complex systems. Then the systems approach is used as a methodological framework to find out solutions to a diverse problems through the world conception in terms of irreducibility attached to a systems and highlighting the whole as a result of complex interrelations among their elements. So, AES, as an abstraction of reality, is integrated by elements, such as social, environmental, economic and technological in agricultural context, and its boundary is defined according to researcher objective. As a result of the elements interrelations emerge properties, which can be divided into structure and attributes. Resilience is an attribute that is expressed, as a function of the vulnerability of the elements that make up AES structure, and has disadvantage, in some cases, as it is a phenomenon not directly observable due to its unpredictability. In the context of agroecosystems, the complexity related to the study of resilience increases as AES is approached due to number of elements integrated in relationship with the hierarchical level. The study of AES can be represented vertically, for example: a geographical region, a farm, or a crop or livestock; or horizontally between geographical regions, farm systems or crops. Another feature, which must be taken into account in resilience process, is the variable nature that make up AES, because in a scenario where system is damaged, the recovery time of the components could be different. For example, if soil suffer erosion, the formation of few centimeters can take at least 100 years, as compared with other elements as the technology, for example an irrigation system, that could be replaced in the short time. It is concluded that resilience is an emergent property of AES and is based on the interactions of the components of system and their nature, so vulnerability depends very much on system ´s strength, the kind of the event and therefore to analyze resilience is matter of probability.

Anne-Marie Grisogono, Roger Bradbury, Dmitry Brizhinev, John Finnigan and Nick Lyall

Consequences of changes in global patterns of human interactions

SPEAKER: Anne-Marie Grisogono

ABSTRACT. We address the very rapid and extensive changes in global patterns of interaction between individuals resulting from exponential growth in the proportion of populations participating in social media and other interactive online applications.

While already significant, we anticipate further rapid growth in both participation rates and in the amount of time people spend online.

We see a number of possible consequences from these changes in social interaction networks, some of which are concerning for the future of democratic societies and for the stability of global order.

We draw insights from the scientific study of collective phenomena in complex systems. Changes in interaction patterns often bring about system re-arrangements that are sudden and transformative, through the emergence and self-amplification of large-scale collective behaviour.

In physical systems these are called phase transitions – whereby the dynamics of the system takes on significantly new characteristics and many degrees of freedom become correlated.

We see a parallel here in the possible effects of changes in human interaction patterns on the structure of global social systems – including the traditional structures of nation states, and national and cultural identities.

In particular, the instantaneous and geographically agnostic nature of online interaction is enabling the emergence of new forms of social groupings with their own narratives and identities which are no longer necessarily confined by traditional geographic and cultural boundaries.

Moreover, since the growth of these new groupings is largely driven by the recommender algorithms implemented in the social applications, whereby people become more and more connected to like-minded others and have less and less visibility of alternate perspectives, the possible trend we are concerned about is towards a global “factorisation” of society into large numbers of disjoint groupings, accompanied by erosion of national identities, and weakening of the democratic base.

We study these new long-range interactions and their disruptive potential through both historical analysis and modelling of the dynamics, and draw conclusions about the risks and their consequences, and about the possibility of mitigating the risks through modest levels of policy initiatives – for example by fostering the growth of weak cross links between the emergent social structures.

Yuan Yuan, *Ahmad Alabdulkareem* and *Alex Pentland*

Social Network Formation Based on Endowment Exchange and Social Representation

SPEAKER: Yuan Yuan

ABSTRACT. The formation and evolution of social networks is a fundamental but poorly understood problem in social network analysis. Large-scale datasets from widely adopted communication technologies, such as cellphone communications, open up new possibilities for studies of social networks. In this paper, we build a novel model for social network formation based on individual characteristics and rationality, and by leveraging large scale datasets we test the effectiveness and predictability of our model.

Our model contains three components. First, we utilize a key concept named endowment, a well-known and useful concept in economics, which represents all attributes of an agent such as assets, abilities, capacities, qualities, etc. In our model, we represent each agent's endowments by a fixed length real-valued vector (hereafter referred to as the "endowment vector"). Second, we use a utility function to decide whether or not a pair of individuals who happen to "interact" should form a social tie, based on the benefits/costs associated with forming a tie considering their endowment vectors. An agent gains positive utility by forming social ties with people who have greater values in beneficial endowment dimensions. However, differences in some other dimensions lead to high communication costs, hindering the formation of new social ties. The utility function decides the willingness of each agent to communicate with another. Last, we use large-scale empirical communication datasets to infer the underlying endowment vectors of each agent. Using optimization methods, we calculate the endowment vector for each individual which would maximize the likelihood of reproducing the observed ground truth social network given our model's dynamics. Like representation learning technique, a popular method in machine learning, the inferred endowments can be utilized to predict the network dynamics and individual attributes.

The results on both synthetic and real datasets demonstrate the effectiveness of our model. The synthetic dataset is a community with 1,000 people and randomly generated endowment vectors. We simulate the dynamics based on our model. The resulting dynamics demonstrate several well-known sociological properties, such as social hierarchy and homophily. Moreover, we are able to successfully recover the underlying endowment vectors for each agent from the network dynamics based on our inference algorithm.

In addition, we use our model to fit a nationwide large-scale mobile communication network in Andorra, by fitting past communication patterns, our model was able to predict future network formation with accuracy that is significantly higher than that reported by competitive machine learning algorithms. Supporting the conjecture that our model provides a causal explanation for social tie formation, the learned endowment vectors can also be used to predict attributes that are likely to be related to endowments, including location, cost of phone model, cellular usage, and special event attendance. Endowment vectors learned by our model are able to predict these attributes with better accuracy compared with state-of-the-art algorithms for network embedding, like DeepWalk, indicating that the learned vectors successfully capture the underlying attributes of agents. This suggests that our model of social tie formation can be used to shape the diversity and usefulness of the network.

Susana Ramírez Vizcaya and *Tom Froese*

Addictions from an enactive and complex systems perspective

SPEAKER: *Susana Ramírez Vizcaya*

ABSTRACT. Addiction has posed a challenge for therapists, health professionals, public policy planners, philosophers, and self-control researchers due not only to the reluctance of addicted individuals to start a treatment and the difficulty to maintain abstinence in the long run, but also to some of the phenomena associated with recovery, such as increases in substance use that result from attempts to suppress thoughts related to the addictive substances, the false hope syndrome regarding self-change, denial, spiral relapse, or weight gain. This poster suggests that the above-mentioned phenomena can be understood under the light of an approach to addictions based on recent proposals within enactivism that generalize the concepts of autonomy, autopoiesis, and adaptivity from metabolic processes to habits. According to these proposals, habits are complex structures that generate and sustain their own identity under precarious conditions. They are conformed by processes involving basic bodily functions, neural mechanisms, intersubjective aspects, and interactions with the environment. One important point of this approach is that habits cannot be understood in isolation, but only as part of a complex network of regional identities that mutually enable and restrain each other, giving rise to a global form of identity (a self). Accordingly, preservation of this net of habits becomes a norm that, along with metabolism-based normativity, guides agent's behavior. However, habits may conflict with each other and with some of the basic metabolic processes. This could explain the occurrence of the so-called "bad" habits, which from an enactive perspective would not be bad for themselves, but for some of the other identities that constitute the agent, such as the metabolic and social identities. We propose to conceive of addictions as a kind of bad habit. Under this perspective, bad habits may be difficult to eliminate because their dynamics influence the formation and maintenance of other habits, as well as the development of a global identity, making it necessary to change many other regional identities. Furthermore, some bad habits, like addictions, can be so deeply entrenched that they may affect the autonomy of metabolism, making it dependent on habits that get incorporated in the agent's physiology. This perspective, which implies a different understanding of self and habits, also sheds light on the success of therapies such as treatments that include the use of psychedelics or mindfulness.

Markus Kirkilionis

A new way of archiving and developing scientific software

SPEAKER: *Markus Kirkilionis*

ABSTRACT. We describe here the novel SARA Systems Analytics platform, which is a new way of computational support for the scientific community, both for individuals and research groups. The main idea behind this new platform and associated software archive is that scientific software has a very short lifetime compared to commercial software. The reasons are usually short funding cycles inside the scientific community. Software associated to research activities then becomes rapidly irrelevant, because it is not brought up to date after its first release. The distribution of the software never reaches a wider range, because it is designed for a limited purpose. Such limitations are in contrast to the need to solve a variety of scientific computational problems, which are of quite similar nature. Here we propose to put more effort into an international structure which works on a commercial basis, and therefore can guarantee the proper archiving and further development of scientific software, independent of funding cycles but in cooperation with scientific institutions.

Ismael Quiroz, *Juan Pablo Martínez* and *Ezequiel Arvizu*

AGROECOSYSTEMS: AN ANALYSIS FROM COMPLEXITY

SPEAKER: *Ismael Quiroz*

ABSTRACT. Agroecosystem's concept represents the interaction of biotic, abiotic, technological and cultural elements respect to a crop where producer defines and makes management decisions based on his traditional knowledge and life experiences in terms of coverage of market demands and social needs. However, this has been approached with positivist-deterministic criteria, so the style of generating knowledge gave way to a linear perspective with the assumption: if the initial conditions of a system were known, it was possible to know its final-global behavior; nevertheless, phenomena such as climate change call into question such predictability, directing agroecosystem's functioning to the imbalance. Current complex phenomena contain a variety of relationships and variables that have a negative impact on the agroecosystem, leading to the development of new approaches to tackle those. This document aims to analyze the agroecosystems functioning as a system that has emergent properties of a complex nature. In order to approach the functioning of the agroecosystem from the Luhmannian complexity approach, it is important to clarify the cultural dynamics of the social system under study, which drives the process of social autopoiesis and the reproduction of agricultural processes. Central theme is culture seen as a factor that is self-reproduced in social systems, its process of environment adaptation, and therefore, agricultural practices built throughout the adaptation and reproduction process, considering present elements: economic, social, technological, political and environmental, among others. Another aspect of complex agroecosystem functionality is critically state (extrapolated from genetic to social context) allowing the system to be reorganized based on its properties of robustness and innovation and a rational level in its productivity, affecting as little as possible ecosystems stability. Then, agroecosystem controller evolves in its practices and the ability of a system to produce and reproduce its own elements to differentiate itself from its environment. In this sense, necessary information to self-reproduce and evolve is found in culture society to which the agroecosystem controller belongs. From preceding approach a redefinition of interdisciplinarity arises: "interdisciplinary research" under a complex system study approach. What integrates an interdisciplinary team for the study of a complex system is a common conceptual and methodological framework, derived from a shared conception of relation society-science, which will allow to define problematic to study under same approach, result of specialization of each member of research team. It is concluded that methodological tool needed to address agroecosystem complexity is interdisciplinary; in addition, criticality state stimulates the producer so that his agroecosystem is dynamic and that its management is self-produced through social autopoiesis.

Hyunuk Kim, *Marcus J. Hamilton*, *Woo-Sung Jung* and *Hyejin Youn*

The structure of mythologies explains the human expansion out of Africa

SPEAKER: *Hyunuk Kim*

ABSTRACT. Mythologies are collections of myths, or corpora of traditional stories, in human cultures to commonly explain our customs and places in the universe and/or the origins of the universe. Historically, comparative mythology has recognized remarkable consistencies in mythological themes and structures across the world. Often, these commonalities have been explained by one of two mechanisms: a shared common origin, or a shared, Jungian, collective imagination. The universality and structural distinctions, however, have not been tested in a comprehensive and systemic way as they are difficult to quantify. Here, we focus on the global distribution of mythemes, mythological motifs that are irreducible thematic units identified within and across individual myths. The statistical properties of co-occurrences of mythemes in traditions are analyzed, and hence ten distinctive clusters of traditions are identified. These clusters remarkably well band with biogeographic regions as shown in Fig 1. Furthermore, information transfer from one cluster to another exhibits a good agreement with human migration trajectory. The result suggests a deep evolutionary history to human mythologies originating with modern humans in Africa < 60k yBP and diversifying as humans expanded out of Africa across the planet. Finally we show how underlying structures of mythemes to explain structural characteristics for each cluster, and the direction of their information transfer.

Hyunuk Kim, Daniel Kim, Young-Ho Eom, Hawoong Jeong, Woo-Sung Jung and Hyejin Youn

Building technology space from microscopic dynamics to macro structure

SPEAKER: Hyunuk Kim

ABSTRACT. Combination of existing ideas has moved into prominent role in technological innovation [1]. These dynamics can well be captured in US patent data where individual technological capabilities are codified as classification system (USPC), accumulation of which accounts for the large repertoire of combinations. Using statistical analysis, we measure the extent to which each pair deviates from the expected random configuration (Z-score), and assign novelty profile to each invention. Analyzing statistics of patent's novelty profile uncovers a secret recipe for high impact innovation: conventional (typical) pairs of ideas with novel (atypical) twist [2]. Built on this empirical result that inventive activity can be considered as a searching process for novel connections of technological building blocks, we provide a mechanistic model to explain how technology space evolves by strengthening conventionality and creating novelty. We find the structural characteristics generated by the suggested model are in a good agreement with the observed macro structure of technological innovation including rich-get-richer phenomenon, modular structures, and the formation of high novelty links.

[1] H. Youn, D. Strumsky, L. M. A. Bettencourt, and J. Lobo, Journal of The Royal Society Interface 12 (2015), 10.1098/rsif.2015.0272. [2] D. Kim, D. B. Cerigo, H. Jeong, and H. Youn, EPJ Data Science 5 (2016), 10.1140/epjds/s13688-016-0069-1.

Marcel Meyer

Quantifying airborne dispersal routes of pathogens over continents to safeguard global wheat supply

SPEAKER: Marcel Meyer

ABSTRACT. Infectious crop diseases spreading over large agricultural areas pose a threat to food security. Aggressive strains of the obligate pathogenic fungus Puccinia graminis f.sp. tritici (Pgt), causing the crop disease wheat stem rust, have been detected in East Africa and the Middle East, where they lead to substantial economic losses, and threaten livelihoods of farmers. The majority of commercially grown wheat cultivars world-wide are susceptible to these emerging strains, which pose a risk to global wheat production, because the fungal spores transmitting the disease can be wind-dispersed over regions and even continents. Targeted surveillance and control requires knowledge about airborne dispersal of pathogens, but the complex nature of long-distance dispersal (LDD) poses significant challenges for quantitative research. We combine international field surveys, global meteorological data, a Lagrangian dispersion model and high-performance computational resources to simulate a set of disease outbreak scenarios, tracing billions of stochastic trajectories of fungal spores over dynamically changing host and environmental landscapes for more than a decade. This provides the first quantitative assessment of spore transmission frequencies and amounts amongst all wheat producing countries in Southern / East Africa, the Middle East, and Central / South Asia. We identify zones of high air-borne connectivity that geographically correspond with previously postulated wheat rust epidemiological zones (characterized by endemic disease and free movement of inoculum), and regions with genetic similarities in related pathogen populations. We quantify the circumstances (routes, timing, outbreak sizes) under which virulent pathogen strains such as 'Ug99' pose a threat from LDD out of East Africa to the large wheat producing areas in Pakistan and India. Long-term mean spore dispersal trends (predominant direction, frequencies, amounts) are summarized for all countries in the domain (Supplementary Data). Our mechanistic modelling framework can be applied to other geographic areas, adapted for other pathogens, and used to provide risk assessments in real-time.

Giacomo Rapisardi, Giulio Cimini and Guido Caldarelli

Empirical correction of the percolation threshold using complement networks

SPEAKER: Giacomo Rapisardi

ABSTRACT. Models of percolation processes on networks currently assume locally tree-like structures at low densities, and are derived exactly only in the thermodynamic limit. Finite size effects and the presence of short loops in real systems however cause a deviation between the empirical percolation threshold and its model-predicted value. Here we show the existence of an empirical linear relation between the percolation threshold and its model predicted value across a large number of real and model networks. Such a putatively universal relation can then be used to correct the estimated value of the percolation threshold. We further show how to obtain a more precise relation using the concept of the complement graph, by investigating on the connection between the percolation threshold of a network and that of its complement.

Inho Hong, *Woo-Sung Jung* and *Hyejin Youn*

Who is the shepherd? Small city follows larger city's trajectory in urban economy

SPEAKER: Inho Hong

ABSTRACT. Identifying the evolutionary paths of urban economy is key to accessing, maintaining and forecasting city's future growth and success. Although path dependency in economic trajectories has been alluded to in the literature, it still lacks comprehensive empirical evidences. Here, we study the evolution of urban economy by analyzing the whole U.S. industries in individual cities over two recent decades. The industrial characteristic of a city is quantified by revealed comparative advantage (RCA), and the temporal change of industrial similarity between cities describes how urban economy evolves. We find that small cities move into closer resemblance of large cities in time as Fig. 1a shows, that is, urban industrial evolution repeats itself in individual cities. Figure 1b shows that when a group of largest cities is fixed in time, the rest of smaller cities become more similar to them with time lag. It is indeed the case that small cities follow the industrial footprints of large cities. We show that these dynamics are relatively general characteristics, not entirely driven by a few industry sectors. Finally, we identify the structural transition in urban economy as a crossover of dominant industries, and the transition point is analytically explained by the distribution of scaling exponents.

Roberto Bernal, *Rick Dale* and *David Vinson*

The Relationship of Social Network Connectivity to Positive Emotion Word Use and Other LIWC Word Categories

SPEAKER: *Roberto Bernal*

ABSTRACT. Linguistic Inquiry and Word Count (LIWC) is a quantitative text analysis program that uses word count strategies to extract psychological and social meaning out of the words people use (Pennebaker et al. 2003). Another method of studying word use is by analyzing social network structures and predicting general language patterns through network analysis and information theory (Vinson and Dale 2016). This study inspects datasets from Yelp and examines the relationship between measures of social network connectivity and positive emotion word use (e.g., love, nice, sweet). The number of friends each user has is a simple measure of social network connectivity. Positive emotion word use is measured by analyzing business reviews of Yelp users using LIWC. We run a linear correlation between users' number of friends (connectivity) and the percentage of positive emotion words in their respective reviews. Results suggest that users with more friends tend to write reviews with less positive emotion words. We further explore relationships between other LIWC word categories and the number of friends and run linear regression models using these LIWC word categories to determine if we can predict the number of friends by the words people use. Extending these findings to other social networks such as Twitter and Facebook will generalize the results and make a stronger theoretical case.

Gergely Tibely, *Imre Derenyi* and *Gergely Szollosi*

Is tumor evolution neutral?

SPEAKER: *Gergely Tibely*

ABSTRACT. Cancer is the result of a somatic evolution process. During tumor growth, however, evolution continues within the tumor, new mutations arise, the tumor divides into more and more parts. It is an interesting question whether the individual subclones grow according to the same dynamics or maybe selective processes can also contribute, which influence makes some subclones more widespread and other ones more limited. According to recent results, in several cases there are no differences between the subclones from the point of view of selection, the subclones grow by the same rate. As we will see in the presentation, however, a closer examination raises serious questions about the significance of the results, or generally the empirical verifiability of theoretical predictions, taking into account the limits of the current and near future technologies. On the other hand, there is a quantity among the employed empirical data, which is less significant from the point of view of subclone selection: the number of frequent mutations within the tumor. The empirical values of this quantity are hard to reconcile with the usual picture about the accumulation of somatic mutations. In this talk, I sketch the possible alternatives and their implications.

Jerry Jacka

El Niño, Food Insecurity, and Challenges to Resilience in Highlands Papua New Guinea

SPEAKER: *Jerry Jacka*

ABSTRACT. The 2015 El Niño severely impacted horticulturalists in highlands Papua New Guinea as accompanying frosts and droughts devastated their subsistence food crops. Responses to previous El Niño events have typically resulted in large-scale migration to lower altitude areas. However, with economic development stemming from large-scale gold mining, population pressures and intergroup conflicts, and changes in access to natural resources in the destinations where people are migrating, customary, resilient responses of highland social-ecological systems are being challenged. The research uses the heuristic of the panarchy to understand how cross-scalar variables interact with peoples' food systems and decision making processes in a time of crisis. Results are based on field research conducted in 2016 and highlight vulnerabilities and the limits of resilience in certain coupled social-ecological systems to extreme climatic changes and socioeconomic development.

Chico Camargo and *Ard Louis*

What Darwin didn't know: the arrival of the fittest

SPEAKER: *Chico Camargo*

ABSTRACT. In evolutionary biology, the expression "survival of the fittest" is often heard as a summary of Charles Darwin's idea of natural selection. This idea has definitely helped us understand how life is shaped by variation (and selective survival), but even Darwin himself acknowledged our lack of understanding of what causes all the variation he observed. Hugo de Vries, one of the first geneticists, famously said: "Natural selection may explain the survival of the fittest, but it cannot explain the arrival of the fittest." More recently, genomics and bioinformatics have added pieces to the puzzle: there is large redundancy in the genome, caused by neutral mutations, implying that multiple genotypes can produce the same phenotypes. That naturally raises questions about how genotypes are distributed over phenotypes, and about biases in that distribution.

In this work, we address these questions using computational models for gene regulatory networks. In particular, we look at the gene network that regulates the fission yeast cell cycle. By working with a coarse-grained model of this gene network, we find that the design space of gene networks has a large bias in the distribution of genotypes mapping to phenotype, which is related to properties such as mutational robustness and evolvability. Moreover, we find that this bias is can also be characterised by applying concepts from algorithmic information theory, such as Kolmogorov complexity and Levin's coding theorem, which suggest that the most likely phenotypes will be the ones with lower complexity.

Ollin Langle and *Jesus Espinal-Enriquez*

Analysis of Mexico's drug-cartels network

SPEAKER: *Ollin Langle*

ABSTRACT. Violence linked to drug traffic in México has increased the last ten years, the reasons of this spread are difficult to quantify. However, a relevant feature to take into account is the large number of drug cartels and the disruption of them into small violent cells.

Many strategies have been proposed to dismantle the operation networks of these criminal groups, being the capture attempt of the cartel leaders the most usual one. This strategy has not have a significant positive outcome decreasing the influence of these groups neither the violence around the country. In this sense, the complex network theory approach emerges as an alternative to understand the dynamics underlying this no-trivial phenomenon. In this approach, a network is composed by nodes such as people, places, cities, etc., and links represent any kind of relashionship between said nodes.

In this work, by means of a semi-automated text mining tool we construct a network of the characters of the Anabel Hernandez's book "Los señores del narco" in order to analyze it's topological and dynamical properties. By performig directed attacks to the most relevant nodes of the network using different centralities, we measure the robustness of this network in terms of the size of the giant component i.e. optimal percolation. We also analyze the resulting network communities after these attacks and observe the exact amount of removed characters needed to dismantle this giant component.

With this approach it is possible not only to propose a minimal quantity of characters to be removed from the network to desmantle it but also if there are differences between the most socially influential nodes and those who are important to the network topology. These kind of approaches could aquire relevance in terms of developing strategies to disable complex criminal structures.

Ollin Langle-Chimal, *Lorena Mariana Malpica Serrano* and *Ana Isabel Millán*

Political dynamics of the mexican senate

SPEAKER: *Ollin Langle-Chimal*

ABSTRACT. With the vast amounts of data available freely about virtually any field of knowledge, one of the greatest challenges for today's scientists is to be able to store, organize and analyze this data and to use it for novel and useful applications. Political sciences and legislation are fields that have seen such an increase. The Mexican government and several of its dependencies have made a lot of their databases publicly available online, with the Chamber of Senators being the main focus of this work. New oportunities to be aware of the actions that decision makers are taking are arising and showing if a real representative democracy is being held. In this work we present a framework for automatic data acquisition, construction of a graph oriented data base and statistical modeling of data taking advantage of the capabilities of cloud computing. The data collection was though the Mexican Senate's official website, so everything is completely open. The information gathered consist of the names of the senators and their alternates, party and comissions they belong to, entity they represent, the edicts, how did the senators vote, attendance and the dates in which the above happened. Followed by this a graph oriented database was build which allows to performm an analysis of the senators actions and find communities in a temporal basis. A distance matrix between each senator was created from the votes which was used to perform statistical analysis such as multidimensional scaling for the projection of the vectors asociated with the senators and the construction of a weighted network in order to find communities amog them and study it's topological properties. Another network was also built from the joint proposals of the edicts by the commissions because each edict is proposed by one or more commissions. A new analysis of communities was carried out for this network, finding 3 great subjects that after a manual review we determined that they reflect the following topics; governance, foreing affairs and social issues. The final part of the paper is to determine if it is possible to predict the vote of a particular senator through his or her history and the metadata we have. Obtaining the best accuracy by means of logistic regression with a value of 0.7082, surpassing the 0.6608 of predicting that they always vote for pro.

Gabriel González and María Elena Lárraga Ramírez

Modeling the Spatio-Temporal Dynamics of Worm Propagation in Smartphones based on Cellular Automata

SPEAKER: Gabriel González

ABSTRACT. In recent years, the worldwide market for smartphones has grown dramatically. Smartphones users have the ability to share programs and data with each other, such as surfing the web, sending or receiving emails, and online shopping. However, these availability and mobile services provided by smartphones increases their vulnerability to malware attacks. Consequently, modeling of worm propagation in smartphones in order to predict the side effects of a new threat and understand the complex behavior of the modeled malware has received significant attention in recent years. One of possible communication channels for the penetration of mobile malware is the Bluetooth interface, where the malware infects devices in its proximity as biological virus do. Due to this strong similarity in the behaviors of self-replicating and propagation between mobile malware and biological viruses, most investigations of malware propagation in smartphones focus predominately on modeling the malware propagation by employing the classical epidemic theories in epidemiology. Cellular Automata (CA) models have emerged recently, as a promising alternative to characterize worm propagation and understand its behavior. However, in the most of the existing CA models for mobile malware, it is assumed that all smartphones are homogeneous and transmission time of the worm is done in one time cycle. Moreover, there are few models dealing with the propagation of mobile worm by means of Bluetooth connections and the most of them only study temporal evolution. However, it is also of interest to simulate the spatial spreading due to the main characteristics of Bluetooth. In this work, a mathematical model to study the spatio-temporal propagation dynamics of Bluetooth worms based on cellular automata and the compartmental epidemiological models is introduced. The model takes into account the local interactions between the smartphones and it is able to simulate the individual dynamic of each mobile device. Furthermore, the model considers the effect of mobility of smartphone users on the infection propagation. Some simulation results indicate that the model captures the spatio-temporal dynamics of Bluetooth worm propagation and facilitates predictions of the evolution of the malware spreading. In particular, results indicate that while Bluetooth viruses could reach all susceptible devices within a time period, the human mobility and the Bluetooth antenna range are crucial factors to the stop the spread of malware. In addition, the computational cost of the model is low in comparison with other existing models, making it suitable to understand the behavior of a modeled malware and predict the spreading curves of Bluetooth worm propagation in large areas.

Berenice Rojo-Garibaldi, David Salas-De-León and Adela Monreal-Gómez

Non-linear analysis of the occurrence of hurricanes in the Gulf of Mexico and the Caribbean Sea

SPEAKER: Berenice Rojo-Garibaldi

ABSTRACT. Hurricanes are complex systems that carry large amounts of energy. Its impact produces, most of the time, natural disasters involving the loss of human lives and of materials and infrastructure that is accounted for in billions of US dollars. However, not everything is negative as hurricanes are the main source of rainwater for the regions where they develop. However, the great progress that has been made in its study to predict the number of hurricanes, their intensity and trajectories from year to year. Despite the progress made, we do not have the ability to fully predict their behaviours. So there are still some questions to be answered. Some of them have to do with their chaotic and non-linear behaviour. In this study we make a non-linear analysis of the time series obtained from 1749 to 2012 of the hurricanes occurrence in the Gulf of Mexico and the Caribbean Sea. The construction of the hurricane time series was done based on the hurricane database of The North Atlantic-basin Hurricane Database (HURDAT), and the published historical information. The Lyapunov exponent indicated that the system presented chaotic dynamics, and the time series spectral analysis along with the non-linear analysis of the hurricanes time series showed a chaotic edge behavior. One possible explanation for this edge is the individual chaotic behavior of hurricanes, either by categories or individual, regardless of their category, and behaves on a regular basis.

Kevin O'Sullivan and James Gleeson

Time Dependence of Meme Popularity Distributions

SPEAKER: Kevin O'Sullivan

ABSTRACT. In this work we present a simple model of the spreading behaviour of memes on a social platform or network structure like Twitter for example. The dynamics of the model can be described quite simply in terms of a (re)tweeting or innovating process. On a Twitter like network memes or tweets propagate in a unilateral direction determined by the so-called friend-follower relationships. With innovation probability μ, a Twitter user generates a new unseen meme which overwrites the meme currently on the user's screen and is broadcast to all of the user's followers, overwriting the screen of the followers [1]. On the other hand, a user may decide to (re)tweet, with probability $1-\mu$, the meme currently occupying his/her screen and broadcast the meme, again overwriting the meme currently on the followers screen. In this work, we consider the density or total number of screens occupied by a specific meme at a given time. We determine via a branching process approximation a simple governing model for the users' actions in the form of an advection equation. The time-dependent probability distributions of the screen occupancies are calculated numerically; the structure of these depends on the follower degree distribution. Asymptotic analysis analytically permits the construction of the large-time probability distribution corroborating the results obtained numerically. It is shown analytically that the distribution of cascade sizes consists of two components, a static or steady-state segment and a component which continues to evolve. We highlight the two components by a rescaling of the distribution of cascade sizes and show the collapse of the distributions, observed at different ages onto a single curve, thus showing the self-similarity of our model at large time-scales. We also obtain the distribution of lifetimes of memes and the results are in good agreement with those appearing in [2].

[1] J. P. Gleeson, J. A. Ward, K. P. O'Sullivan and W. T. Lee, ``Competition-Induced Criticality in a Model of Meme Popularity", Phys. Rev. Lett, 112, 048701, (2014).\\ [2] K. I. Goh, D. S. Lee, B. Kahng, and D. Kim, ``Sandpile on Scale-Free Networks", Phys. Rev. Lett, 91, 148701, (2003).

Natália Coelho de Sena, Marco A. Amato, Tarcísio M. Rocha-Filho and Ademir E. Santana

Finite size effects in the glass transition: a field-theory approach

SPEAKER: Natália Coelho de Sena

ABSTRACT. Super-cooled liquids are out-of-equilibrium systems in which a material remains in the liquid phase at temperatures lower then its melting point. At even lower temperatures, these materials stop flowing, passing through the glass transition, solidifying to an amorphous glassy phase. In this work, we present the effects caused by changes in the system size, using a field-theory approach. We compactify one dimension of the system, leading to a quasi bi-dimensional film. We show that the transition temperature increases with decreasing thickness, reaching a divergence when it vanishes, which suggests a fundamental difference between two- and three-dimensional systems. We also present preliminary numerical results, reinforcing the analytical one.

Bruno Vieira Ribeiro and *Yves Elskens*

Numerical observations of an Ornstein-Uhlenbeck process for the velocity process of an N-particle system interacting stochastically

SPEAKER: *Bruno Vieira Ribeiro*

ABSTRACT. We consider a 3-dimensional N-particle system with mass m and no potential energy. The interaction is modeled as random momentum exchange between particles, obeying conservation of energy. The dynamics of the system is given by a single stochastic differential equation for a $D = 3N$ dimensional velocity vector ($\mathbf{V}$) driven by a D-dimensional Brownian noise term. A quick look at this evolution equation shows us that a single component of $\mathbf{V}$ evolves independently of the remaining directions according to an one dimensional Ornstein-Uhlenbeck process driven by a single noise term along the same direction (corresponding to a particle moving in ``white noise" with friction) , when this component is small enough. Our interest, however, is to study the limiting process for the components of $\mathbf{V}$ when these are of order one. Let A be the noise amplitude and $k_{\mathrm{B}} T /2$ be the total energy per degree of freedom. We thus consider the component V_1 of $\mathbf{V}$ and the component AB_1 of the noise term driving $\mathbf{V}$. Call U_1 the Ornstein-Uhlenbeck process driven by the noise AB_1 in a viscous bath with friction rate $mA^2 /(k_{\mathrm{B}} T)$. We prove that V_1 converges in probability to this U_1 as $N \to \infty$. The proof easily extends to any finite number $n(< 3N)$ of components of the velocity vector $ \mathbf{V}$; these n components become independent and identically distributed (i.i.d.) in the limit $N \to \infty$. Furthermore, we show that our model relates to the class of Kac systems. If we impose total momentum conservation, the three-dimensional velocities of individual particles converge in probability to independent three-dimensional Ornstein-Uhlenbeck processes as $N \to \infty$. Further, a change in velocity variables, proposed in \cite{KL06}, allows to analyse the N-particle system with total energy and momentum conservation in terms of a $(N-1)$-particle system with only energy conservation.

Pilar Pena

OPTIMIST, NEGATIVE AND ADMINISTRATIVE VIEWS ON THE KNOWLEDGE OF COMPLEX SYSTEMS

SPEAKER: *Pilar Pena*

ABSTRACT. Public administration is a complex system considering that complexity theory requires a new conceptual framework to characterize nonlinear dynamic systems in organizations where change is part of nature and interactions. There was perceived instability everywhere, dissipated structures and non-random behaviors close to the chaos that require a new field of knowledge and application of the administrative process, redesigning organizational systems in which they participate: individuals, processes and organization as the model of strategic management Of the complexity to explain the new dynamics of our time. Because we are in the knowledge society requires a paradigm shift in Public Administration and a redefinition of roles and responsibilities of public entities in charge of a certain activity. Therefore, there is a need for recurrent innovation in water management as well as the training of public administrators, regardless of public sector reforms.

Florentino Borondo, Juan Carlos Losada and Rosa M. Benito

Complexity and Control of the Nonlinear Vibrational Dynamics of the HCN Molecule

SPEAKER: Florentino Borondo

ABSTRACT. We study the complexity of the vibrational dynamics of a model for the HCN molecule in the presence of a monochromatic laser field. The variation of the structural behavior of the system as a function of the laser frequency is analyzed in detail using the smaller alignment index, frequency maps, and diffusion coefficients. It is observed that the ergodicity of the system depends on the frequency of the excitation field, especially in its transitions from and into chaos. This provides a roadmap for the possibility of bond excitation and dissociation in this molecule.

Molecular vibrational dynamics has been the subject of an intense research activity in the past years, this giving rise to numerous publications that appeared in this field. The theoretical framework for these kinds of studies is based both on classical and quantum mechanics, having profound roots in the characterization of chaos in Hamiltonian systems. This topic was nicely addressed in the seminal work of Kolmogorov, Arnold, and Moser, that produced the celebrated KAM theorem. The study of dynamical chaos theory has substantially flourished thereupon, becoming an area of active research within the scientific community of dynamical systems.

One topic of much interest in this branch of chemical dynamics is the active control of molecular nonlinear dynamical systems and chemical reactivity, typically using lasers. An extensive literature has been produced on this subject. In relation to our work with the HCN molecule, the laser control of bond excitation, bond dissociation (typically of the strong CN bond), and the isomerization of HCN have been extensively considered in the literature. Brezina and Liu considered the possibility of controlling the CH and CN excitations and dissociation with laser pulses. For this purpose, they used a classical mechanics widespread vibrational model consisting of two kinetically coupled Morse bond functions freezing the bending at its equilibrium value. Special attention was paid to the role played by IVR, considering different values of the laser frequency and amplitude. These authors found that simple linearly chirped pulses are effective in exciting and dissociating the CH, while this is more difficult for the stronger CN bond. Recently, Sethi and Keshavamurthy revisited the same problem, concentrating only in one of the laser frequencies. This work was a start in the identification of the main aspects of the dissociation dynamics and mechanism in phase space, and the characterization of the system in terms of the classical dynamical resonances (Arnold) network. They found the importance of two regions of frequency space, the dissociation hub, which constitutes a gateway for dissociating trajectories, and the noble hub, characterized by very irrational frequency ratios, that constitutes a very sticky area of trapped trajectories for long times.

In this paper, we extend previous work, by considering the influence of the laser frequency on the dynamics, to use it as a possible control parameter by varying the dynamical structure of the system. In this way, we can be more precise than previous works in predicting which laser frequencies are best in order to promote dissociation.

Katya Luna Chrzanowski and *Felipe Lara-Rosano*

Innovative Educational Intervention Based on Self-observing Interactive Pupils

SPEAKER: *Katya Luna Chrzanowski*

ABSTRACT. New educational approaches try to foster in a school group peer recognition, self-observation and pupils' freedom to express themselves in reflective terms and about their experience in the classroom.
The objective of this research was to investigate how the interventionist strategy of the teacher facilitated these interactions and how such interactions favored the group's self-organization.
To that end, a questionnaire was applied to the pupils with questions regarding the classroom environment and the teaching innovative strategies, to identify the observed differences of the course with other courses as well as changes in the pupils themselves.
Reorganizing the classroom space from a traditional layout of rigid row benches looking forward towards a flexible arrangement where all students could make visual and physical contact with each other, was the most innovative strategy that promoted the largest interaction. In this case, it is interesting to link these forms of interaction derived from spatial reorganization from the enactive approach (Varela et al., 1991) and the enactive approach to social interaction (Froese, 2015), especially regarding "Making sense" and "embodiment". The multi-agent system schema of Froese and Di Paolo (2011: 12) "... is possible when two adaptive agents, who share an environment, are involved in a sensor-motor coupling, in which their activities are intertwined so that mutual interaction results in a process of interaction characterized by an autonomous organization ... "
In the repeated interactions of self-observation among the agents of the system, perceptions of trust, physical contact, group recognition and interaction emerged, as well as meaning discovery and group reflection of experience. Hence, we can affirm that they are elements of the domain of enaction in the sense of Froese (2011). Such emergencies are new properties of the system - school group -, since the observers distinguish them as out of normality and their expectations at the beginning. With this study, some important results have been emerged: group connection, recognition of the other, freedom of expression, construction of meaning, and a definition of what a model of formative intervention is outlined. These results will be presented as the discourse expressed by the students in the answers to the questionnaire.

M. Denisse Rueda-Contreras, *J. Roberto Romero-Arias*, *José Luis Aragón Vera* and *Rafael Barrio Paredes*

Phyllotactic pattern formation driven by curvature and stress

SPEAKER: *M. Denisse Rueda-Contreras*

ABSTRACT. The arrangement of repeated lateral plant organs, such as leaves, floral structures, ribs in cacti or scales in a pine are a Phyllotactic process. The emergence of these phenomena has fascinated humans along centuries and can be considered as the oldest branch of mathematical biology and one of the open questions in developmental biology. The positioning of lateral organs around the plant roots, the organization of plant tissues to resist environmental stresses or the choice of the oriented cell division planes seem to have a common response to mechanical stress and their feedbacks. These kind of phenomena suggest that the physics, genetics and biochemist of development are not separated issues for an organism to grow and develop. In this sense, we propose a model that integrated some intrinsic features of growth, physical forces, mechanical and geometrical constraints that feedback a phyllotactic process. Our propose is a novel mechanism that integrated a Turing system on growing domains and the phase-field theory for measure the changes of the curvature and the stress.

Manu Lekunze

Cameroon's security architecture: A complex adaptive system?

SPEAKER: *Manu Lekunze*

ABSTRACT. This article evaluates Cameroon's security architecture against literature on complex adaptive systems. It uncovers that Cameroon's security architecture is made up of multiple actors which are relatively autonomous, heterogeneous, interdependent and could follow simple rules. The security architecture is hierarchically organised, anti-reductionist, auto-catalytic, co-evolutionary, dynamic, capable of learning and adaptive. It consists many systems within a larger security system. It is therefore concluded that, Cameroon's security architecture is a complex adaptive system. This lays down the foundation for the use of complexity sciences in the study of security. The use of complexity sciences signifies a paradigm shift in security studies which have traditionally focused on linear analysis of actors, threats and consequences on the referent.

Claudio Juan Tessone

A complexity perspective of the Bitcoin economy: design, reality and emergence

SPEAKER: *Claudio Juan Tessone*

ABSTRACT. Abstract Bitcoin is an original attempt to create a currency without a central issuer. In contrast to fiat currencies where money supply is dictated by policies of a central authority, Bitcoin creation follows a stringent rule that makes bitcoins laborious to create, while any user can participate of the supply. Users connect to a peer-to-peer network, hide themselves behind multiple aliases (so-called addresses) and issue transactions to others. To ensure validity, transactions are recorded in a public ledger so that Bitcoin ownership can be independently verified. All together: the mechanism of supply, users, and the transactions constitute the Bitcoin economy. While anonymised, it is possible to aggregate aliases into users. Doing so, we reveal the main characteristics of the Bitcoin economy. This closed system, having followed a technocratic approach in its immutable design, is the only case of an economy where all monetary transactions can be traced back with full detail. Our analyses show that the number of Bitcoin users has been growing at least exponentially since the introduction of Bitcoin, while the number of bitcoins mined grew linearly. This creates a mismatch between large-scale adoption and scarce supply, partly explaining the explosive price increase against fiat currencies in the last years. One of the main advertised characteristics of Bitcoin is the decentralised nature of mining. However, the proportion of users who participate of the supply has become vanishingly small. This leads to: (i) increasing accumulation of wealth in the hands of a few, far exceeding the wealth inequality observed in real countries; and (ii) the emergence of a hierarchical flow of bitcoins emanating from the miners, a phenomenon only visible at the level of the user network. Interestingly, this fixed incentive scheme has created the emergence of large levels of centralisation and economic flow, as our analysis show.

A Reshak

Complexity at the nanoscale "A new era in nanotechnology Graphene the New Horizon"

SPEAKER: A Reshak

ABSTRACT. A honeycomb two dimensional lattice of a monolayer carbon atoms is a new material called graphene which discovered recently. Graphene consists of a single atomic layer of sp2 hybridized carbon atoms that result in a hexagonal lattice. Around each carbon atom, three strong σ bonds are established with the other three surrounding carbon atoms. Graphene opened a new era in nanotechnology. The outstanding mechanical, electrical and physical properties of graphene warrants its use in a variety of areas such as hydrogen technology, electronics, sensing and drug delivery, among many others. The zero band gap of the graphene sheets renders the construction of graphene based field effect transistors very difficult. Therefore, several groups have been proposed different methods to open a band gap in graphene. The electronic structure of pristine graphene sheet and three different adsorption sites of H2S onto graphene sheet were studied. Calculations show that the adsorption of H2S on top site open very small direct energy gap. Comparing the angular momentum decomposition of the atoms projected electronic density of states of pristine graphene sheet with that of H2S-pristine graphene for three different sites (bridge, top and hollow), we found significant influence and strong hybridization between H2S molecule and graphene sheet. Thus pristine graphene sheet is very good adsorbent materials for H2S molecule. In addition the linear and nonlinear optical susceptibilities of pristine graphene and H2S adsorbed at three different sites onto graphene sheet are calculated so as to obtain further insight into the electronic properties. Calculations show that the adsorption of H2S on top site cause significant changes in the linear and nonlinear optical susceptibilities. That is attributed to the fact that adsorb H2S onto graphene sheet cause significant changes in the electronic structures, and strong hybridization between H2S molecule and graphene sheet, as a results of the strong hybridization a strong covalent bonds were established between C, H, and S. A DFT calculations based on all-electron full potential linearized augmented plane wave (FP-LAPW) method, was used. In order to understand the adsorption properties of H2S molecule adsorbed onto graphene, all possible adsorption configurations (top, bridge and hollow -sites) were considered.

Andrzej Szymkowiak

Crowdsourcing as a source of popularity for mobile applications

SPEAKER: Andrzej Szymkowiak

ABSTRACT. What drives consumers to choose and download mobile applications from over 2.8 million available on android? Is the decision-making process different when we pay or download a free application? In what situations are consumers willing to share an application's opinion? How many other opinions affect the number of downloads? The study was carried out by 5881 of the most popular applications in each of the 49 categories. Statistical surveys have made it possible to identify statistically significant factors. The study separated the analysis separately for paid and unpaid applications, including the number of downloads, the number of appraisals and their value, and the application history.

David Pastor-Escuredo, Maria Jesús Ledesma-Carbayo and Nadine Peyriéras

Computational cell lineage dynamics to understand embryogenesis

SPEAKER: David Pastor-Escuredo

ABSTRACT. Digital cell lineages reconstructed from 3D+time imaging data provide unique information to unveil mechanical cues and their role in morphogenetic processes. Our methodology based on a kinematic analysis of cell lineage data reveals deformation patterns and quantitative morphogenetic landmarks for a new type of developmental table. The characteristic spatial and temporal length scales of mechanical deformation patterns derived from a continuous approximation of cell displacements indicate a compressible fluid-like behavior of zebrafish gastrulating tissues. The instantaneous deformation rate at the mesoscopic level of the cell's neighborhood is spatially and temporally heterogeneous. The robustness of mechanical patterns results from their cumulative history along cell trajectories. Unsupervised classification of mechanical descriptor profiles was used to assess the homogeneity of biomechanical cues in cell populations. Further clustering of cell trajectories according to their cumulative mesoscopic biomechanical history during gastrulation revealed ordered and coherent spatiotemporal patterns comparable to that of the embryonic fate map.

Shanee Stopnitzky, Stephan Munch and Donald Potts

The chaos of coral reefs: an assumption-free approach to causality, dynamics and predictions in ecosystems

SPEAKER: Shanee Stopnitzky

ABSTRACT. Although there is a high risk of continued coral reef loss on a global scale, responses to widespread stressors at local and regional scales indicate that resilience to chronic stress is possible, but also variable. Coral reefs are complex systems that exhibit nonlinear behavior, including chaos, feedbacks, multistabilities, cascading effects, adaptation and emergent phenomena. Using traditional models to resolve the dynamical processes that control resilience is problematic due to error from excluded variables, incorrectly identifying mirage correlations as system drivers, and untestable assumptions about relationships between variables. Alternatively, a changing coral reef can be considered a trajectory through different states, whose change over time depends on previous states and is determined by a set of rules. We present a promising technique for understanding and forecasting ecosystems that is adapted from single-species Empirical Dynamic Modeling, using time series data to reconstruct nonlinear state space. This reconstruction preserves the topology of its chaotic attractor manifold, which represents a trajectory of linked variables through state space, allowing us to correctly discern shared causal drivers from interactions. Without the need for error-inducing model assumptions, this approach also outperforms many other tested models for forecasting system dynamics. We show ecosystem-scale predictions from simulated and real data that demonstrate the tremendous value of this tool for improving our understanding and management of coral reefs in a changing world.

Arturo Leos Zamorategui

Dynamical approach to the phase transition in kinetically constrained spin-gasses via population dynamics.

SPEAKER: Arturo Leos Zamorategui

ABSTRACT. By means of a population-dynamics algorithm we explore statics and dynamics of the Fredrickson-Andersen and the North-East kinetically constrained model in two-dimensional set-ups with L^2 sites, they correspond to strong and fragile glasses, respectively. We investigate these systems with two different boundary conditions: the FA with all the sites on the left boundary active (FAL), the FA with the corner active (FAC), and the NE with the corner active (NEC). The so-called cloning-algorithm allows us to explore the dynamical phase transition occurring at a finite s corresponding to the modified evolution of the master equation of the process, which scales as s = 1/L for the FAL and s=1/L^2 for the FAC and NEC. With such algorithms we have access to, in principle, unphysical configurations corresponding to rare events. In particular we explore a 'less-active-than-average' regime where mobile defects propagate along the system more slowly than for the unmodified dynamics corresponding to the physical system. Finite-size effects are discussed and some heuristics about the transition are given.

Sehyun Kim and Soo Yong Kim

A new approach to detecting sub-community structure in high-dimensional data

SPEAKER: Sehyun Kim

ABSTRACT. For complex systems described as networks, modularity maximization has been emerging as one of community detection methods like PCA and network analysis, due to their intuitive concept and application potential to real systems in spite of the resolution limit. By the traditional methods, however, sub-community structure may not be clearly revealed in many cases. For the complex system of which nodes are expressed in high-dimensional feature vectors, we propose a new procedure using archetypal analysis (AA) and an invented quality function for uncovering the multiscale community structure of the system, visualize the structure with t-SNE and also use machine learning techniques for optimization issues. In this study, we reveal macro- and sub-community structures of various complex systems including generated system, financial system and bioinformatics system with the proposed approach and other traditional methods, and also show that the proposed one can overcome the limit of traditional ones in community detection.

Marcos Aurelio Gomes Da Silva

chemistry complexity

SPEAKER: Marcos Aurelio Gomes Da Silva

ABSTRACT. Complexity" is a subject that is beginning to be important in chemistry. Historically, chemistry has emphasized the approximation of complex nonlinear processes by simpler linear ones. Complexity is becoming a profitable approach to a wide range of problems, especially the understanding of life.

Ton Jörg

On A Generative Revolution in the Age of Complexity

SPEAKER: Ton Jörg

ABSTRACT. Living in the Age of Complexity “we are running against the hard wall of complexity” (Barabási, 2003, p. 6; emphasis added). This describes nicely the problem posed by complexity for both science and society at large. Actually this state of the art describes the very ‘crisis of knowledge’ we are in nowadays (Cilliers, 1998, 2011; Jörg, 2014). The knowledge available has very much become a problem itself instead of the solution (see Müller-Prothmann, 2006, p. 14): that is, the solution of the deep problem of complexity for science and society. We seem to be very much imprisoned in our regular description of society (Wierzbicka, 2014). Helga Nowotny has described this state of the art as “the embarrassment of complexity” (Nowotny, 2013, 2016). We not only do not know what we do not know. We also do not know how to know what we do not know. According to the Santa Fe Institute we still have no general theory of complexity available (SFI, 2015) for an adequate description of the complexity of our society. Some scholars like Stuart Kauffman (2009) have recognized that we urgently need “a radically altered account of reality” (p. xv). It may be argued that for such an altered account of reality we really need to go beyond mainstream science (see Mitchell, 2011, p. 303). We urgently need a new science of complexity. The concept of complexity as we know it is insufficiently complex, unable to deal with the true nature of complexity of reality which is dynamic, multi-dimensional, and web-like. The so-called ‘paradigm change’ involving complex systems and complexity (Nowotny, 2016, p. 42) and the corresponding science of complexity “is still in its early stages” (Mitchell, 2011, p. 303), waiting to be developed. To deal with complexity, and to develop an adequate science of complexity which fully recognizes the true nature of complexity of reality, we may actually need a new scientific revolution: that is, a generative revolution (Jörg, 2017). This generative revolution may show the possibility of a new foundation for science: that is, a generative foundation (Jörg, 2017). This generative foundation implies a generative approach of complexity: an approach which fully recognizes complexity as generative, emergent complexity (Jörg, 2011, 2016; cf. Lichtenstein, 2014). We may open up new spaces of complexity in which complexity may operate as self-potentiating and self-perpetuating (see Rescher, 1998; and Arthur, 2015) within networks and their “dense and highly dynamic web of interconnections” (p. 132). From this we may derive a radically altered account of reality: an account in which the boundaries between “a reality that exists and a reality that is being made become blurred” (ibid., p. 132). Reality, then, may be taken as a new kind of generated reality (cf. Nowotny, 2016, p. 132). Finally, we may develop a science of complexity with “new kinds of complexity” (ibid., p. 132). Interestingly such a science of complexity may be viewed as a verb-based science (Arthur, 2015, p. 25).

Fabricio Vasselai

Life's butterflies - a simulation-based analysis of Conway's Game of Life sensitivity to random perturbations

SPEAKER: *Fabricio Vasselai*

ABSTRACT. In this paper, I utilize a General-Purpose GPU based implementation of Conway's Game of Life (GoL), in order to conduct a highly computer-intensive assessment of how sensitive GoL is to randomly introduced perturbations. Since the GoL is fully deterministic and dependent on the games' initial configurations, I argue that it is relevant to differentiate perturbations of two types: 1) random slight changes in the initial conditions of a given model-run and 2) random alterations to the live cells of the simulation space at a randomly chosen iterations - which resembles the so-called butterfly effects. I run thousands of different GoL runs, each with its own pseudo-random number generating seed, which I call benchmark runs. Then, I repeat each of such runs also thousands of times – but then introducing random changes at random iterations. Such changes can be juts flipping the live-dead state of one or a few given cells, or it can be introducing an oscillator or a glider in the simulation space. In all cases, I store the type of introduced perturbations, the iterations when they were introduced, their relative position in relation to the mass of live cells at the moment when perturbations were introduced, as well as the percentage of different live cells of each subsequence iteration in comparison to their counterparts in the same-seed benchmark game run. Doing that means processing dozens of millions of GoL cells, which is why I resort to highly parallel computing using Nvidia's CUDA to implement GoL at the GPU. The basic idea of the simulation is to measure the extent to which the GoL is indeed sensitive to changes in initial conditions, but more importantly, to the occurrence of later butterfly effects. More importantly, however, the elaborate goal is to measure how much space and time affect the effect of such butterflies. That is, to which extent the GoL iterations are altered depending on how close butterfly effects happen? How long does it take to big changes to manifest in relation to when perturbations were introduced? Since it is well known that GoL's self-organizing criticality is itself sensitive to the size of environment grid, to increase the robustness of the simulation, I aim at implementing GoL grids that have each side being of a big enough size such that no living cell ever reaches the boundaries. Which is a technical way to implement unbounded grids at the GPU. Also, I vary the pseudo-random generation of the initial conditions by using uniform, normal and poisson distributions. If time permits, it is also in the plans to test the simulation on Perlin-noise based initial conditions and on the well-known complicated initial configurations.

Dario Riva Palacio Rosado and *José Eduardo Mejía Venegas*

From to be or tohave in the Situational Adaptive Complex System; An epistemological critique of the neoliberal theoretical path.

SPEAKER: *Dario Riva Palacio Rosado*

ABSTRACT. The scientific ideal of the seventeenth and nineteenth century conceived the world as a completely deterministic system, and consequently economic theories were erected and remain valid for their study and application. In contrast to this method; in this work we address the socio economic interrelationships as a complex adaptive system which we call situation (or situational system).

The operation of a system as an interrelated set of teleological subsystem functions generates a self-organized dynamic interaction towards an emerging order. Given these interrelationships, emerging processes would arise, causing a system to be complex, and because this is homeostatic, we can talk about complex adaptive systems.

Taking the previous considerations into account, we tackle neoliberalism, which is characterized by devising economic, political and social positions against regulation or economic intervention from the state. Against inequality and individualism, it recovers the individual freedom notion and the laissez faire, laissez passer (free market).

The situational trajectory is the concept of our system in time, its structure, and its adaptive capacity. In the first part of this work, we will deal with the historical reconstruction of this path.

Neoliberalism gets access to the previous situational structure from the ideological and cultural subsystem as a catalyst that modifies the legal and political subsystem.The consequences that were persecuted (and still are) were, apparently, purely economic. And yet, as it is empirically verifiable, these consequences are spread throughout the systemic structure.

In the context of the economic policy that started in the eighties, Neoliberalism in Mexico was characterized by the liberalization of markets including the financial sector; under the opening of this sector, we could take note of the devaluation of that productive work and that this effect spreaded to the ideological and cultural field. We broke down the concept of work and the relation with the State, Money and its flow to the productive field which propagated or spreaded some virtual values that were completely away from the creative source of value. We generated an internal structure which currently shows the symbolism of money and the ideological flow between two concepts: To be and To have.

Along with this vision, it is revealed that the unidisciplinary theoretical fetishism has impacted on everything, for example, in its respect, the political fetishism dissociates itself from the society that is to represent; the economic fetishism in terms of pricing but not dealing with social problems; or the cultural - ideological fetishism in terms of that ethnic or racial segregation which supports broadcast stereotypes; this becomes evidence.

The hypothesis that complex (social) reality can not be understood from the theoretical approaches that support the neoliberal ideological model is asserted. It cannot be understood from the unidisciplinarity. And, therefore, it cannot be tackled and treated from such approaches. The public sector problems are not economic problems; they are not political problems; nor any problems of any other particular kind either; they are all holistic, transdisciplinary and dynamic. They are all complex problems.

Jose Osorio- Antonia, *Lila Bada- Carvajal*, *Luis Arturo Rivas- Tovar* and *Fredy Juarez- Perez*

Competitiveness Analysis of Maize Producers in Chicontepec Veracruz, using agent-based modeling

SPEAKER: *Jose Osorio- Antonia*

ABSTRACT. The objective of this research is to evaluate maize production in Chicontepec using agent-based modeling that describes the relationship between organization, support policies, climatic conditions, production costs, yield, marketing to design a model to ensure competitiveness. (Veracruz State) and local (Chicontepec municipality), as well as the production levels of the most prominent countries, as well as the leading Mexican entities to the municipalities of greater production in the state of Veracruz and the characteristics of the nature of corn production in the municipality of Chicontepec. Research subjects were Chicontepec maize growers from Tejeda Veracruz. The method was the complex system analysis to the variables to be used in this research are based on the theoretical, contextual and state of the art presented previously, which will serve to evaluate the production of corn in the municipality of Chicontepec and simulate the competitiveness of the same through modeling Based on agents with the software called NETLOGO. The results determined that the main maize producers in Mexico are the states of Sinaloa, Jalisco, Mexico, Michoacán, Chihuahua, Guanajuato and Veracruz. According to its volume of production since although Sinaloa sows less hectare than Chiapas, its rate of productivity in the country's largest 9.95 vs 1.62 (Agri-food and Fisheries Information Service, 2017) and the Veracruz field is one of the engines that Promotes the development of the country; Historically, the state of Veracruz is among the top seven maize producers in Mexico, the main producing areas are San Andrés, Papantla, Soteapan, Isla, Jose Azueta, Playa Vicente among them is Chicontepec in 2015 Place number 15; The municipality of Chicontepec is one of the most productive and has the potential however the low price of production has led the producers to switch to the cultivation of orange. The relevant of findings is that our work is the first research to study maize production in Chicontepec using agent-based modeling.

Eduardo Martinez- Mendoza and *Luis Arturo Rivas- Tovar*

Complexity and patterns formation in Wind energy in Oaxaca

SPEAKER: *Eduardo Martinez- Mendoza*

ABSTRACT. The objective of this investigation is to show the interrelation between the economic, social and environmental impacts of a wind project. Wind energy is one of the most environmentally friendly sources of energy. However, there are questions about its benefits in the economy of the communities where it is installed, and in the case of the Isthmus of Tehuantepec, the uncertainty about its impacts on human health, flora, fauna and wáter. The lack of information about of wind farms impacts and the deficiency in the inclusion in decision-making have generated serious social conflicts in the Isthmus of Tehuantepec, which have culminated in the division of communities, legal processes, acrimony, and fights with the police and even death of people. The research method started from the literature review to identify the main economic, social and environmental impacts of a wind project and its interrelation. Qualitative analysis was used for the treatment of interviews carried out to development companies, local authorities, opposition organizations and academics to know the relationships that keep the impacts studied. This analysis offered information to develop the Forrester diagrams, and to model the relationships that exist between the impacts studied of the wind sector. The results show the existence of pattern formation between the economic, social and environmental impacts of wind energy. This information reveals that decision-making must occur from a systemic perspective, not only under the environmental or economic emphasis as has occurred in the study area. Complex systems are one opportunity to analyze the evolution of impacts across the time, to analyze wind energy development through different scenarios even before building a wind farm. The wind energy development can be analyzing as complex system, where a lot stakeholders are integrated, and anyone have different knowledge, interests, and have different perception about the wind energy impacts. The relevance of this research is that is the first research about Economic, social and environmental impacts of wind energy in the Isthmus of Tehuantepec.

Edith Garcia- Garcilazo, Luis Arturo Rivas- Tovar and Magali Cardenas- Tapia

Patterns Analysis of drug traficc at the International Airport of Mexico City

SPEAKER: Edith Garcia- Garcilazo

ABSTRACT. The objective in made an analysis of those patterns of concealment that passengers use when they want to enter drugs at the Airport, in this case in particular in Mexico City. The research was carried out by conducting a network analysis and, above all, an analysis of those new methods of concealment that have been detected by the airport authorities and are currently used in our country. The importance of the study lies in the analysis of the patterns, using most of the public statistical data of the customs authorities and the data compiled in the main newspapers of the country. The method will be the network analysis between Airlines, country, and drug dealer profile with use of software CYTOSCAPE 3.2. The results reveal that the entry of these products into Mexico, mainly cocaine, cannabis and pseudoephedrine, is increasingly taking on innovative methods of concealment, from being introduced into the body, such as making utencils made from the same drug. It is certainly a difficult task for the customs authorities because it is necessary to have increasingly sophisticated instruments to detect them in time. The relevance of this research is vital as it is highlighted in the government's fourth report of 2016, which in the first seven months of 2016 secured 414 tonnes of cannabis, a reduction of 25% compared to the 558 tonnes insured in 2015. (4th Government Report, 2016). Undoubtedly a subject of great relevance at the national level. This is the first analysis using Complex Systems Analysis in drug traffic in Mexican airports.

David Salas-Rodriguez and Luis Arturo Rivas-Tovar

Complexity Analysis in Air management in Guanajuato State (Mexico)

SPEAKER: David Salas-Rodriguez

ABSTRACT. The Objective in this research is a study of the models of air quality management applied in the five megacities of the state of Guanajuato. Air quality management takes a new and relevant approach with the Paris agreement of 2015 because it includes a greater number of countries ratifying the agreement as well as the inclusion of other stakeholders such as civil society, industry, financial institutions, Cities and subnational authorities. The importance of the study lies in the study of air quality management models as complex systems formed by subsystems using unconventional methods such as complex systems theory and structural modeling to explain their impact on air quality management in the megacities. The Method used was mixted: a) Documentary research is applied to build the theoretical model of air quality management in official documents such as air clean acts, ONU climate change convention, Paris 2015 agreement and b) Structural modeling is applied and a comparative analysis with Spain case and to a set of thirteen manifest variables obtained from the public database of the World Bank. The Results were parameters examined applying the LART 2009 environmental management model, identifying the eight instruments: international instruments, legal, economic, political, cultural, educational, social and technological explaining the alignment of the agreements of Paris 2015 with the local management in the cities, the case of Spain is taken for this study. Data were collected from the World Bank on greenhouse gas emissions, urban density, agricultural and wildland extension to construct a structural model to identify the main factors related to climate change management in countries reporting their emissions in 1995 using the STATA software. We also found two formative factors of two latent variables that explain: CO2 emissions per capita, urban population, use of fossil fuels and access to solid fuels as well as agricultural land, jungle areas and exposure to emissions Of PM2.5.. The interpretation at the time of this result observing the indicators of 1995 reveals that the management of the climatic change was insufficient because one of the two manifested variables formed by the indicator: agricultural surface, forest area and exposition to the PM2.5 present positive charges for the agricultural area and exposure and negative for the wildland area. The relevant of Findings shown that No studies have been found regarding models of air quality management that include management variables, most of them refer to mathematical models for the prediction of pollution, taking as variables: meteorological aspects and pollutant criteria.

Magali Cardenas- Tapia and *Luis Arturo Rivas- Tovar*

Network Analysis in Scientifics Collaboration in Mexican Environment researchers

SPEAKER: *Magali Cardenas- Tapia*

ABSTRACT. The objective is the pattern formation analysis of an environment network from National Polytechnic Institute in Mexico. Networks have acquired an important relevance as a vehicle for collaboration and knowledge generation with regard to finding solutions to environmental problems. The importance of the study lies on the analysis of the network, using graph theory to explain network's structure. The coauthorships network reveals important structures that compose the scientific community social network. The method was the network analysis to three variables: Betweenness centrality, Clustering coefficients and Node Degree distributions. We collected information from the network members' scientific production in order to examine their collaboration with other researchers and analyzed their coauthorships. The collaborations of 231 researchers were analyzed in the scientific production of Articles, Books, Books chapters and Thesis Direction, in the 2011-2013 period. The researchers belong to 14 research centers of the IPN, which are members of the Environment Network (REMA).The software used was CYTOSCAPE 3.2. The results reveal that the network is in its beginning, and the parameters betweenness centrality, clustering coefficients and degree distributions are low (Freeman, 2000, & Newman, 2003) with respect to a fully connected network. The results suggest that it will be necessary to review institutional policies in terms of resource allocation to encourage collaborative work, in order to increase the parameters value of betweenness centrality, clustering coefficients and node degree.

Roland Terborg and *Virna Velázquez*

IS DISADVANTAGE IDENTICAL TO LINGUISTIC INEQUALITY? A COMPLEX PERSPECTIVE.

SPEAKER: *Roland Terborg*

ABSTRACT. According to the catalogue of the National Institute of Indigenous Languages in Mexico indigenous languages are an integral part of the cultural heritage of the nation that gives the Mexican Nation greater expressions of multiculturalism. This leads us to the questions: Should we save the speakers to promote their culture or should we support culture to help speakers? What at first seems the same sometimes can be very different. In this paper we will deal with the problem of Spanish in conflict with the indigenous languages of Mexico and if language shift of these languages will lead to disadvantages for their speakers. Our purpose is to analyze if disadvantage is identical to inequality from a complex perspective. Using our theoretical framework of 'ecology of pressure' we will analyze if indigenous language speakers experience disadvantage in contrast with monolingual speakers of Spanish and if so, if disadvantage will always coincide with inequality.

Roberto Sánchez, *Javier Ureña* and *Omar Torres*

Recommendation Algorithm of Social Policy Based on Risk Analysis and Early Warning Systems.

SPEAKER: *Roberto Sánchez*

ABSTRACT. In order to improve the targeting of social programs, the System of Integral Social Information (Sistema de Información Social Integral - SISI) strives to create a platform to help analyze multi-dimensional data not usually taken into account when developing social policy in Mexico. The proposed approach is to create various compound indicators based on different early warning systems tailored to tackle areas of interest in social policy; as such, all indicators would create a profile of geographical areas and help target social programs in a more thorough manner.

Maria De La Paz Ramos Lara

Complex systems for studying the history of educational institutions

SPEAKER: *Maria De La Paz Ramos Lara*

ABSTRACT. Complex systems have made advances in the social sciences and the humanities in recent decades. This paper presents a proposal to study the origin and evolution of one of the most important educational institutions in our country, the National Preparatory School (ENP), considered the origin of the National Autonomous University of Mexico. The ENP was created in a social, political and economic environment on the edge of chaos, between order and disorder, where the teaching staff worked as a small world network generating a process of self-organization, through which their educational model was reproduced in other regions of the Mexican nation and with the capacity to help in the creation of other institutions.

Edgar Gaytan

Complex interactions between Social and environmental process in Mexico Valley

SPEAKER: *Edgar Gaytan*

ABSTRACT. I researched, through an interdisciplinary and complex adaptive systems approach, the explanatory burden that the environment has in the manifestation of specific diseases associated with chronic stress. The study focuses on human populations vulnerable environmentally and socio-recurrent exposure to risk of disaster, particularly by severe flooding. I propose to describe the interwoven complexity in the interaction between environmental and social systems. Chronic stress is an emerging bio-cultural process that affects urban co-morbidity and mortality differential in human populations exposed to factors of socio-environmental risk. Through the support of multivariate statistical modeling procedures I analyzed the relationship between adaptive responses and socio-environmental factors that contribute to the expression of comorbidity associated with living conditions in vulnerable and not vulnerable urban contexts. Allostatic load was measured in two urban communities located within designated vulnerable zones and high risk of flood in the region of Valle de Chalco, Mexico and two control populations located in the Coyoacan and Tlalpan municipalities of Mexico City. This methodology combines different qualitative and quantitative data analysis. The variables that I considered were constructed from anthropometric and physiological parameters associated with the presence of stress as a factor in chronic diseases such as: hypertension, cardiovascular disorders and obesity, among others. The methodology of the thesis focuses on the review and analysis of the processes that result from the interactions between the social system and the environment. I qualitatively analyzed the perceptions and social representations of spatial context at the local level in four colonies and extracted physiological biomarkers from a sample of 160 people to measure the response of perceived stress and environmental pressures. I concluded that the environment plays an important role in the manifestations of non-communicable diseases such as hypertension and obesity.

Erick Adrian Pérez Mora

Comparative institutionalization for Open Government.

SPEAKER: *Erick Adrian Pérez Mora*

ABSTRACT. This paper propose to compare how Open Government (OG) has been implemented by the Open Government Partnership (OGP) participating countries; as well as, to analyze institutionalized practices related to the issue in all other countries.

Neftaly Cruz-Mireles, *Georgina Estrada-Navarrete*, *Carmen Quinto* and *Federico Sánchez*

Autophagy is essential for the symbiotic relationship between Phaseolus vulgaris and both rhizobia and arbuscular mycorrhizal fungi

SPEAKER: *Neftaly Cruz-Mireles*

ABSTRACT. Most plants establish symbiotic interactions with soil microorganisms such as arbuscular mycorrhizal (AM) fungi and/or rhizobacterias. Such interactions provide nutrients that are not readily available in the soil for plant uptake. These mutualistic interactions require the regulation of different intracellular trafficking pathways. Phosphatidylinositol 3-kinase (PI3K) Class III is a key trafficking regulator by mediating the synthesis of Phosphatidylinositol 3-phosphate (PI3P). It is known that PI3K is regulated for the AutTphagy Gene 6 (ATG6) by forming a complex. Although both proteins have been studied in plant immunity as key regulators, its role in symbiotic interactions is poorly understood. Here, we report that down-regulation of Phaseolus vulgaris PI3K (PvPI3K) severely impairs both nodule and mycorrhiza symbiosis pathways. Concordantly, PvPI3K down-regulation affects early stages of symbiosis responses involved in root colonization. Furthermore, we show a drastic reduction in transcript accumulation of autophagy-related genes in PvPI3K down-regulated background. Seemingly, loss-of-function of the autophagy gene Beclin1/Atg6 phenocopies PvPI3K down-regulation in transgenic roots. Our findings show that autophagy related proteins are crucial for mutualistic interactions of P. vulgaris with beneficial microorganisms.

J. Adrián Sánchez Castro, Mauricio González Soto, Raul Zagal Rojo, Ollin D. Langle Chimal, A. Isabel Millán Careaga and Adolfo Javier De Unánue Tiscareño

Complex Social Network Analysis of Key Player's Role on Conversation Dynamics

SPEAKER: J. Adrián Sánchez Castro

ABSTRACT. The new Online Social Networks (OSN) are examples of complex social systems that reflect continuous interacting behavior among individuals and organizations. All the prominent actors of the Mexican Entrepreneur System are part of Twitter (an example of online social media network platform) that constantly interact through this network, by publishing the most relevant content (ideas) that each of these actors produce or share.

In this paper, we define an explanatory model of the Entrepreneur System in Mexico's behavior through Twitter online social network. We aim to model a complex system of the Mexican Entrepreneur System actors that interact through microblogging (tweets) to grasp an emergent social phenomena: a pattern behavior that correlates the conversation topics and the flow of information through the network by understanding the network's central key players.

For achieving this endeavor, we rely on a Data Product Architecture (DPA) realization allowing us to model thousands of conversations gathered from tweets of Mexican Entrepreneur System's actors in a streaming basis. The idea is to extent the advantages of a data science product architecture that can provide the extraction of patterns of large data volumes and model them into a heterogeneous-multiplex network in a graph-database engine.

Like many of the real world networks, the graph-model that we propose is defined by multiple types of actors and distinct types of interactions that defines a complex graph. We demonstrate that conversation flows and spread of information are well defined by central key players in the system. Those so called key players define the structure of the network as a hierarchical one, making the propagation of information asymmetrical in different layers. Using our model we prove that key player performe a central role in the information dynamics of the network.

In addition, by capturing the conversations of each key player actor in this network, we perform a Natural Language Processing (NLP) analysis in order to obtain the topics and sentiments of conversations. By the propagation of topic conversations through the network, we can understand not only how the information is flowing but also what kind of topic this information is coming from. Moreover, by applying a dynamic network analysis we detect and represent structures of the social system that can enhance the explanation of the occurrence of the collective whole behavior.

Samuel Hidalgo-Caballero and Felipe Pacheco-Vázquez

Dynamics of saturated granular media discharged from a silo

SPEAKER: Samuel Hidalgo-Caballero

ABSTRACT. The flow rate of grains discharged from a silo is independent of the height of the granular column above the outlet. In contrast, for a liquid, the flow rate depends on the hydrostatic pressure. Now, if both materials are discharged simultaneously, a model to describe such dynamics is missing in the literature. On one hand, Darcy's Law is used to describe the steady-state water flow through sand columns. It states that water flux in saturated porous media is linearly proportional to hydraulic gradient. Nevertheless, for low-permeability porous media, Darcy's law is not adequate because of the strong fluid–solid interaction that results in non-linear flux-gradient relationships. On the other hand, the Kozeny-Carman relation is used to calculate the pressure drop of a fluid flowing through a packed bed of solid particles. This approach considers a laminar flow in a collection of capillaries where we can use the Poiseuille's law for a laminar viscous flow. However, if the packed bed is also moving, we do not have a simple relation to describe the granular or liquid flows.

Here we studied the dynamics of saturated spherical glass beads being discharged from a vertical silo. We found that in this case the flow rate depends on the column height but also on the grains size and aperture diameter with a non-linear behavior. We estimate experimentally the permeability for each packed bed, then we solved numerically the Navier-Stokes equations for a non-compressible laminar flow in the cylinder, and finally we compared the theoretical results with the experiments.

Josue Miguel Flores-Parra, Manuel Castañón-Puga, Luis-Guillermo Martínez, Ricardo Rosales, Carelia Gaxiola and Alfredo Tirado-Ramos

Towards social network analysis for student project team formation

SPEAKER: Josue Miguel Flores-Parra

ABSTRACT. In some undergraduate courses in computer science or engineering, it is necessary to form teams with the students to accomplish projects. For many teachers, classroom projects are a learning strategy that could help develop the proposed course skills. An important skill to practice is teamwork, especially in engineering where the student is expected to learn how to collaborate with peers. There are many ways to configure a student group to set up a team, but we would like each team to be qualified to develop the proposed tasks successfully. One way is to create groups randomly, but some of them could be unproductive and fail. Another way is voluntarily set groups, but the success of all cannot be assured equally. Even more, there are other strategies based on student profiles, such as personality traits, learning styles, or other information that we can group through some clustering methods. Finally, we could use social networks to analyze the relationship between students to discover other ways to create groups for teamwork. Sociograms is a visual social network description of individual preferences to other peers. It is used to build a social network to find social traits or identify featured individuals. For example, we could use it to discover structures, applying social network analysis algorithms to find triads of individuals with similar attributes. The triads can express the local structures in social networks. Many theories about social relations can be tested using hypotheses about the triad census. In this work-in-progress paper, we used sociograms to represent social links between students. In our case of study, each student expressed their preferences for working with other three peers at the course beginning, and this information was used to detect cliques within the social network using network analysis algorithms. Although first we were focused on clique structures in order to describe the natural formed groups, then we tried find triads structures because we are interested in three members' team's behavior specially. Finally, we compared the network analysis results versus groups formed by a teacher in a real course, and we discussed the advantages and disadvantages of the student project teams from complex networks analysis approach.

Citlalli Limpens and Roberto Álvarez-Martínez

Modelling immune response dynamics as predator-prey systems

SPEAKER: Citlalli Limpens

ABSTRACT. Predator-prey models, specially Lotka-Volterra-type models, are one of the oldest mathematical approaches to ecological dynamics. They are even used -in addition to other techniques- to model immune response dynamics, in which the immune systems acts as the predator; and the parasite (or parasites) act as prey. In this work, we analysed five immune functional responses and four parasite growth functions from existing and new predator-prey type models. The models we are contemplating for the immune system functional response are: Lotka-Volterra, Holling type II, Holling type III, DeAngelis-Beddington and Crowley-Martin. These last two, hadn't been previously proposed as immune system models. For the parasite growth functions we are considering exponential growth and the logistic model, both with different parameters for micro and macro parasites. Our preliminary results show that stationary stable states for the parasite remain the same for every parasite growth type, in spite of the changes in the immune system functional response, however the immune response stable states change depending on both aspects of the function. Finally, we performed a symbolic regression approach using time-series data from immune and parasite populations inside an individual. So far, the method shown here is the first capable to infer mathematical models directly from data. Given the difficulty to calculate some of the parameters involved in our equations, this technique proved to be the most exact and achievable.

Carla Elisa Chong González and Gustavo Pacheco Guevara

Dipole-Dipole And Dipole-Ion Intermolecular Interactions: A Complex Approach

SPEAKER: Gustavo Pacheco Guevara

ABSTRACT. Dipole-dipole and dipole-ion intermolecular interactions play an important role in a wide variety of phenomena involved in different areas, e.g. the behaviour of dielectric materials in electronics as well as in biological processes such as a polypeptides' choice of structure.
This project presents a model of molecular interactions of the aforementioned type, accompanied by a simulation based on cellular automata. It also includes a comparison between such model and its results and one determined by MD calculations as well as with experimental data.
Its main goals were to gain a better understanding of the larger scale phenomena that may arise from this kind of interactions so as to have a more complete picture of the systems involved at a larger scale, as well as determining whether cellular automata modelling can contribute to their study.

Jesús Enrique Hernández-Zavaleta, *Vicente Carrión-Velázquez* and *Gustavo Carreón-Vázquez*

The complexity of the educational phenomenon. The case of the basic mathematics teaching

SPEAKER: *Vicente Carrión-Velázquez*

ABSTRACT. The collective –students, teachers and their interactions- as a complex phenomenon has been studied in education in recent years. A complex approach considers the classroom as an environment where the students cover the needs of learning. The prevailing knowledge, the teacher participation, and the ways of communication are established.

In the case of mathematics education, several researches have been interested in the collaborative learning of the students including the creativity and the problem solving. A way of approaching to teaching - learning process is studying the development of the collective ideas and depersonalizing the individual contributions; this means the emergence of new ways of assessments.

This work shows some empirical results about the tendencies of subjects involved in a mathematical problem situation and the characterization of obstacles for solving it; for example the presence of obstructions coming from the semantics over the syntax and vice versa, the provision of the intermediate senses, the impossibility of trigger operations that could do moments before, between others.

By using the Agent Based Modeling we propose an abstract model of a classroom to analyze the collective learning and propose a mechanism to model the obstacles coming from empirical results. It considers two representative agents, the student and the teacher. The relations among them are established by communication channels, where “knowledge units” flows. The assessments are the feedback mechanism that measures the performance of the agents.

Nayely Velez-Cruz and *Manfred Laubichler*

The Phenotype-Genotype-Phenotype Map

SPEAKER: *Nayely Velez-Cruz*

ABSTRACT. Here we introduce a robust mathematical and data analytic framework for a mechanistic explanation of phenotypic evolution that is conceptually rooted in developmental evolution theory. We respond to the lack of evolutionary models that integrate multiple simultaneously-occurring mechanisms of inheritance with developmental mechanisms in order to explain the origins of evolutionary novelty. We explore a re-conceptualization and an associated mathematical formalism of the Phenotype-Genotype-Phenotype (PGP) Map, which is based on Laubichler & Renn’s framework for extended evolution. Conceptually, rather than to begin with the genotype, as is the case with the genotype-phenotype map, we instead begin with a phenotype—an agent in Laubichler and Renn’s extended regulatory network model. A phenotype can be a single trait, a complex of traits, an organism, or a system at any scale. The phenotype is then “decomposed” into a unit of inheritance (genotype, or “features”) which passes the generational divide and is then “reconstructed” via developmental processes. Examples of features include, but are not limited to, gene regulatory network motifs, specific interactions between molecular agents (e.g. transcription factor modules), developmental mechanisms, epigenetic interactions, and of course, an organism’s genotype. This abstraction avoids later post-hoc assumptions about the genotype-phenotype map in exchange for a model of phenotypic evolution that places the explanatory power in the processes of inheritance and development. The PGP Map framework is thus capable of uniting the proximate/mechanistic explanation with the evolutionary explanation by providing a mechanistic explanation of phenotypic evolution. To accomplish this, we have developed a mathematical and associated computational framework for the PGP Map based on digital signal processing (DSP) and wavelet analysis, as it ensures that the conceptual framework, mathematics, and computational implementation are as identical in structure and logic as possible. The framework integrates concepts and methods from wavelet theory, machine vision, and graph theory and is thus a flexible tool that facilitates the conceptual interpretation and multi-scale modeling of known phenomena of phenotypic evolution (e.g. multiple mechanisms of inheritance, gene regulatory network dynamics, among others). The PGP Map is implemented in TensorFlow, a machine learning interface used for data analysis via custom designed computational graphs. This makes the PGP Map amenable to empirical test by allowing for the integration of multiple types of biological data, such as single-cell genomics and epigenomics data, gene expression data, and/or phenotype-environment interaction data, to list a few.

Luis Enrique Marines Hernández

Knowmap: Antidisciplinary cartographies for tackling complex problems

SPEAKER: *Luis Enrique Marines Hernández*

ABSTRACT. To approach complex problems for research and collective intervention purposes requires a self-organization process between heterogeneous agents that regularly originates conflicts in terms of ideology, language, terminology, techniques and methods, —mostly because of epistemological contrasts among fields of knowledge. These conflicts have direct impact in the coordination of agencies, and in the way that strategies are variated, selected and adapted, enabling or obstructing the interactions flow and its productive results.

This paper conceives that kind of conflicts as disciplinary interaction processes that bring into play a series of forces, interests and positionings of both individual and collective human identities related to a disciplinary formation. Disciplinary interaction has different orientations, such as mono, inter, multi, trans and metadisciplinarity; and it represents by itself a complex problem related to the modes of knowledge production and small groups dynamics.

To face this scenario, the author proposes to design a strategic instrument for disciplinary interaction called “Knowmap”, based on the following assumptions: (i) Research and intervention for complex problems requires the formulation of systems-oriented strategies to be developed collaboratively. (ii) In disciplinary interaction processes, human agents’ profiles are not determined by their disciplinary formation, so it seems pertinent to describe them as “knowmads”, a term coined by John Moravec as an evolution of Peter Drucker’s “knowledge workers”. (iii) Cartographic techniques of collective mapping are useful to deploy approaches and representations of problems that involve a multiplicity of agents, systems and interactions. (iv) The metaphor of the stratified map allows to identify different modalities of human creativity where agents can interact. As a reference, we take the four modalities deployed on Neri Oxman’s Krebs Cycle of Creativity (KCC): Science, Engineering, Art and Design. In the same way that the KCC propounds to understand human knowledge as intellectual energy (CreATP), this paper aims to track and represent the flow of strategies, interests, conflicts and agreements taken between diverse agents by using visual thinking tools like cartographies developed in group sessions to tackle complex problems.

Diego Espitia and *Hernán Larralde Ridaura*

Using network theory to characterize natural languages

SPEAKER: *Diego Espitia*

ABSTRACT. The study of natural languages from the complex systems point of view has atracted the interest of researchers in different fields in recent years. In this work we use network theory to elucidate some of the complex behaviour behind natural languages. After constructing the co-ocurrence and visibility word networks, we use different network-based measurements, such a degree distribution, distance distribution, clustering coefficient, etc, in order to study texts written in natural languages (Spanish, German, English, Arab, Turkish, Russian, French) as well as a text written in an unknow alphabet or language (Voynich manuscript). We show how the analysis of these networks captures some statistical properties of the languages.

Fernando Andres Calzada Salas and *Arturo Morales Castro*

Hurst Exponent and its use in Financial Markets. An application to exchange rate yields.

SPEAKER: *Fernando Andres Calzada Salas*

ABSTRACT. In this research, MXN/USD (Mexican Peso / US Dollar) exchange rate yields behavior is studied in terms of the conditions needed to be analyzed with conventional risk analysis methods; in order to validate the use of the referred methods.

This research involves the analysis of these features:

• The kind of data distribution related with the statistical sample, • the similitude between its variations and simple Brownian motion and, if any, its persistent behavior.

In order to be able to analyze these given features, some techniques that involve statistical and fractal analysis were used, such is the case of: heavy-tailed distributions –a. k. a. leptokurtic distributions– fractal geometry, fractal brownian motion and, specially, the Hurst exponent –and how obtain it by means of computer algorithms using the rescaled-range Method– to determine the behavior of the analyzed information: random, persistent or anti-persistent.

Obtained results, show that the MXN/USD yields have a heavy-tailed distribution –in contrast with the normal distribution raised as initial condition for some risk analysis methods– and, their variations' behavior is similar to fractional Brownian motion; this, determined by the related Hurst exponent – Rescaled-range Method as an alternative to calculate this variable is also emphasized.

The contribution of this research lies in the addition of algorithms and concepts related to Fractal Geometry to support our hypothesis –including its interaction with statistical concepts and the software developed to estimate Hurst exponent, the use of the mentioned software could be extended to analyze further financial variables.

Finally, it's worth mentioning the relevance of the Hurst exponent as a valuable tool for evaluation of financial assets' risk, based on its relation with models that evaluate this variable, such as VaR (Value at Risk).

Ricardo Rizo, *Luis Enrique Marines Hernández* and *Marco Reyes*

Tending rhetorical bridges for real collaboration: the epistemic value of metaphors on interdisciplinary spaces and its pertinence for better practices in multidisciplinary groups

SPEAKER: *Luis Enrique Marines Hernández*

ABSTRACT. In cases where relations between human knowledge and that we refer as real or "the world" are ignored into scientific research and this debate is considered only for philosophers, epistemological obstacles and methodological consequences could modify in one or another case our findings; for instance, two restrictions at fact: (i) several limitations of our research objects and its construction, and (ii) interdisciplinary groups quality deficiencies. For the first case, that can be seen as a negative effect for our pretension and ideal holistic complex system crossdisciplinary approaches; in case two, knowing similarities in those disciplinary lebenswelt who are inside in our academic collaborative groups, could be so helpful for methodological handbooks. The use of tropes, specifically metaphors, as a classical epistemic access to the world, are in this context relevant objects of research. Thus, we search into two interactive complex systems: (i) those neuronal and symbolical scaffolds involved in certain cognitive access to the world, relevant for meaning construction in disciplinary frameworks and scholars' points of views, and (ii) collaborative 'spaces' and the ways of naming that sites of crossdisciplinary approaches, in many cases institutionalized and immeasurable. In that sense, both systems and its external and internal interactions are conceptualized by metaphor structures, in order of our epistemic interest spotligh. Our findings are the result of a one year study sponsored by two universities, made by three junior scholars, and one of its products is presented here in this Congress as a conceptual matrix who shows nodes of conceptualization of the word 'space' in several cases studies into the institutional sponsors, Universidad Nacional Autónoma de México and Universidad Autónoma Metropolitana, and its agents (individuals, groups of individuals or each discipline in particular) involved in those crossdisciplinary and collaborative academic groups. Finally, our discussion on the conceptual matrix in the poster presentation searches into the possible influences of the nodes of rhetorical figures, as a powerful epistemic tool, for the future of handbooks of mixed and interdisciplinary methodologies or practical collaboration, and its incidence for better practices of multidisciplinary groups in the way of crossdisciplinary investigations.

Krishna Bathina

Discovering Epistatic Interactions of Continuous Phenotypes Using Information and Network Theory

SPEAKER: *Krishna Bathina*

ABSTRACT. Epistatic genetic interactions are typically ignored in genome wide association studies because of the underlying mathematical and computational complexities. One proposed method from Hu et al. 2011 uses information and network theory in order to identify important single nucleotide polymorphisms (SNPs) that engage in epistatic behavior. Hu uses Information Gain (McGill 1954) as a measure of the amount of information gained only from the combined effect of two SNPs shown in the equations below. A and B represent the allelic values for two SNPs, C is a discrete variable representing the phenotypic status, I(x;y) is the mutual information of x and y and I(x|y) is the conditional entropy between x and y.

This method works well for discrete phenotypes but does not extend to continuous phenotypes. We use the Kullback–Leibler divergence (KL) as an approximation of the continuous entropy. The second form of Information Gain can be thought of the difference between the mutual information of A and B with a fixed C and a variable C. This form has a natural extension using KL divergence shown below where P is the probability distribution from the data.

We combine the method from Hu with the KL divergence and test our model using a toy dataset of 3000 samples and 30 SNPs. The value for the alleles for each sample where chosen assuming Hardy-Weinberg equilibrium using a random value less than 0.5 as the minor allele frequency. We then calculate the Information Gain between every pair of SNPs. We purposely assign phenotypes as a linear combination of SNP1, SNP2, and SNP1*SNP2 with respective coefficients 0.1,0.1,5 along with a small random normal error. This process forces the continuous phenotype to be very large if both SNP1 and SNP2 are present but very small if not.

We then build a network for each of the data sets in which the nodes are SNPs and edge weights are the Information Gain between them. We then analyze the network by first thresholding the edge weights and calculating basic network properties, such as size of the network, the connectivity, the size of the largest component, and the node and edge distribution. The final cutoff for thresholding is decided by a 100 fold permutation test as the null model. In each permutation, the phenotype class is randomized, the Information Gain is recalculated, and the network is rebuilt. The cutoff is determined by finding the threshold in which the topological properties differ most from the null model with a p value < 0.5.

We then evaluate the thresholded network and rank the SNPs using degree, betweenness, and closeness centrality. In our simulation, SNP1 and SNP2 were outputted as the nodes with the most epistatic influence, thus matching our linear model. In order to further validate our model, we will apply our method to a dataset with a continuous phenotype and then investigate the associated genes and pathways of each ranked SNP for interactions in biology literature.

Andrea Margarita Cervantes Alvarez, *Yesica Yazmin Escobar Ortega* and *Felipe Pacheco Vazquez*

GRANULAR BUBBLES

SPEAKER: *Andrea Margarita Cervantes Alvarez*

ABSTRACT. A water jet impacting on a pool generates bubbles due the air entrapment during the deformation of the air-liquid interface. In this work, we study the formation of air bubbles when a jet of grains hits on the water surface. Once a bubble is created, the grains stick at its surface due to capillarity forming a granular capsid. Using fluid dynamics, we describe the bubble formation and we analyze the interaction of the three different media involved in the phenomenon: liquid, air and grains. We performed experiments at different impact velocities, grain size and liquid surface tension, and we analyzed the different regimes in terms of Weber and Froude Numbers.

Yesica Yazmin Escobar Ortega, *J. Noe Felipe Herrera Pacheco* and *Felipe Pacheco-Vázquez*

Dynamics of a repulsive granular gas

SPEAKER: *Yesica Yazmin Escobar Ortega*

ABSTRACT. When a container with solid beads is shaken, the particles move in such a way that remember us the typical image of a gas in kinetic theory. Vertically vibrated granular materials are called "granular gases" and exhibit a wide variety of phenomena: clustering, bouncing beds, undulations, phase coexistence, etc., and these phenomena have been considerably revised in the literature. In a typical granular gas, the particles only interact through contact forces. In this work we study experimentally the physics of a granular gas formed by repelling magnetic particles. The system consists of cylindrical magnets inside a two-dimensional cell with their dipoles oriented in the same direction to produce repulsive interactions among them, and therefore, the particles never collide. We analyze the dynamics and the collective phenomena that appear under this long distance interaction, depending on the vibration amplitude and the volume fraction.

Muhammad Nazirul Aiman Abu Supian, *Fatimah Abdul Razak* and *Sakhinah Abu Bakar*

Analyzing the Malaysian Twitter Community in Respond to 2014 floods

SPEAKER: *Fatimah Abdul Razak*

ABSTRACT. Malaysian are highly prolific on Twitter, so much so it has been said to be the second highest country per capita that uses Twitter. Twitter has this great potential to be useful in time of disaster where accurate information is of utmost importance. We would like to investigate the utilization of Twitter for this purpose in Malaysia as well as understand the behavior and patterns of Twitter usage in the face of such events. On 27 December 2014, Malaysia was hit by its worst flooding in 30 years, displacing an estimated 160,000 from their homes. Twitter data with keyword ‘banjir’ (flood) was obtained for 4 days starting 27th December 2014. Flood were occuring both in Malaysia and Indonesia so the first classification of tweets was to separate between Malaysian and Indonesian tweets. The second classification of tweets is between emotional and informational ones. And the last classification was to determine whether the informational tweets are facts or rumors. We see different patterns of emotional and informational Tweets emerging from the Malaysian data in contrast to the Indonesian data. This due to the different flood occurrences in both countries and the time of day in which the tweets were posted. The result gathered reflects local tendencies, one can see the trend of lunch tweets and night owls. We identified some rumor debunking tweets as well as some key players in from the network obtained from the data set.

Julian F. Latorre and Juan Pablo Ospina Lopez

An axiomatic proposal for cooperative adhoc networks

SPEAKER: Julian F. Latorre

ABSTRACT. In response to several of the challenges imposed in the coordination of the tasks that man and his social organizations are carrying out today, vast methodological proposals have been made with the aim of collectivizing the creation of knowledge and decision-making processes [1] [2]. In the solution, diffuse lines that separate individual interests and preferences from global interests and preferences [3] are interposed, opening the way to known social paradoxes that show the tensions between individual and collective rationality [4]. Then is when promote the emergence of cooperation between individuals (or communities) becomes important to achieve high-value objectives when, in a spontaneous, random or planned way, an event of common interest is generated.

The mechanisms that seek to promote the emergence of a new cooperation result in a set of formal models with possible strategies for rational decision-making, coupled with reputation mechanisms, based on incentives (or virtual payments, which have been modeled as credits), based on emerging links, based on mixed mechanisms, or based on punishment, etc. There are still serious challenges in addressing the problems of distribution and justice in distribution [5] of the resources required for the execution of a specific task. This article proposes, model, the provision of a service in a communications network through the execution of collective actions, where a community of agents is in charge of managing the service through the generation of coordination processes and the cooperation among its members.

This proposal aims to explore an axiological model for the dynamics of knowledge, at the interior of the decision-making process between two more communities of socially inspired artificial agents. From a conceptual model for each agent, its computational implementation is evaluated through a block structure that configures the definition of a finite automaton which demarcates its rational behavior within the limits imposed by the negotiation of the group. Adapting for this, some conditioning factors widely studied in the social sciences: trust and social reciprocity. A second dimension of analysis is proposed for the evaluation of the inter-community negotiation scheme, where a coalitionist vision is established and some observations are made regarding the description of the activities of the negotiating community, its hierarchical chain, level of Centralization/Decentralization, communication and autonomy for decision. The foregoing concepts are treated within the design of an adhoc telecommunications system known as "TLÖN".

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Ricardo Rosales, Felipe Lara-Rosano, Manuel Castañón-Puga and Nora Osuna-Millan

Modelling interaction using BDI agents

SPEAKER: Ricardo Rosales

ABSTRACT. New technology has revolutionized the availability of information becoming a more complex interaction of users and systems. The learning process is essential in the construction of new knowledge in the pursuit of the user experience improvement. On this paper, the interruption factor is considered on interaction quality because it emerges during learning process. We present the users in a children's museum in Mexico as a case study. We model the interaction of an interactive exhibition using BDI agents; we adapted the BDI architecture using Type-2 fuzzy inference system to add perceptual human-like capability on agents in order to describe the interaction and interruption factor on user's experience. The resulting model allows describe content adaptation by creating a personalized interaction environment. We conclude that managing interruptions can enhance the interaction, producing a positive learning process that influences user experience. We can achieve a better interaction if we offer the right kind of content considering the emergent interruptions.

Raúl Amarilla, Arturo Gonzalez, Gerardo Blanco and Cecilia Llamosas

Multi-criteria Planning Analysis of the Use of Hydroelectricity Surplus in Paraguay based on the Analytic Network Process (ANP)

SPEAKER: Arturo Gonzalez

ABSTRACT. The abundance of electric energy, generated mainly by the binational hydroelectric dams of Itaipú and Yacyretá, constitutes a strategic asset for the development of Paraguay. This has a great impact on the economic growth and social progress of the country, through the planned infrastructure growth and the development of the productive sector, mainly industry, based on a greater share of electricity in the energy matrix. In fact, it can be said that Paraguay, from different perspectives, urgently needs to take advantage of the large levels of clean energy available, encouraging the penetration of hydropower into the energy demand matrix, replacing biomass and oil. In this context, a wide public debate on the use of hydropower surplus has been around in the country for many years. The different alternatives for its implementation are often characterized by the conflict between different objectives, such as political, social, economic, technical and environmental points of view. Under these circumstances, an approach based on multi-criteria decision analysis models (MCDA) is required. In recent studies an analysis of the problem was carried out using the analytical hierarchical process (AHP), which is probably the most popular method for prioritizing alternatives. With this proposal, it is planned to generalize the analysis hierarchical process, the Analytic Network Process (ANP) to develop a decision-making tool for the best use of Paraguay's hydroelectric surpluses within the framework of a sustainable policy, considering quantitative and qualitative aspects, difficult to identify through usual evaluation approaches. This tool has a high scientific and avant-garde component to make essential decisions that would produce the greatest benefits for the integral development of the country. This case study analyze four energy policies, that is (A1) a trend scenario, (A2) a scenario of high hydroelectric power export, (A3) a scenario of high level penetration of the Electro- intensive industry and (A4) scenario of high development of national industries. Finally, these strategies are evaluated according to economic, technical, environmental, social and implementation feasibility criteria The result of the use of the integral ANP model, taking into account the interaction between environmental, economic, social, technical and political criteria, as well as energy consumption in Paraguay and possible strategies for this case study showed that the most appropriate strategy for Paraguay is the development of its industrial sector through the use of available electric energy, which would bring great benefits in many aspects compared to other alternatives.

Oliver López-Corona, Vanessa Pérez-Cirera, Graciela Teruel, Miguel Reyes, Ana Teruel and Luis Osorio

Measuring Poverty Governance with Fisher Information

SPEAKER: Oliver López-Corona

ABSTRACT. We propose to use the concept of poverty governance in the same way it has been used in water governance, as the political, social, economic and administrative system in place that influence poverty phenomena. In a more abstract sense we conceptualize governance as system controllability and hence system observability. We pose that greater levels of observability (governance) are only achieved with large enough Fisher Information (FI) values. We use the formalism developed by Frieden, Cabezas and others to compute FI of poverty time series, generated following the CONEVAL's official methodology used in México. We analyzed the complete multidimensional poverty data as well as each component in order to understand if there are specific dimensions with low levels of governance and its relation with has been called in the poverty literature as poverty traps.

Douglas S. R. Ferreira, Bernardo Machado, Jennifer Ribeiro, Otávio Neves, Paulo Oliveira Junior, Andres Papa and Ronaldo Menezes

On the Agreement Between Small-World-Like OFC Model and Real Earthquakes from Different Regions

SPEAKER: Douglas S. R. Ferreira

ABSTRACT. Despite all the existing knowledge about the production of seismic waves through slips on faults, much remains to be discovered regarding the dynamics responsible for these slips. A key step in deepening this knowledge is the study, analysis and modeling of the seismic distributions in space and time. The concept of self-organized criticality (SOC), widely used in statistical physics, refers, generally, to the property that a large class of dynamical systems has to organize spontaneously into a dynamic critical state without the need for any fine tuning of some external control parameter. A signature of self-organized criticality in a system is the invariance of temporal and spatial scales, observed by power-law distributions and finite size scaling. Aiming to contribute to the understanding of earthquake dynamics, in this work we implemented simulations of the model developed by Olami, Feder and Christensen (OFC model), which incorporate characteristics of self-organized criticality and has played an important role in the phenomenological study of earthquakes, because it displays a phenomenology similar to the one found in actual earthquakes. We applied the OFC model for two different topologies: regular and “small-world”, where in the latter the links are randomly rewired with probability p. In both topologies, we have studied the distribution of time intervals between consecutive earthquakes and the border effects present in each one. In addition, we also have characterized the influence that the probability p produces in certain characteristics of the lattice and in the intensity of border effects. Furthermore, in order to contribute the understanding of long-distance relations between seismic activities we have built complex networks of successive epicenters from synthetic catalogs produced with the OFC model, using both regular and small-world topologies. In our results, distributions arise belonging to a family of non-traditional distributions functions (Tsallis’ family), as we can see in Fig. 1. We also performed the complex network analysis for real earthquakes, taking in account two different ways. The first one, considering only regional earthquakes separately (in regions with high seismicity, as Japan and California, and low seismicity, as Brazil). In the second, considering events for the entire world, with magnitude larger or equal than 4.5, in Richter scale. It is noteworthy that we have found a good agreement between the results obtained for the OFC model with small-world topology and the results for real earthquakes. Our findings reinforce the idea that the Earth is in a critical self-organized state and furthermore point towards temporal and spatial correlations between earthquakes in different places.

Oliver Smith

The price of anarchy in smart energy newworks: designed versus emegent behaviours

SPEAKER: Oliver Smith

ABSTRACT. Please see the attached PDF.

Octavio Orozco Y Orozco and Jorge A. González

Confronting Current Century's Problems: Interdisciplinary Methodologies for Complex Systems

SPEAKER: Octavio Orozco Y Orozco

ABSTRACT. The science of complexity and the constructivist theory of complex systems are two different scientific approaches applied to the study of complex phenomena. This poster describes an integration of both approaches into a practical workshop designed to share, learn, discuss, and apply interdisciplinary methodologies oriented to effectively confront current century’s problems. The aim for each person participating in the workshop is to be part of a multidisciplinary team that applies a proposed method to identify and describe a proposed problem as a complex system. The aim for the workshop is to set-up real and virtual interactive spaces where the proposed problems meet-up and match with proposed interdisciplinary methodologies. The expected outcome for the workshop is both, to identify and describe as a complex system some of the problems faced by the participants and to facilitate the beginnings of geographically distributed networks among participants to confront those problems. Furthermore, these networks will plausibly induce the creation of a specialized interdisciplinary organization to address each specific problem identified as a complex system during the workshop. This organization should thus apply a complex systems approach to deal with its chosen problem. A concrete step in this direction is the creation of the workshop’s virtual interactive spaces containing each at least three elements. First, the summary of the proposed interdisciplinary method and the summary of the proposed problem as matched by the networked participants during the workshop. Second, the description of the problem as a complex system. Third, future steps to address the problem.

Gonzalo José Hernández and *Manuel Ernesto Bolaños*

New Visual Strategies to Teach Programming

SPEAKER: *Gonzalo José Hernández*

ABSTRACT. It is common to encounter discouragement in students learning the language of programming while they cannot make sense of its logic. This fact tends to result in desertion.
Practice is one of the strategies used to achieve learning, but if the planted exercises do not stimulate it, it is possible that student will be driven to monotony, therefore causing the previously mentioned result.
The group of investigation GRIAS, from the Department of Systems in the University of Nariño, realized an investigation that aimed to study the behaviour of a group of students in their first programming course. New pedagogical strategies were applied to their learning process, which aimed to reinforce the following elements:
Motivation: achieving student participation in the learning process in a more dynamic way.
Simplicity: reducing the number of required instructions, avoiding irrelevant elements that could cause distraction from the central theme.
Precise verification of results: providing promptness in the discovery of the origin of the source of error, avoiding moving away from the concept being studied.
Facility in error correction: offering tools for error correction as part of the learning process.
Computer graphics-related exercise were created in order to reinforce the four elements mentioned above.
The investigative process was conducted with second-semester Systems Engineering students from the University of Nariño, who were randomly separated into two groups. The first group (Experimental), was given the First Programming Workshop (Taller de Programación I), using the new strategic pedagogy methods. Group two (Control), was taught the same course, using traditional teaching methods.
The investigation was divided into three stages:
Phase I (Design): in this stage, the investigative instruments were created, course themes were restructured, a new software tool was created for support, and the exercises to be used were defined.
Phase II (Application): in this stage, the First Programming Workshop (Taller de Programación I), was given to both groups, according to the design proposed in the first phase.
Phase III (Results and Conclusions): in this stage, data was collected through investigation instruments, and conclusions were obtained according to the experience of the process.
In all of the 14 categories evaluated, the students belonging to the experimental group achieved higher grades than those in the control group, obtaining an average of 4.2, in comparison to 3.5.
The learning process was easier for the professor, because the exercises were didactic, more specific, and easier to evaluate.
The students manifested significant pleasure due to the inclusion of exercises related to computer graphics. This resulted in greater student participation, due to their motivation at the time to resolve the planted exercises.

Georgi Georgiev, Atanu Chatterjee, Thanh Vu and Germano Iannacchione

Agent Based Modelling of action efficiency increase and entropy reduction in self-organization

SPEAKER: Georgi Georgiev

ABSTRACT. Self-organization is defined as the spontaneous emergence of order arising out of local interactions in a complex system. The central to the idea of self-organization is the interaction between the agents, the particles, the elements that constitute the system. In biological systems, particle-particle interactions or particle-field interactions are often mediated by chemical trails (chemotaxis), or swarm behaviour that optimizes system efficiency. In non-biological systems, particle-field interaction plays the crucial role, as these interactions modify the surrounding field or often the topology of the energy landscape. Interactions in a system, or a system and its surroundings, are governed by energetic and entropic exchanges, either in terms of forces or in terms of statistical information. Since, energy and time describe all motions, we look into the Principle of Least Action to search for answers as it involves both time and energy into its formulation. Since, the Action Principle minimizes action and directs the system elements along least action trajectories on the energy landscape (surrounding field), it is imperative that a one to one correspondence exists between the Second Law of Thermodynamics and the Action Principle. In a system in equilibrium, the system particles can occupy all possible microstates whereas in a self-organizing, out-of-equilibrium system only certain microstates will be accessible to the system particles. In these systems, in order to organize efficiently the system particles interact locally and coordinate globally, in a way that lets swarms of agents to uniformly follow least action trajectories and simultaneously degrade their free-energies in order to maintain the organizational structure of the system at the expense of entropy export along the least action paths. In order to address this issues, we perform agent based simulations, looking for dependence of rate of increasing of action efficiency on the number of agents, in order to compare it with similar data in CPUs, previously studied by us. We found that the rate of self-organization depends on the number of agents in the system. In this simulation it is also possible to calculate the entropy reduction, counting the reduction of the number of possible micro-states in the system. Other dependencies, such as the rate of increase of action efficiency, as a function of the size of the system, the separation between source and sink, and others are also studied. We aim to confirm experimentally measured values of those dependencies in our previous research with results from the simulations and to be able to find any universalities between the two.

Jorge Posada

Attractors landscape restructuring of the GRN-Arabidopsis thaliana root stem cell niche

SPEAKER: Jorge Posada

ABSTRACT. The genetical regulatory network (GRN) of the Arabidopsis thaliana root stem cell niche (SCN) proposed by Azpeitia et. al. 2010, allows an explanation for the gene expression observed in the cell-types of the root SCN. The Network converges to 4 attractors that belongs to the principal cell-types of the root SCN: vascular initials cells (VI), cortex-endodermis initials cells (CEn), quiescent center (QC), and lateral epidermis cap root initials cells (EpC). In Davila-Velderrain 2015, a method for the analysis of the impact of rate-decays values on attractors landscape (AL) was proposed. The objetive of this work was to explore the ability of the different states values ([0-1]) from each of the 9 nodes of the A. thaliana root SCN-GRN for making changes in the AL. In order to achieve that goal, the dynamics of the discrete and also his equivalent continuos model of the root SCN-GRN were analyzed. Finally, a bifurcation analysis on each of the 4 attractor by a systematic increase in the rate-decay values of each node was made. We found that 5 network´s nodes (SHR, SCR, Auxin, WOX5 and MGP) were capable of making changes in the AL, suggesting themselves as point controls for the cell in the differentiation route.

Kelly Finn, Dmitry Shemetov, Andrew MacIntosh and Jim Crutchfield

Modeling Structure in Macaque Monkey Movement

SPEAKER: Kelly Finn

ABSTRACT. Movement data has long been used as an indicator of health and wellbeing, as seen with the recent explosion of self-tracking devices. Similar technologies have become increasingly popular for long-term data collection of animal behavior. Multiple features of an animal's behavior can be measured, though often we only capture summary statistics such as frequency, count, speed, or duration. In this light, the temporal structure of animal movement is an untapped yet fundamental source of information. Indeed, structure in behavior patterns appears to vary across individuals and within individuals across different behavioral or health states. However, little is known about which pattern properties might be relevant or might reveal such differences. To address this, we investigate the temporal structure of macaque movement using statistical measures of correlation and dependence adapted from information theory. Data include 56 activity sequences from 14 Japanese macaques on Koshima Island, Japan, (with observation length ranging between 17-68 minutes) and 17 activity sequences from 5 captive Japanese macaques in field enclosures at the Primate Research Institute (observation length of 34 minutes), recorded using continuous focal animal sampling. Activity was recorded as binary sequences of discretely categorized locomotion, and the location, terrain, and behavioral contexts (foraging, social, travel) of each observation were noted. From these time series, we estimated Shannon entropy rates using (i) block entropy from binary sequence distributions, (ii) Bayesian structural inference (BSI) of hidden Markov models, and (iii) closed-form expressions for estimated alternating renewal processes. As a calibration for unstructured behaviors, we also estimated entropy rates of simulated binary Poisson sequences and of randomized versions of the macaque movement sequences. Preliminary analysis reveals substantial differences in entropy rates of real and randomized data, indicating that macaques perform nonrandom, structured behavior. While all estimation methods converge on the same entropy rate values for simulated Poisson sequences, they yield different values from real macaque data. Further analyses will include measures of past-future mutual information (excess entropy) and memory (statistical complexity). They will employ BSI to infer epsilon-machines of renewal process and alternating renewal process model classes. By identifying the kinds of structure in macaque movement, we hope to eventually explore movement patterns within the context of individual characteristics and behaviors.

Elise Jing, Yong-Yeol Ahn and Simon Dedeo

Creativity and Popularity of Fanfictions in Fandoms

SPEAKER: Elise Jing

ABSTRACT. Many creative products in human history are recreations, remixes, and modifications of archetypical products. For example, The Iliad was written by Homer based on oral traditions existing before his time; the Little Red Riding Hood was developed into various versions starting from the 10th century. In the contemporary pop culture, such practices of recreation and remixes can be better established and more easily shared through the Internet, particularly in the form of fanficitons — creative works made by fans based on existing original works. Emerging in the 1970s, this subculture has gained attention in cultural studies and gender studies, but few quantitative data-driven analysis has been carried out. Here we analyze data from the website Archive of Our Own (AO3) to study the relationship between popularity and creativity of fanfictions in a fandom (a community consisting of fanfiction authors and readers). We model each fanfiction with a unigram model, and use the Kullback-Leibler divergence to evaluate the distance between fictions. A "typical" fiction in a certain time period is constructed, and other fictions are compared to it. We show that the fictions that are more similar to the typical fiction receive more kudos, in other words, being close to the "mainstream" of a fanfiction is an indicator of its higher popularity. This result reveals a relationship between creativity and acceptance of audience, which may be extended to other creative works.

Clàudia Payrató-Borràs, Laura Hernandez and Yamir Moreno

Testing nestedness metrics against a novel null model

SPEAKER: Clàudia Payrató-Borràs

ABSTRACT. No more than two decades ago, the translation of mutualistic communities into the language of networks revealed the existence of a non-trivial, structured organization of interactions. Positive links - defined as mutualistic when they involve individuals of different types and benefit both, as happens between plants and pollinators- do not simply match aleatory partners, but actually display a property known as nestedness. A perfectly nested structure appears when the counterparts of a species of degree k constitute a subset of the counterparts of all species of degree k'>k, this being true for both guilds. A configuration this special seems to entail, furthermore, special dynamics. Indeed, nestedness has been claimed to play a relevant role in the assemblage, stability and resilience of socio-ecological communities.

The interest arisen by these discoveries has stirred up the need for a clear and unified measure of nestedness. In a previous work, also presented in this conference, we addressed the question of how nested structures emerge. We showed that nestedness naturally appears as a consequence of solely local constraints -in particular, the number of interactions per specie-, without needing to include any global mechanism that shapes interactions' configuration. By employing the randomizing methods developed by Squartini and Garlaschelli, we found that a null model in which we fix the average degree sequence is enough to reproduce the observed nestedness of real mutualistic networks. Interestingly, this implies that the non-random appearance of mutualistic communities is a macroscopically emergent phenomenon, whose origin can be traced back to microscopic rules. It also provides us with a new set of sufficient requisites for randomizing nestedness' measures.

Here we exploit this novel null model to test the performance of various metrics. To achieve this, we produce a large sampling of the randomised ensemble using the probability of existence of each of the mutualistic links -which we had previously obtained by the aforementioned methods-. Among the ensemble, different networks sometimes slightly differ in their degree sequences as well as in their size and fill, since the constrained degree is only matched in average. Our aim is to take advantage of such variability as a way to weigh the robustness of the measuring system. For a robust metric, we expect that the measure is not sensitive to any matrix feature apart from nestedness. Our development, indeed, permits to check whether these conditions are actually met, by quantifying the fluctuations on the measure within the randomized sample. Large deviations indicate a great disparity between measures and thus a strong responsiveness to tiny network's variations. Moreover, in some cases we are able to compare the sampling outcome with the analytical result of the randomization, for instance for the NODF by Almeida-Neto et al. In this particular case we found that the two randomised values are significantly different and also that the metric's sensitivity is generally exacerbated for small dimensions. Beyond NODF, we applied these ideas to a diverse set of commonly used metrics and studied the connection of our results with the network's characteristics.

Oscar M. Granados

Banking Networks and Urban Dynamics: The Bogota Case

SPEAKER: *Oscar M. Granados*

ABSTRACT. This article evaluates the urban transformation of the city of Bogota from the relationship between the population and banking, which have built extensive networks of attention and services, becoming part of the everyday life of people in the city´s complexity. Likewise, in the last six decades, banking institutions have been able to construct a series of interfaces that emerge as a way of transforming urban space and thus participate in the development of localities, which are not constants. To understand the city´s complexity and urban dynamics, it is necessary to use complex adaptive systems, open systems, swarm intelligence and network theory, to integrate the instability of social structures and the changes that have brought the banking in those places where the population lives, works or agglomerate. This is the result of a financial activity that offers products and services in branches, which has transformed the habitability and everyday life of the population of Bogota. The city is characterized by a permanent movement, which brings it closer to being a living organism. Likewise, it has been formed by a group of sub-systems that needs to be analyzed together to better understand its evolution, in this case, the banking sector represented by a network is a part of a sub-system. In addition, to integrate it with the urban dynamics of Bogota and understand how they have acted together and how they have harmonized spaces in the city. Although this methodology can use in other cities, but I will use to Bogota from 1949, the moment the city began its recovery after the massive riots. To achieve this goal, I establish first the city as an open system that interacts externally and permanently. Second, banking networks as a sub-system that adapt to the processes of the financial business and the interaction with the population through its service supply. However, banking networks have carried out their expansion process under the logic of urban transformation and agglomeration but not of human mobility. This logic can be a way to research the future change that bank networks will have in the city of Bogota and the city's own design. To visualize the data of the expansion of the banking networks will use ArcGIS, from the modeling of a complex network that adapts and integrates to the changes of the urban system. For this, I will use some years as layers to simulate the transformation that has lived the city to integrate the banking networks. Similarly, the digital services and interaction with machines have determined a different form of expansion and transformation of urban space towards the increasing recreation of artificial systems where interactions will require convergent technologies.

Daniel Amor and *Jeff Gore*

Inducing transitions between alternative stable states of microbial communities by transient invaders

SPEAKER: *Daniel Amor*

ABSTRACT. The microbial communities that live in or on our bodies are complex ecosystems exhibiting alternative stable states. Perturbations such as changes in diet, infections or exposure to antibiotics can threaten the stability of these ecosystems, with important health consequences. However, little is known regarding the mechanisms driving long-term community dynamics after short-term perturbations. Here, we study transitions between stable communities in a bistable laboratory ecosystem that we expose to short-term perturbations. We find that a broad range of different perturbations favor one of the two stable community states, indicating that some states can be much more robust than others. In our case, this difference in robustness is driven by the need for one species to grow cooperatively, thus limiting its ability to re-establish following a severe shock. Moreover, we demonstrate that the introduction of an invader species can also lead to transitions between the stable states. Interestingly, in many cases the invading species did not survive in the final community state, making these species what we call a "transient invader." This suggests that short-term invasions (such as infections) could be a common mechanism driving transitions between stable states in microbial communities.

Raúl Gerardo Parra Rosales, Saùl Aguilar Contreras, Miguel Alejandro Flores Lara, Miguel Ángel Gavia Gutiérrez, Francisco Aarón Reyes Hernández, César Eduardo Torres Vargas and José Francisco Cervantes Loretto

The social dynamic of tourism in Real de Catorce, Mexico, as a complex system

SPEAKER: Raúl Gerardo Parra Rosales

ABSTRACT. This research is an approach to the social dynamic of tourism in Real de Catorce, located in the state of San Luis Potosí, México, proposed as a complex system.

Real de Catorce was founded in 1772 and during the 18th and 19th centuries was an important mining center. At the beginning of 1900, the mining industry collapsed and the town was abandoned in 1921. At that time, Catholic pilgrims began to arrive. They were going to adore San Francisco de Asís, as they do until our days. In the sixties and seventies, foreign visitors began to arrive and the municipality was positioned as a tourist destination.

In this system, many heterogeneous elements interact, such as neo-rural residents, Catholic Franciscan pilgrims, indigenous Wixaritari, and national and foreign tourists. It is also composed of several subsystems, such as the Transport, Lodgement, Feeding, Handricrafts, Tourist Guides and Government subsystems. They fulfill different functions and are interdependent and interdefinable, because among them maintain the operation of the system.

First level processes take place in the system, but this is also determined by the second and third level processes, wich occur at the national and international scales. Therefore the system has a hierarchical structure. It is also self-organized, adaptable to a complex environment and has emerging behaviors. It's autopoietic, because it has generated the structures that have perpetuated its operation, such as the establishment of a network of people who offer tourist services and the implementation of ways of transportation for the visitors inside the town, such as horses and vans.

This phenomenon presents the characteristic of the fractality, since it occurs at a similar way at different scales. The system is open, because it has a great flow of exchanges with the environment. It also has the property of multifinality, because despite starting from initial conditions very similar to tourism in other regions, it has had different results.

Rising John Osazuwa

Towards better User Experience: The Case of Universities' Academic Portal

SPEAKER: Rising John Osazuwa

ABSTRACT. Nowadays, how to promote the existence of User Experience (UE), which is also known as interaction experience of the use of digital artifacts, such as Web sites, virtual worlds, personal digital assistants and so on has become a concern (Hassenzahl and Tractinsky, 2006). This is because the 'loyalty decade', where interaction experience will become the main success factor (Nielsen, 2008) is here. Hence, the need for models that measures the attributes of UE in order to be able to put a tab on the extent to which UE correlates and positively influence high-quality user-system interactivity. For Universities' websites it is necessary to draw on the concept of UE. The aim will be to provide a utility driven UE to users in a manner that better supports their work (Pennington, 2015; 2016), The foregoing goal will be pursued from the specific objective point to (i) identify appropriate scales or items to measure UE, (ii) elicit ordinal data using the scale in (i), and (iii) formulate a measurement model for UE measurement and (iv) validate the model. To identify appropriate scales or items to measure UE, appropriate literature will be consulted in order to get relevant (and existing scales). The scales using the questionnaire and interview fact finding techniques will be employed to elicit ordinal data from stake holders. The stakeholders will be from within the University community and from a sample size of 1000 regular users of the University portal. The factor analytic technique will be employed to computationally using inferential statistics to formulate the intended measurement model. The model will be validated using appropriate fit statistical indices (Lee, 2010). This work will contribute to knowledge in the area of user experience evaluative modelling by providing useful information on how to identify appropriate scales or items to measure UE, validate user experience measurement model and elicit ordinal data from stakeholder. It will also develop a measurement model to measure the perception of users based on their experience from the use of digital artifact like the University Website. This will have implication on how UE should manifest as a quality in design, in interaction and in value, with diverse measures from many methods and instruments (Law and van Schaik, 2010). Researchers will be able to resolve issues that bother on the challenges that relate to UE with respect to how to select appropriate measures to address the particularities of an evaluation context. Professionals will be able to learn about measures that enable the benchmarking of competitive design artifacts and to select appropriate design options. It will also be useful to guide stakeholders how to model users' experience as a basis for producing design guidance (Law and van Schaik, 2010). This work is limited in that more sample size will be needed to validate the result, and whenever the approach employed in this work is to be deployed the context of deployment must be well understood.

Bootan Rahman, Yuliya Kyrychko and Konstantin Blyuss

Dynamics of unidirectionally-coupled ring neural network with discrete and distributed delays

SPEAKER: Bootan Rahman

ABSTRACT. In this research, we consider a ring neural network with one-way distributed-delay coupling between the neurons and a discrete delayed self-feedback. In the general case of the distribution kernels, we are able to find a subset of the amplitude death regions depending on even (odd) number of neurons in the network. Furthermore, in order to show the full region of the amplitude death, we use particular delay distributions, including Dirac delta function and gamma distribution. Stability conditions for the trivial steady state are found in parameter spaces consisting of the synaptic weight of the self-feedback and the coupling strength between the neurons, as well as the delayed self-feedback and the coupling strength between the neurons. It is shown that both Hopf and steady-state bifurcations may occur when the steady state loses stability. We also perform numerical simulations of the fully nonlinear system to confirm theoretical findings.

Gustavo Jaime-Munoz

Social interaction dynamics in adaptive working environments

SPEAKER: *Gustavo Jaime-Munoz*

ABSTRACT. Collective performance of a community / society is the result of all the interactions between its members internally and externally.

In recent years the use of tools such as Internet Relay Chat (IRC) have facilitated communication in the form of text between people. It is meaningless mentioning the success of platforms based on this concept on the internet among communities for different purposes, but it is remarkable the incorporation in academic and labor environments.

Understanding how these interactions happen between members enables streamlining of information flows that lead to the success of projects undertaken by the community or correct bottlenecks in the flow of information that leads to labor problems.

This can be achieved when social interactions are mapped to a graph and analyzed using the tools that have been developed to study complex systems. The properties obtained from these graphs can help make decisions that could be critical to the community.

An analysis of the interactions of a small community < 50 members who maintained communications using IRC-ish tools was performed. To this end, a data model was constructed to relate members, with their communications (messages, emoticons, etc.) in a directional way and to evaluate their influence in the community.

For this, the interactions were mapped to graphs. The information was stored using graph databases (Neo4J) and explored using graph theory and categories.

Results are shown from the computational perspective with the technological implications and limitations as well as results from the professional-labor perspective of the application of such constructions to efficiently process internal processes.

Eduardo Mojica-Nava and *David Martínez*

Meaningful Information in Multi-Agent Learning Systems

SPEAKER: *Eduardo Mojica-Nava*

ABSTRACT. In this work, we propose to use information theory tools such as rate distortion and maximum entropy in order to include bounded environmental information in multi-agent learning systems, where the decision process follows an evolutionary game specification for large-scale networks. One of the cornerstone challenges in Large-scale networks is dealing with the amount of information needed to guarantee the proper operation of the system, in addition with the high computational burden for the decision process for such large-scale systems. Environment information is commonly used in agent learning algorithms as we can observe in literature related to machine learning, mostly focused on single agent cases. We can also find some research direction of learning in which the multi agent context or environment are included as it is shown in some reinforcement learning algorithms and evolutionary game implementations. However, most of the cases are not concerned with the amount of information from the environment needed to make decisions, which leads to have many data that could be overvalued. Therefore, it is necessary to define a boundary to identify the point where environmental information becomes redundant or misunderstood, i.e., the point in which every agent has just the information that it needs about its surroundings. In this regard, we propose a method that uses rate distortion theory and maximum entropy to find a border in which the environment information is neither misunderstood nor redundant. Additionally, based on ecological principles, we give a fitness value to this environment information in order to improve the agent strategies selection inside of a population ruled by an evolutionary game learning process. The combination of information theory and evolutionary game theory is the basis of the proposed approach, which define a multi-agent learning framework where redundancy and misunderstanding define a border in which we obtain valuable environment information that it is used to improve the learning process for every agent in a system. This valuable information can be understood as a meaningful information in the learning process, which aims to improve the versatility of the multi-agent system to respond to fluctuations in its environment.

Eduardo Mojica-Nava and *Claudia Catalina Caro-Ruiz*

Criticality in Complex Networks: A Hybrid Systems Approach

SPEAKER: *Eduardo Mojica-Nava*

ABSTRACT. Technology today has made infrastructures becoming smarter and interdependent. Smarter infrastructure uses data in feedback loops, which provides evidence for coordinated decision-making. Also, the system includes agents that can monitor, measure, analyze, communicate and act without human intervention. Moreover, dierent kinds of infrastructure are coupled together, such as water systems, communications, transportation, fuel, nancial transactions and power grids. In particular, for power grids, failures due to interdependency and newer smart energy resources could have a severe impact on services, economic or productions losses, citizens well-being, even the proper functioning of governments. Thus interdependency and smarter technologies impact on networks operation are worth to be investigated. Under this motivation, nowadays, there exists an increasing interest in the research of power grids from the network perspective. New techniques of modeling and analysis have been developed to capture the whole power network structure complexity. These methods comprise both the requirements in structure and dynamics. The thorough understanding and application of complex network framework in power systems are essential to the advancement in the design and control of these smarter infrastructure. Complex networks deal with the behavior of nature and human systems displaying signs of order and selforganization. Mostly, they have a large number of interacting parts, whose collective behavior cannot be inferring from the behavior of its components. Also, the interaction between components can be as important as the parts themselves. Those systems may exhibit predictable behavior close to their regular dynamical mode. But certain events can drive them away from such modes, leading to large-scale flow rearrangements and possibly collapse. Although Network science approaches allow to nding some general properties to understand and control of networks dynamics under this phenomena, a lack of analytical tools to understanding and dealing with these operational changes exist. Also, most of the models found in the literature are conceptual approaches, and its analysis is not directly applicable in engineering. This work leads to study transitions in network dynamics by methods of control theory, proposing a model that includes the complete system behavior and facilitates its analytical study. We use a hybrid systems approach where it produces complex behavioral patterns by dierent discrete transitions triggered by stochastic events and the interaction of various types of discrete and continuous dynamics. Finding on the analysis of this model could have signicant implications for the design of control mechanisms and resiliency in engineering applications.

Felipe Urbina, *Sergio Rica* and *Marco Montalva Medel*

Fixed points and periodic orbits in the Q2R cellular automaton

SPEAKER: *Marco Montalva Medel*

ABSTRACT. The Q2R model is a dynamical variation of the Ising model for ferromagnetism that possesses a reversible and conservative dynamics. Because of its complex dynamics it appears that Q2R is a good benchmark to test the principles of statistical physics. Moreover, this conservative and reversible system appears to behave as a typical macroscopic system, as the number of degrees of freedom increases, showing a typical irreversible behavior, sensitivity to initial conditions, a kind of mixing, etc. However, the phase space is finite, hence the dynamical system only possesses fixed points and periodic orbits; therefore it cannot be ergodic, at least in the usual sense of continuous dynamics. Nevertheless, for large enough systems, the phase space becomes huge and it has been observed numerically that the periodic orbits may be exponentially long, thus, in practice, of infinite period. For any purpose, the observation of a short periodic orbit is really improbable for large enough systems with random initial conditions. In general, there is a huge number of initial conditions that are almost ergodic.
The Q2R model is based upon the two-step rule: $y^{t+1} = x^{t}$ and $x^{t+1} = y^{t} \Phi(x^t)$, where $ \{x^t,y^t\}$ is the state of the system at time t described by a square $L\times L$ matrix with even rank. Further, $\Phi(A)$ is a nonlinear Heaviside-like function that depends on its argument A by the following rule: at every site k, $[\Phi(A)]_k= +1$ if $\sum_{i\in V_k}A_i \neq 0$, and $[\Phi(A)]_k= -1$ if $\sum_{i\in V_k}A_i = 0$, where V_k is the von-Neuman neighborhood of the site k. As shown by Pomeau [1], the Q2R automaton preserves a energy-like function. Notice that, because the system is conservative, there are neither attractive nor repulsive limit sets; all orbits are fixed points or cycles.
The phase space of the Q2R system of N sites possesses 2^{2N} states and, in this oral presentation, we partitioned it in different subspaces of constant energy and, more interesting, into a large number of smaller subspaces of periodic orbits or fixed points. In this context, we derive exact results concerning the number of fixed points and period 2 orbits. A fixed point is characterized by a state $\{x,x\}$ such that $\Phi(x)=1$ (one at every site of the lattice), and the cardinality of this set is $N_{FP}= K^2$, where K is the total number of configurations x without null von-Neuman neighborhood in its even (or odd) sites, i.e., x restricted to its even (odd) sites must satisfy $\Phi(x)=1$. The period 2 cycles are characterized by $\{x,y\}\to \{y,x\}\to \{x,y\}$, and we show that the cardinality of this set is $N_2 = N_{FP}(N_{FP}-1)$. Finally, we discuss general results concerning orbits with larger periods.

Andrea Calandruccio

From Information-Theoretic Causality Measures to Dynamical Networks of Financial Time-Series

SPEAKER: *Andrea Calandruccio*

ABSTRACT. Mutual Information from Mixed Embedding (MIME) and Partial Mutual Information from Mixed Embedding (PMIME) were developed by Vlachos and Kugiumtzis[1, 2] to assess non-linear Granger causality. Compared to other non-linear measures, PMIME offers three main advantages: - No significance test is needed, as PMIME = 0 if there is no significant causality; - No pre-determination of embedding parameters, as this is part of the measure; - No curse of dimensionality as more co-founding variables have no effect on statistical accuracy.
Therefore, PMIME is a good candidate for causality analysis of complex real-world systems, as also shown by some independent analysis[3]. In particular, the application to EEG data has been extensive and very promising, while financial time-series have only been marginally analysed, yet with interesting results.
In this work we firstly test PMIME accuracy on a synthetic dataset generated by the Tangled Nature model[4], further showing its ability to capture such complex dynamics. We then apply PMIME to global financial time-series, constructing dynamic networks of interactions and analysing them in light of the underlying economic and financial relationships.

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Antonio Fonseca, *Sergio Bacelar* and *Jorge Louca*

New Metrics Characterising Global Migration Flows

SPEAKER: *Antonio Fonseca*

ABSTRACT. In the International Migration Outlook 2016 from OECD, Stefano Scarpetta, Director of the OECD Directorate for Employment, Labour and Social Affairs, wrote that: “The public is losing faith in the capacity of governments to manage migration” and concluded its editorial stating that “Unless systematic and coordinated action is taken … migration policy will continue to seem abstract and elitist, at best trailing behind the problems it is supposed to be addressing. And, as is already apparent, the result is likely to be a more strident political populism.” Very recently Pope Francis, in an interview with Die Zeit, also warned of the dangers of the rising populism in western democracies. In fact, recent times have shown the rising of this new political trend in Western countries which is coincident with the rise of migration into Europe, both as regular migration but also as a refugee crisis from Syria, Libya, Iraq and Afghanistan.

Migration is a phenomenon which can be characterized by its motivation: there is labour migration which can be temporary or for long periods, migration for education, for family reasons, due to natural disasters or war. Migration at a global scale always has a long term positive effect through the efficient reallocation of human resources, thus improving the global economy. But, if not properly managed, can have short term unwanted local effects due to the overweight on labour, housing and transports, health and education systems. This management inability, per se, might induce social and political aversion and is a fertile ground for the emergence of populism and xenophobia.

In this poster we will address the issue of migrations from the perspective of complexity sciences. Supported on the recent release of the 2015 International Migration Flows Dataset from the United Nations and other economic and geographic data, we applied network based metrics to the migration flows between countries at a global level. Although the drivers of migration are mainly local, specific both in time and in space, the so-called episodic ‘push and pull factors’, we were able to obtain some wide-ranging results. One of these is the expansion over time of the reach of regular migrants, probably due to the progressive reduction of transport and communication costs. Other results concern measuring migration flexibility. We propose a new metric named Migration Flexibility Index(MFI) which is inspired in a economic complexity measure previously developed by Hausmann and Hidalgo. We found that some regions are prone to migrate to very diverse destinations, which by their turn receive from very diverse origins. Some other regions are instead rigid, with fewer migration destinations and very less cultural diversity. We found that, with the notable exceptions of China, India (which have exceedingly large population) and the UK, all the ‘New World’ countries that emerged from the 15th century maritime discoveries belong to a different class of global migration (see Figure 1).

Haruka Miyazawa

Information, Computation and Linguistic System

SPEAKER: *Haruka Miyazawa*

ABSTRACT. Since the advent of molecular biology, it has been said that cell is a kind of 'machine', which stores its specification inside itself. Although the perspective of systems biology derived from this understanding well prevails, we still do not have a clue to address cellular system deductively, due to the lack of mathematical insights into the system. Here, I propose a conceptual framework where it is possible to abstract the essential features of the system and project them onto the purely mathematical problem. The framework mainly includes the following three concepts; information, computation, and linguistic system. Each concept can be understood independently with explaining specific features inherent to biological system. Nonetheless, the intersection of these concepts can provide us with the fertile results to understand their relationship and hierarchy. In this framework, 4 bases (A, T, G, C) in biology correspond to symbols in information theory and it enables us to discuss probability of occurrence of each symbols, channel capacity and entropies. The DNA-protein interaction, which is one of the most important chemical reactions within cells, corresponds to computation in automata theory, which leads to the understanding of genome as formal languages. What the molecular interactions (cascades, pathways, protein complexes and so forth) correspond in the framework is linguistic system, which I introduce as a definitely new concept in order to explain the interaction between matured components. The apparent discrepancies among those three concepts can be solved by mathematical explanation. Long-standing questions like whether viruses are to be categorized into life or not will be shed light on by viewing them as a mere set of strings which do not have a function of computation. In this paper, I aim at explaining biological system from the perspective, which is completely different from the previous ones.

Haruka Miyazawa

An Extension of Artificial Communication System for Self-Organized System

SPEAKER: Haruka Miyazawa

ABSTRACT. Despite of its obvious relationship, it's rather difficult to completely apply the whole picture of information theory to the essential process in biology (i.e. transcription, translation, replication etc) due to the lack of some components. According to the original paper by C. Shannon (1948), general communication system is composed of the following 5 parts; 1. an information source, 2. a transmitter, 3. the channel, 4. the receiver and 5. the destination. As pointed out in the paper by S. Ito & T. Sagawa (2015), there is no explicit channel coding within a cell if focusing on the robustness of signal transduction against noisy environment. Likewise, if one regards genome (DNA) as an information source, then there is no exact counterpart to channel coding or decoding, and on the other hand, if cellular state (a set of protein expressed at given time within a cell) is regarded as information source, it's hard to find the correspondent of information coding in information theory to that in central dogma. One of the plausible reasons why this discrepancy can be observed might be that one is artificial system and the other is self-organized system. In such a physical system that power-law distribution appears, it has been widely accepted that scaling domain of q-exponential as one-parameter extension of exponential can be used to explain the phenomena, correctly. Being deduced from q-exponential, some important formulas for power-law system can be given, including, q-product, q-multinomial coefficient and Tsallis entropy. Particularly, non-additivity of Tsallis entropy (especially called 'pseudo-additivity) has a potential to be applied to a system where statistical independence fails due to nontrivial interaction among each components in a system, including biology. Here, I will review the difference between artificial communication system and self-organized or biological communication system and show the possibility of development for extension of artificial communication system including it as a special case. In doing this, I will show evaluation of various entropies for self-organized communication system including Reny entropy, transfer entropy and Tsallis entropy and why Tsallis entropy is better choice to be utilized as in the system. This result will stimulate the research on self-organized communication system, not only like biological phenomenon but also like natural language.

Ylenia Casali and Hans Heinimann

Characterization of the development of Zurich road infrastructure network under a topological and planning prospective

SPEAKER: Ylenia Casali

ABSTRACT. Infrastructure systems are the backbones of cities for the services they provide. Their structures evolve in space and in time with the change of demography and development program of the administrative planning. Although there are about 200 years of experience in planning "modern" infrastructure systems, we do not well understand how infrastructure networks grow and how this growth is related to demographical and economic development. The purpose of this contribution is 1) to characterise the growth of the road network infrastructure, and 2) to explore if there are signature between the topological network growth and the economic and demographic development. We are using the 1955 to 2012 period to explore the development of Zurich, for which we have high-quality data. The study yields that 1) centrality patterns enable to recognise infrastructure development, 2) to the identification of densification process in the whole city. Future work will investigate the development of network infrastructures across different cities in the world.

Luisana Claudio Pachecano and *Hernán Larralde Ridaura*

Modeling agglomerations of stores

SPEAKER: *Luisana Claudio Pachecano*

ABSTRACT. One of the most intriguing phenomena in the retail world are the causes for the different space distributions of retail stores according to their trade (the products they sell). For some trades it appears to be more convenient for retail stores to be aggregated in a small region, meanwhile for other trades the tendency is to be far away from each other, forming an homogenuos distribution throughout space (city). Why does this happen? For the case of agglomerations, how many stores can be part of an agglomeration? Where do these agglomerations form? In order to answer these and other questions, we need to understand how stores interact. This interaction has its origin in the customers, therefore we need to understand their behavior. We take two aspects into account in customer's decision: one depends on the costs of buying the product under consideration and the other aspect characterizes the heterogeneity of the consumers. The model we propose here allows us to calculate the profits for a store in an agglomerate and for a monopoly. We compare these profits to give an estimation of the best place for a new business to be established. In this work we propose a discrete space model in order to define sites which can be capable of having more than one store, therefore agglomerations of stores may be formed. We intend to model the price competition at each agglomeration as arising from the Nash equilibrium between stores.

Sotiris Moschoyiannis, *Alexandra Penn* and *Stelios Savvopoulos*

On the interplay between topology and controllability of complex networks

SPEAKER: *Alexandra Penn*

ABSTRACT. Complexity theory has been used to study a wide range of systems in biology and nature but also business and socio-technical systems, e.g., see [1]. The ultimate objective is to develop the capability of steering a complex system towards a desired outcome. Recent developments in network controllability [2] concerning the reworking of the problem of finding minimal control configurations allow the use of the polynomial time Hopcroft-Karp algorithm instead of exponential time solutions. Subsequent approaches built on this result to determine the precise control nodes, or drivers, in each minimal control configuration [3], [4]. A browser-based analytical tool has been developed in [5] which can be used by stakeholders in collaborative decision-making, and has been applied to policy-making in industrial networks. One key characteristic of a complex system is that it continuously evolves, e.g., due to dynamic changes in the roles, states and behaviours of the entities involved. This means that in addition to determining driver nodes it is appropriate to consider an evolving topology of the underlying complex network, and investigate the effect of removing nodes (and edges) on the corresponding minimal control configurations. The study of the ability of each node to control the network in [6] showed that control centrality is determined by the degree distribution and in some cases (absence of loops in directed weighted networks) by the node's layer index. In our work we take this one step further and investigate the effect of removing nodes (and edges) on the corresponding minimal control configurations. We propose a classification scheme that combines existing work on topological features [7, 8], with principles of controllability in complex networks. In particular, we consider three categories of nodes based on the effect their removal has on controllability, in terms of the cardinality of the maximum matching, CMM, in the network: a node is delete-redundant, iff CMM is unchanged; delete-ordinary, iff CMM is reduced by one; and, delete-critical iff CMM is reduced by more than one. We experimented with randomly generated directed networks of varying size, and studied pertinent characteristics such as in- and out-degree, average degree distribution as well as connectivity and isolated nodes. Firstly, nodes from each category were removed and we examined the effect on the control configurations of the network. As the edge probability approaches 1, delete-critical nodes decrease rapidly while beyond 1 all nodes tend to become delete-ordinary. Secondly, some nodes (5%, 10%) were randomly removed and we examined the effect this has on the different categories of nodes in the network (for N=500, N=1000). It transpires that the delete-redundant category is the less stable category while delete-ordinary is the most stable as the probability of edge distribution increases. The results of our analysis confirm our hypothesis – structural control theory provides information which is orthogonal to network analysis. The combined information provides a solid basis for the behavioural modeling of a complex system and can provide an important dimension when it comes to scenario appraisal for collaborative decision-making.

Tuhin Chakrabortty and Manoj Varma

Inferring Existence of Physical Feedback Mechanisms from Short-lived Synchronization Events in Complex Systems

SPEAKER: Tuhin Chakrabortty

ABSTRACT. Phase synchronization of periodic dynamical systems is a common phenomena observed in systems ranging from coupled mechanical pendulums to complex biological systems. In biological organisms synchronization may confer fitness advantages for foraging, mating and other essential necessities to sustain life. Equations of system dynamics, which include a physical feedback mechanism coupling the phases of interacting oscillators, result in phase synchronization of oscillators under constraints of noise levels, initial difference and so on. An example of a generic model for phase synchronization with such a feedback mechanism is the Kuramoto model, which exhibits global synchronization of a collection of independent oscillators above a critical coupling (feedback) strength. This model has been extended to include effect of noise in a stochastic environment such as might be expected in a biological setting. In such scenarios, very often we see synchronized behaviour only for a very short duration of time from which one needs to conclude if the observed synchronization event was result of an underlying feedback mechanism or by pure chance. This question is of critical relevance in the context of complex systems where it may be very difficult to postulate feedback generating mechanisms due to the large degrees of freedom.

In this context, we will describe experiments with a model biological organism called, Caenorhabditis elegans, which is a cylindrical microscopic worm with length and width around 1 mm and 50 microns respectively, to look into swim stroke synchronization between worms swimming close to one another. These worms, when put into a drop of water, will start to swim randomly in an undulatory fashion. When two worms come close to each other, they synchronize their swim strokes for a brief period of time before moving away from each other. From these observations one may conclude the existence of a feedback mechanism leading to swim stroke synchronization. For instance, the worms may be sensing the strokes of its neighbour and modulating its own strokes to avoid collisions. It is rather difficult to search and demonstrate the exact mode of feedback due to the complexity of the problem. Therefore, before embarking on such a laborious task, one would like to get some confidence on the hypothesis that a feedback mechanism exists.

Intuitively, observation of long periods of synchronization may seem like a good evidence supporting feedback. However, our numerical simulations show that oscillators with significant inertia leading to a persistence time scale in their frequency fluctuations can produce synchronization events without any feedback which are comparable in length to those arising from systems with physical feedback. Therefore distribution of length of synchronization events is not a robust metric to infer the existence of a physical feedback mechanism. Subsequently, we have explored the statistics of synchronization without feedback in such systems extensively. Based on these studies we propose a metric based on the behavior of the fraction of time the system spends in a synchronized state as a function of external noise as a more robust metric to infer the existence of a physical feedback mechanism.

Eric Hernández-Ramírez and Marcelo Del Castillo-Mussot

Degree distribution of the six main taxonomic classification trees of human languages.

SPEAKER: Eric Hernández-Ramírez

ABSTRACT. We built the taxonomic classification trees of human languages of the six main families from the information on Ethnologue website and we analyzed statistical properties of them. Six linguistic families were analyzed, Afro-Asiatic, Austronesian, Indo-European, Niger-Congo, Sino-Tibetan, and Trans-New Guinea, which cover more than 85 percent of number of speakers and represent more than 60 percent of the living languages of the world. We obtained the degree distribution for the whole taxonomic classification trees not only some levels. We found that the six languages families have similar degree distribution and that this can fitted with a power-law distribution, all fits with correlation coefficients above 0.98. Another important feature found in these trees was that rate between leaves and nodes is close to 0.7, i.e., a considerable part of this structure are leaves.

David García-Gudiño, Emmanuel Landa, Joel Mendoza-Temis, Alondra Albarado-Ibañez, Juan Toledo, Irving Morales and Alejandro Frank

Enhancement of the early warnings in the Kuramoto Model and in an Atrial Fibrillation Model by noise introduction.

SPEAKER: David García-Gudiño

ABSTRACT. When a system is externally disturbed, some statistical moments are affected depending on the nature and the amplitude of the perturbation. This lead us to the following question: how does a perturbation affect the behavior of the early warnings (EWs)? This is the purpose of this work, to determine how EWs are enhanced depending on the amplitude and complexity of the external perturbation introduced to the system, and to show what kind of alerts are more sensitive to this effects. For our purpose we have analyzed several EWs, based in the metric and the memory of the system, for two models: The Kuramoto Model, which is a paradigm of synchronization for biological systems; and an atrial model based on a cellular automata, which has been used to diagnose and treat reentry fibrillation. For each model we have introduced different kinds of perturbations by changing either its nature or its intensity. We have observed that, regardless of its nature, a system can present EWs; further, we have found that the stronger and complex the perturbation introduced into the system, the more the EWs are increased helping to detect them better.

Pavel Soriano-Hernandez, Marcelo Del Castillo-Mussot and Ricardo Mansilla-Corona

Non-stationary individual and household income of poor,

SPEAKER: Pavel Soriano-Hernandez

ABSTRACT. Despite Mexican peso crisis in 1994 followed by a severe economic recession, individual and household income distributions in the period 1992–2008 always exhibit a two-class structure; a highly fluctuating high-income class adjusted to a Pareto power-law distribution, and a low-income class (including poor and middle classes) adjusted to either Log-normal or Gamma distributions, where poor agents are defined as those with income below the maximum of the uni-modal distribution. Then the effects of crisis on the income distributions of the three classes are briefly analysed.

Lev Guzman-Vargas, Ivan Fenández-Rosales and Fernando Angulo-Brown

Distance distributions of human settlements

SPEAKER: Lev Guzman-Vargas

ABSTRACT. We study the spatial distribution of human settlements based on the distance between pairs of cities and in terms of its population. The pair-wise distance distributions can be described by a variety of shapes ranging from quasi-symmetrical to left skewed. Next, we evaluate the degree of inequality by means of a Geo-Gini index, which is defined in terms of distances between pairs of cities and their sizes. Moreover, the spatial correlation between cities is calculated by using the Geary Index. We find that countries with high spatial correlation also exhibit a low level of inequality in city space distribution with a more symmetrical distance distribution. Finally, we discuss our results above in the context of some socioeconomic indexes.

Juan Pablo Ospina López, Diego A. Vega, Jorge A. Quiñones, Joaquin F. Sanchez and Jorge Eduardo Ortiz Triviño

An artificial agent model to achieve emergence of social behaviours in self-organized communications networks

SPEAKER: Juan Pablo Ospina López

ABSTRACT. Nowadays communication systems require a high level of self-organization in order to build scalable networks, consisting of a huge number of heterogeneous and autonomous components. However, there are several challenges that need to be addressed before to achieve systems that can face inherent complexity of large scale networks, heterogeneous architectures, resources constraints and dynamical environments. Until now, many self-organization methods have been developed to face these problems, particularly in the context of ad hoc networks. Most of the proposed solutions are based on bio-inspired computing and successfully solve problems related with routing, synchronization, security and distributed search. Nevertheless, there is a new challenge related with developing mechanisms to improve the cooperation processes among a set of agents. It is necessary to design strategies to achieve mutual benefit and enhance the system ability to solve problems through collective actions. These models are required to handle common- pool resources, to control selfish behaviours and in general to achieve new kinds of social organization that improve the overall system satisfaction. To do this, we can use self-organization mechanisms of human society like trust, justice, reputation to inspire computational models in order to increase the social ability of artificial systems.

In this paper, we propose an artificial agent model to exploits both self-organizing principles: biological and social. We argue that many challenges of modern communication networks can be faced through massively use of self-organization as control paradigm. Bio-inspired computing to achieve efficient and scalable networking under uncertain conditions. Socio-inspired computing to generate new behaviour patterns to solve problems through collective actions. These mechanisms allow a collection of agents adapt their behaviour towards an optimal organization according to the operation context and at the same time, face the tension between individual and collective rationality common in social dilemmas. An artificial agent architecture based in a hierarchy of behaviour is proposed. We formalized the model using a finite state machine and used builder software pattern to implement the agent in a real ad hoc network. To test our proposal, we modelled a non-cooperative game and used the concept of social reciprocity and genetic algorithms to adapt the cooperative behaviour of the agent during the network operation. This test scenario is completely distributed and the result showed that the agent adapts effectively to the environment changes. Furthermore, the agent behaviour is extensible from the point of view of the implementation, making possible use it other contexts.

Tony Liu and *Duane A. Bailey*

Computation and Robustness in Spatially Irregular Cellular Automata

SPEAKER: Tony Liu

ABSTRACT. Dynamic, spatially-oriented systems found in nature such as plant stomatal arrays can produce complex behavior without centralized coordination or control. Instead, they communicate locally, with neighborhood interactions producing emergent behavior globally across the entire system. Such behavior can be modeled using cellular automata (CA) because of the system's ability to support complex behavior arising from simple components and strictly local connectivity. However, CA models assume spatial regularity and structure, which are not present in natural systems. In fact, natural systems are inherently robust to spatial irregularities and environmental noise. In this work, we relax the assumption of spatial regularity when considering cellular automata in order to investigate the conditions in which complex behavior can emerge in noisy, irregular natural systems. We conduct both density classification and lambda parameter experiments on CA systems with spatially irregular grids that are created through a Voronoi process using generator points derived from plant stomatal arrays. We then quantify their behavior and compare them to traditional cellular automata.

In the density classification experiments, we see that the task performance profiles of the irregular grid automata are similar to those of standard automata, suggesting that irregular grids could be suitable for supporting complex behavior much like standard, square grids. Note that this result is achieved despite the lack of periodic boundary conditions in the irregular grids, which decreases neighborhood connectivity and hinders information transfer across the grid space. For comparison, local majority task performance for regular grid is reduced significantly when periodic boundary conditions are removed.

We also generate lambda-entropy profiles of irregular cellular automata in order to detect the presence of critical transition points. Despite the irregularity in cell orientation and non-periodic boundary conditions in these grids, these lambda-entropy profiles exhibit the same shape and jumps in entropy indicative of a transition event in regular CA systems. Furthermore, the transition characteristics are retained when we degrade the connectivity of these grids, an indication of the robustness of computation conditions even in irregular grids.

Though we have relaxed many of the spatial assumptions made in traditional CA systems, both our density classification and lambda experiments have produced remarkably similar results to their regular grid counterparts. It appears that features of regular grids that initially seem crucial for supporting CA behavior such as uniform neighborhood sizes and periodic boundaries are in fact not necessarily required for supporting complex behavior. These results help explain how natural dynamic systems can support emergent computation while handling environmental imperfections.

Magali Arellano, Miguel Robles Pérez, Marlene Zamora Machado, Ernesto Guillermo Kuri-Ramírez and Oscar Jaramillo Salgado

Dynamical analysis of wind data for detection and classification

SPEAKER: Magali Arellano

ABSTRACT. Each year the Santa Ana Winds (SAW) are presented In California and Baja California as a dry, Foen desert type winds, that blows from the Northeast or East quadrant. This winds flow with an intense magnitude and strong bursts that circulate to the sides of the mountains and plateaus. The SAW reach that region with a velocity greater than 4 m/s, the direction of the sustained wind in the quadrant 0-100 degrees and a decrease in relative humidity.

The empirical method of identification takes into account four factors: Speed, direction, relative humidity drop and atmospheric pressure increase. Experimental data was obtained from an automatic station that captures information every 10 minutes, for 5 years, operated by the National Water Commission (CONAGUA). This station is located in the mountainous zone of ``La Rumorosa'' (1263 m a.s.l.), Baja California, México.

The aim of this research is to identify the presence of the SAW automatically by means of a clustering algorithm. For clustering, Gaussian mixtures model is used. A mixture model can be defined as a probabilistic model to represent the existence of subgroups contained in a group. Mixing methods are used to create statistical inferences, approximations, and predictions about the properties of subgroups. The Gaussian mixture model (GMM) is a parametric probabilistic density function represented as the sum of densities of Gaussian components. Each group is modeled by a density function, which represents a family of density functions.

The GMM can be used to represent characteristic distributions in data obtained from meteorological stations is motivated by the possibility that individual components of densities may contain subsets of wind modes hidden in the data. There are previous studies in regions of USA where the k-means algorithm has been used to identify winds. One problem with using K-means or GMM is that there is no way to choose the optimal number of clusters because the number of clusters is an input parameter of the algorithm. However, there are 2 criteria (AIC and BIC) that help to find a grade for each cluster, so that when comparing these grades it is possible to determine how many groups are better.

The analysis was performed on experimental data for the years 2010-2014, as well as an empirical analysis of the SAW, with the characterization of the winds in ``La Rumorosa'' region. The results obtained by GMM were compared with those obtained by the empirical analysis. The comparison shows an agreement rate above 85 % in some cases and the best ones up to 94 %.

Ricardo Cayetano Laurrabaquio-Alvarado, Marcelo Del Castillo-Mussot and Pável Gustavo Soriano Hernández

Econophysics Study of World Income.

SPEAKER: Ricardo Cayetano Laurrabaquio-Alvarado

ABSTRACT. The main objective of the work, is the comparison of the world distributions of the income over several years, obtained by Milanovic Branko and Martín I. Salas. The purpose of this comparison is to know how far apart the two forms of calculating this distributions are, and then to determine a limit distribution to which all distributions tend to exist if such a distribution exists. Obtaining the powers that are believed to follow the tails of the Pareto distributions at the end of higher incomes. This is expected to determine a better approximation of the distribution of income to subsequently make an adjustment, in which the model to be used (regardless of whether there is a limit distribution or not), is based on the analogy of economic transactions, with particles in a system sharing kinetic energy through collisions. These transactions also include saving factors, since in reality (and in general) an economic agent does not lose all its capital (a particle its energy) in a single interaction.

Juan Hernandez and *Carmen Pedroza-Gutiérrez*

The network topology and the agility of a supply chain

SPEAKER: *Juan Hernandez*

ABSTRACT. We analyze the influence of the network structure on the agility of a supply network, which is understood as the “ability to respond rapidly to unpredictable changes in demand or supply”.
Previous results point to the prevalence of scale-free structures and derivatives as the most convenient topologies for agile supply networks. Our main hypothesis is that this is not the case for supply networks where every agent is supplied by other agents in the precedent tier and supply to agents in the subsequent tier. This condition is adapted to the case of some real food supply chains.
In order to test our hypothesis, we build a model that represents a supply network with three tiers (suppliers, wholesalers and distributors) and specific rules to allocate orders and supplies. We assume that the agents' degree distribution in every tier can follow three probability distributions (regular, zero-truncated Poisson, zero-truncated power-law). We simulate a sudden demand change and measure the order fulfillment rate (OFR). The results show that the OFR when assuming power-law degree distributions is lower than when assuming other homogeneous distributions. Thus, the highest agility of the supply network is achieved when degree distributions are homogeneous (regular or Poisson). These results illustrate that the most efficient topology in a supply network is not necessarily scale-free, but depends on the conditions of the specific supply chain.
The model is tested with a real fish trade market, the Mercado del Mar (MM) in Guadalajara, Mexico. The data was collected from several interviews to a sample of 10 wholesalers in the MM. The results show that the pattern of interrelationships in the MM is suitable for the aspects of the supply chain efficiency analyzed theoretically.

Fernando Herrera, *Arturo Morales* and *Fernando Perez*

Stochastic risk model for risk management of exchange rate Peso / Dollar.

SPEAKER: *Fernando Herrera*

ABSTRACT. The exchange rate represents the relationship between two currencies and their behavior is a key factor in the economic performance of a country. During the last few years there has been a significant increase in the exchange rate peso/dollar. From the point of view of risk management this situation is a challenge since the entities should have the sufficient capital to face any sustained increases in the price of the dollar. This paper aims to present an stochastic model based on Brownian motion of Robert Brown and Norbert Wiener for the management of the exchange rate risk. It uses of historical exchange rate information during the 2015-2016 period to simulate the possible trajectories over a year that determines the 0.01, 0.05, 0.5, 0.95, and 0.99 percentiles for each time instant, resulting different confidence bands. It is observed that the behavior of the exchange rate for each year follows a consistent trend over the expected value of the model and in moments of high volatility is located within the risk bands obtained. Due to the above the proposed model can be a useful tool within an entity for risk management purposes.

Marivel Zea, *Jöns Sánchez*, *Angela Jimenez*, *Leopoldo Tapia* and *Hernando Chagolla*

VEHICLE DETECTION THROUGH COMPUTER VISION TECHNIQUES TO DEVELOP INNOVATIVE STRATEGIES IN TRAFFIC SYSTEMS

SPEAKER: *Marivel Zea*

ABSTRACT. Currently, the city of Queretaro requires a counting and a comparative analysis of the emissions produced by the vehicle park since the population is growing exponentially every year, causing the increase of pollutants.

There are different studies to get information of this type, one of them are the vehicular census which use traffic gauges in order to gather data of an area that is representative of a city.

The aim of this project is to develop a system for the detection of moving objects through artificial intelligence to classify and count the real-time vehicle park, which will allow decision-makers to carry out innovative actions in favor of better mobility.

The study will be carried out on Avenida Universidad, which is one of the busiest avenues in the city of Querétaro.

For the development of this system were integrated different tools such as image processing, artificial vision, Gaussian models and Feed-Forward Artificial Neural Networks. Gaussian models are a parametric probability density function represented as a weighted sum of densities of the Gaussian components. We managed to integrate artificial neural networks, which made it possible to recognize the vehicles and classify them as automobile or microbus type.

The data used for the training and verification of the neural network were derived from an experimental design. The variables examined were the number of video frames, the number of Gaussian mixes and the learning speed.

The main findings after implementing this new system were the reduction of at least 70 percent of the time needed to carry out the vehicular census and a reduction of at least 50 percent of the costs of performing the vehicular census, mainly with regard to the personnel that is usually required.

Alexandra Guzman Velazquez, *Carlos Islas Moreno* and *Juan Antonio Nido Valencia*

A chaotic time series that studies the average speed of a Metrobus route

SPEAKER: *Alexandra Guzman Velazquez*

ABSTRACT. This poster presents the results of the chaotic analysis of time series obtained from the data of average speed per hour of route 5 of Bus Rapid Transit (BRT) of Mexico City, during the month of May 2014. The idea of studying the velocity data of a transport system arose from Shang and Kamae's paper ``Chaotic analysis of traffic time series'' (2004), in which researchers assert that they are complex entities. In this work a statistical study was carried out and its most relevant characteristics were examined, as well as apply the techniques of chaotic analysis described by Takens's Theorem. The results obtained are as follows: the series is stationary and its mean is 38.94 km/h. For the phase space reconstruction, the delay time is 2 hours and the immersion dimension is 8 units. The correlation dimension is 0.1063152, an indicator of the chaotic behavior of ``minor dimension''. The maximum Lyapunov exponent results from 0.02231185, positive and finite value implying that the trajectories diverge exponentially and that there is a chaotic behavior. Thus, the rebuilt attractor turned out to be chaotic. Given the study of the time series with the mathematical and computational tools described by different methods, which together encompass the techniques of chaotic analysis allows us to analyze which are the stations with more influx and the time when it happens, or makes us question whether the data they provided is correct. Route 5 is suggested as an alternative transportation system for the Metropolitan Zone of the Valley of Mexico along with other forms of mobility. Some problems are discussed in its operation: that the BRT units reach speeds of more than 100 km/h after 11 pm and very early in the morning, that the speed is very low in hours of heavy traffic. The suggestions to these scenarios are: punishments with speed increase and introduction of intelligent traffic lights.

Georgi Georgiev

A Principle of Decreasing Average Unit Action in Self-organization of Complex Systems

SPEAKER: Georgi Georgiev

ABSTRACT. First principles determine the equations of motion and the conservation laws in physics. Those same principles should determine the evolution of complex systems towards more organized states. The principle of least action states that all motions occur with the least amount of action as compared to alternatives. This can be translated that they occur with maximum action efficiency, if we divide by the action necessary for the occurrence of one event. Since this is a first principle in physics, there is no reason that it will be violated in complex systems. Therefore we investigate the action efficiency of organized systems, as a measure of their level of organization. We find that they evolve toward more action efficient states. Therefore the principle of least action, not only determines all motions and all conservation laws in all of physics, but also the evolutionary states in complex systems. In order to measure action efficiency in complex systems, the principle of least action needs to be modified, from the minimum of action along a single trajectory, to the minimum of the average action per one event in a complex system, within an interval of time. This is an extension of the principle of least action for complex systems. We measure that the increase of action efficiency in the evolution of complex systems happens in a positive feedback with the rest of the characteristics of the complex systems, such as the total amount of action for all events in it, the total number of elements in the system, the total number of events, the free energy rate density in it and others. This positive feedback leads to exponential growth in time of all of those characteristics, and a power law dependence between each two of them, which is supported by experimental data. This causal loop we find is the mechanism of self-organization in complex systems. Further, the tendency for action minimization expresses itself by decreasing action not toward a fixed value, as in simple motions, but further without an obvious limit. This can be termed as a principle of decreasing average unit action, which expresses the tendency to action minimization through bringing the endpoints of the trajectories closer, achieved by increased density in complex systems. Other mechanisms are decreasing the size of the agents in a system, such as in CPUs. Therefore, instead of achieving a state of least action and stopping its evolution there, a system keeps decreasing its action, without any obvious bounds. This makes it an open-ended process, with an attractor – the least possible average action per one event in a system. Thus, systems can self-organize and evolve, starting from simple physical systems, through chemical, biological, social and future. Action efficiency, theoretically can be increased at least to the Planck's limit. This is when one Planck's constant of action is necessary for the occurrence of one event in a system. It is possible that quantum computing can overcome even this barrier.

Andres Anzo Hernández

On the basic reproduction number for vector-borne disease in a metapopulation system with human mobility: a dynamical network approach

SPEAKER: *Andres Anzo Hernández*

ABSTRACT. The basic reproduction number (Ro) is an index whose value defines a threshold to know if a given disease will spread into a completely susceptible population. Furthermore, in the context of dynamical systems, the basic reproduction number is related to the stability of the disease-free equilibrium point in an epidemic compartmental model as the well know Susceptible-Infected. In specific, if Ro<1 the disease-free point is locally asymptotically stable, and if Ro > 1 it is unstable. Then, from the mathematical analysis, it is possible to determine and explicit form for Ro via the next generation matrix or by a direct linearization of the model over the free-disease equilibrium point. Even more, an expression for Ro in vector-borne disease as those transmitted by mosquitoes (Dengue, Zika or Chikungunya) it is also possible to obtain in terms of mosquitos-entomological parameters. However, it is not straightforward to get an expression for Ro in a metapopulation system in which the disease is propagated over a set of multiple connected communities and where humans are able to travel between them. In this work we use the formalism of dynamical networks in order to obtain Ro in a metapolution model using both methodologies: the next generation matrix and the master stability function. We address this problem from the Lagrangian perspective where human-mobility is introduced via the resident dwell-time parameter pij, which stand from the fraction of time that residents from the community i spend in community j. In this context, the system is modeled by a dynamical network with weighted and unidirectional links given by pij and where the dynamic of each node is described by a compartmental model of Susceptible-Infected for both humans and mosquitoes. We prove that Ro depends on the following parameters: mosquitoes-entomological (effective biting rate, per-capita mortality of adult female mosquitoes, etc.), human features (recovery rate) and human mobility (pij). We analyze under which range of values from the above parameters occurs that Ro<1 and we investigate the effect over Ro of network's topology and the distribution of the values for pij.

Carlos Minutti and *Susana Gomez*

Improved Characterization of Naturally Fractured-Vuggy Carbonate Reservoirs Through a Statistical Multivariate Analysis

SPEAKER: *Carlos Minutti*

ABSTRACT. Characterization of naturally fractured carbonate reservoirs has been a major challenge in the oil, gas and underground water industry. The world's largest oil and gas reserves are present in these giant carbonate reservoirs. Dynamic reservoir modeling is still under study, specially due to the triple porosity which adds another dimension of complexity to the characterization of these reservoirs, with multiple solutions.

In order to characterize these reservoirs through well test analysis, we use a triple-porosity double-permeability model, and a triple-porosity single-permeability fractal model. Using the analytical solution of the model, a statistical sensitivity analysis of a large number of synthetic cases is performed, and the behavior of the different parameters involved in the model is studied by averaging the effect of each parameter in the pressure and the magnitude of this effect. Also the importance of each parameter over different time values is evaluated. By unifying this information, an ad-hoc methodology for reservoir characterization (with the studied model) is proposed.

This methodology significantly reduces the estimation error of the reservoir parameters, from 29% to 11% on the median overall error for the less-sensitivity parameters, making it possible to estimate these parameters to changes in wellbore pressure. It also predicts the range of values in which each parameter has a higher estimation error and can eliminate multiple solutions that can be reached with an optimization algorithm due to numerical precision.

We present results on Mexican carbonate reservoirs and make a comparison with results using commercial dual porosity software. We show that our characterization increases the amount of information of the reservoir, gets more accurate fit, and demonstrate that considering triple porosity is crucial for these types of reservoirs.

Daniela Sosa, Alma Piñeyro, Elena R. Alvarez-Buylla and Aaron Castillo Jiménez

Comparative analysis of the molecular evolution of the Gene Regulatory Network underlying trichoblast formation in over 850 ecotypes of Arabidopsis thaliana.

SPEAKER: Alma Piñeyro

ABSTRACT. Plants are sessile organisms that contend with environmental changes through the dynamic modification of their physiology, genetic expression and morphology. While these changes occur at the individual level, advantageous changes can diffuse and eventually fixate in a population. Thus, populations from a given species subjected to different environmental cues can locally adapt, giving way to distinct varieties or ecotypes that can in turn have contrasting phonological, developmental or growth patterns. The comparative study of natural variations in response to different environmental cues across the ecotypes of a particular species can allow to empirically assess the robustness and evolvability of particular nodes within a Gene Regulatory Network (GRN). In this work we analyze the effects that potential local adaptation to contrasting environments can have in trichoblast patterning in the root, through a comparative analysis of the molecular evolution of the genes recovered as necessary and sufficient in the GRN underlying trichoblast and atrichoblast patterning in plants. The study case presented in this work involves a comparative analysis of the mutational changes fixed in over 850 ecotypes of the plant model species Arabidopsis thaliana. These ecotypes have evolved in different parts of the world, some under contrasting ecological and climatic conditions. Thus, we use an ecological evolutionary developmental biology (eco-evo-devo) approach to survey which genes within the trichoblast GRN have incorporated more non synonymous mutations as well as which ecotypes present divergent mutational patterns with respect to the most widely used A. thaliana ecotype for genetic and functional studies: Columbia-0. Furthermore, we present preliminary data pertaining correlations between select A. thaliana ecotypes with extreme patterns of gene variation with their ecological settings.

Malgorzata Turalska and Ananthram Swami

Propagation of cascading overload failures in interconnected networks

SPEAKER: Malgorzata Turalska

ABSTRACT. Cascading failures are frequently observed in networked systems and remain a major threat to the reliability of network-like infrastructure. To assess system resilience, we analyze the effect of link failure on the process of the sandpile avalanche propagation through interconnected networks. We observe a positive feedback between link failure due to overuse and sandpile dynamics, where damage spread is controlled by the link strength and density of interlayer connections. Our work provides insight into the problem of optimal robustness of systems of interconnected networks. We consider a classic model of cascading failure, the BTW sandpile model, on a system of interdependent networks. Additionally we assume that links in the system fail after they have transported more than θ grains of sand. For simplicity and ease of visualization, we consider a system of two square lattices, with periodic boundary conditions in each layer, where both inner and interlayer links are characterized by the same strength θ. In a weakly connected system where θ is low structural damage to the network propagates radially from a site of initial failure causing an abrupt collapse of the entire system (Fig.1; top, left). An increase of link strength θ causes more gradual and uncorrelated damage spread, with different parts of the system failing at different times (Fig.1; bottom, left). In both cases an increase in coupling P between layers leads to increase in the number of sites at which failures originate followed by simultaneous destruction of remaining links (Fig.1; right). Strong and weak links, however, affect system resilience in diametrically different manner. Increase of coupling P between layers in a system with weak links leads to greater diversity of times at which links fail, with an abrupt collapse of the network occurring at later times (Fig.1; top, right). Thus when operating a system built on weak components the increase of coupling between layers comes as a strategy improving resilience to failures. On the other hand, an optimal resilience for a system of strong components is reached at low connectivity, where greater variability of failing times is observed. These results come in line with observations of numerous nature and man-made networks characterized by a modular structure, where clusters of strongly connected nodes are weakly coupled with each other. Our work suggests that such mixed topology might be most robust one with respect to failures propagating through the system.

Julio Cesar Ruben Romo Cruz, David Garcia-Pelaez and Arturo Rodriguez Chacon

A simple model of friendship rank-distribution on a social closed network and its academic impact.

SPEAKER: Julio Cesar Ruben Romo Cruz

ABSTRACT. We present an analysis of an ordinary classroom as a (closed) social network. We show that the relations of friendship amongst the agents of the classroom are given by a degree distribution that follows a strong random trend, and that its connection probability distribution function P(k) is of a Gaussian kind. On the other hand, we show that the relations of animosity amongst the agents have a highly correlated behavior, which can be seen as a connection probability distribution described by power laws. Later on, we analyze the impact of the level of harmony (or disharmony) on the academic performance of the agents as a whole, and we propose an analytic model that describes this impact by a Beta-like function. To finish, we conclude that as the degree distribution of the agents of the network becomes more homogeneous, the academic performance of the agents improve.

Daniela Pedroza-Paez, Luis Bojorquez-Tapia, Germán Ponce-Díaz, Antonio Diaz-De-Leon and Francisco Arreguín

Regulating loggerhead sea turtle fishing bycatch in Gulf of Ulloa Mexico: An exploratory modeling approach

SPEAKER: Daniela Pedroza-Paez

ABSTRACT. The case of incidental fishing bycatch of loggerheads epitomizes the challenges in policymaking regard-ing highly migratory endangered species. Sea turtles are protected by multilateral agreements that identify fishing bycatch as a major threat. In our case, the U.S. government notified Mexico of possible trade sanctions because the lack of proper regulations to address this threat. In Mexico, authorities, scientists, and stakeholders faced deep uncertainty arising from a combination of very down-to-earth factors, such as limited information, conflicting descriptions of causal relationships, disagreement about evidence, restrictions embedded in formal spatial models, linguistic imprecision, statistical variation, and measurement error. In addition, “politically induced uncertainty” exacerbated conflict as government agencies used disciplinary authority and knowledge to narrow the scope of the available scientific data and downplayed gaps of knowledge in favor of their institutional mandates. Accordingly, we implemented a transdisciplinary approach to address the conceptual, institutional and social barriers that historically had impeded consensus building about regulations to curtail fishing bycatch of loggerheads.

We addressed the analytical and methodological challenges of tacking such an urgent, political and contested issue through exploratory modeling. In particular, our research was framed in conformity with the Mexican legal requirements of duly grounded and reasoned decision making. Hence, we combined two techniques. The first aimed to generate an early warning indicator and entailed the implementation of ecological risk assessment. The second aimed to elicit an optimal zoning scheme and entailed the implementation of the area-oriented multiple use framework. One innovative aspect of the latter was the use of multicriteria modeling to estimate the relative costs of segregating fishing or conservation activities in each zone. Results constituted the backbone of the regulations aimed to set a bycatch cap and a refuge area for loggerheads in Gulf of Ulloa, which were considered comparable in effectiveness as those of the U.S. government apply in Hawaii.

We argue that our results identified the short-term course of action that was consistent with the long-term goal of preserving the Eastern Pacific loggerhead population, in accordance with the international commitments of Mexico. We generalize that this case shows how exploratory modeling can be used to enhance the ethical and epistemological dimensions of transdisciplinary inquiry. The corollary of the whole process teaches that an exploratory modeling rationale enabled a structured interpretation of the stakeholders´ positions, which not only exposed some key logical fallacies but also improved governance of the loggerhead population-halibut-fishermen system.

Regnier Cano and Rodrigo Patiño

Urban Growth and Complexity related to Social Energy and Food Consumption.

SPEAKER: Regnier Cano

ABSTRACT. Many branches of science try to define complexity, it does not exist a unified definition of it, however some physicist attempt to construct a definition. This definition basically fixes a way of measuring the complexity, that is the energy rate density, that considers the amount of energy flowing through a system per unit time and per unit mass. This free energy is related with the entropy changes in a system (Chaisson, 2011). In this work, it is proposed to understand the complexity of human societies through their urbanization processes. Particularly, it is analyzed the effect of these processes on energy consumption and how it is related with complexity. This research explores the idea that, as a society is more urban (complex), the greater is its energy consumption; this process is also related to an increase in food consumption. Many countries in the world were studied and the analyzed data were: (i) the total primary energy supply, obtained from the International Energy Agency; (ii) the urban population, total food and animal food, obtained from the Food and Agriculture Organization of the United Nations. Both the primary energy data (in the period from 1990 to 2014), and the food consumption data (in the period from 1990 to 2011) were conversed to energy rate densities, as a quantification of complexity. These values were related to those of urban population to establish different behaviors of national energy and food consumptions. Indeed, while some countries show excessive energy consumption, some others are moderated or even efficient in their urbanization growths. We conclude that the urban population of a society is an adequate indicator to describe the corresponding values of total primary energy supply and food. The results presented here will provide clues for the construction of a model that will allow identify key factors to find solutions for sustainable energy consumption.

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Pablo Carlos López and Andrés García

Approximation to the quantum planar rotor coupled to a finite temperature bath

SPEAKER: Andrés García

ABSTRACT. An approximation to the description of the dynamics of a quantum planar rotor coupled to a finite temperature bath is derived by considering a microscopic model of interaction based on an angular momentum exchange with two different environments coupled independently to the positive and negative angular momentum spectrum. A non-Lindblad master equation is derived for this microscopic model by using the Born–Markov approximation in the weak coupling limit. We show that under this approximation the rotor dynamics presents the correct damping behavior of the motion and the thermal state reached by the rotor is in the form of Boltzmann distribution. The case of the quantum rotor in an external uniform field and the quantum kicked rotor are briefly discussed as exemplification.

Quetzalcóatl Toledo-Marín and Gerardo Naumis

Short time dynamics determine glass forming ability in a glass transition two-level model: A stochastic approach using Kramers' escape formula

SPEAKER: Quetzalcóatl Toledo-Marín

ABSTRACT. The relationship between short and long time relaxation dynamics is obtained for a simple solvable two-level energy landscape model of a glass. This is done through means of the Kramers' transition theory, which arises in a very natural manner to calculate transition rates between wells. Then the corresponding stochastic master equation is analytically solved to find the population of metastable states. A relation between the cooling rate, the characteristic relaxation time, and the population of metastable states is found from the solution of such equation. From this, a relationship between the relaxation times and the frequency of oscillation at the metastable states, i.e., the short time dynamics, is obtained. Since the model is able to capture either a glass transition or a crystallization depending on the cooling rate, this gives a conceptual framework in which to discuss some aspects of rigidity theory, for example.

Marzieh Zare, Mostafa Jannesari, Ali Reza Saeedi, Silvia Ortiz-Mantilla and April A. Benasich

Emergence of Criticality in Infant Brain: An EEG study

SPEAKER: Marzieh Zare

ABSTRACT. Background: Self-Organized Criticality (SOC) is a characteristic feature of complex dynamical systems. Study of SOC in the human brain has attracted widespread attention among physicists, and there is extensive empirical evidence that the brain works near criticality. At the criticality, avalanche size and lifetime distributions display power-law exponents limited to a specific range. Invasive studies investigated criticality in brain activity by examining Local Field Potentials (LFP) and ECoG data; however, noninvasive methods also demonstrate criticality in human brain activity. Recent studies report power-law behavior (PLB) in EEG, MEG and fMRI data. Some studies propose that the human brain is a non-linear self-organized system and thus power-laws represent a signature for a healthy, well-functioning brain. On the other hand, neuronal avalanche dynamics represent a particular type of synchrony. Large-scale synchronization has been shown to emerge in higher frequency bands. Here, we explore whether PLB is a signature of SOC that emerges in infancy and if that signature also tracks developmental trajectories. We also examine the evidence for the origin of criticality and PLB specific to different frequency bands.

Methods: EEG from 62 scalp electrodes was recorded from 12 healthy infants at 6 and 12-months-of-age (N=24) who were awake, and comfortably seated on their parents' laps. Each child's EEG data was examined for changes in evoked activity. EEG signals were sampled at 250Hz and band-pass filtered online at 0.1–100 Hz. We examined evoked data from an oddball paradigm that presented two blocks of paired complex tones, one separated by a 70ms ISI and a second by a 300ms ISI. Average duration of the recording was ~10 minutes for each child for each ISI condition. Using automatic channel rejection (EEGLAB), noisy channels were identified, removed and interpolated. Time series were broken into six frequency bands: delta, theta, alpha, beta, gamma and high gamma. To detect avalanches, data were Z-scored. Neural avalanche analysis was performed separately for each frequency band for each subject at each ISI. Activity was defined based on a threshold computed as a factor of SD and whether the negative peaks of the EEG exceeded that threshold. If separation of two activity periods was less than a specific window length, regardless of electrode location, we counted them as the same avalanche. Thus the "size" of an avalanche is the number of activities and their "duration" equals the time difference between the first and last activity within an avalanche.

Results: These results demonstrate that, even in infancy, the human brain is a SOC system. Power-law behavior was demonstrated in 6-month-olds. In a subset of subjects, however, this pattern only emerged at 12-months, suggesting an extended developmental trajectory for appearance of PLB. Our results also revealed that, at least at these ages, only higher frequency bands exhibited PLB. As higher-frequency brain activity has been associated with conscious attention, cognition and critical thinking, the significance of this finding needs further exploration. But we propose that local brain synchrony can propagate via a neuronal avalanche mechanism and that SOC follows a variable developmental progression.

Juan Carlos Pascual

Correlation of pollution and traffic flow in Mexico City. Predictive analysis for the impact in possible scenarios of chaotic events in the future.

SPEAKER: Juan Carlos Pascual

ABSTRACT. Abstract — Mexico City Metropolitan area is one of the biggest and most polluted urban areas in the world; no specific data exists indicating the impact and correlation of the traffic flow, on the air pollutants and how the increase on motor vehicles and changes in the infrastructures will impact in Critical condition of contamination and possible collapse of vehicle circulation. This aim of this study is to begin the acquisition of data in the critical season of high pollution of spring that in year 2016 was in critical pollution index that make the government change regulation for verification of vehicles but not in traffic flow. Begin to develop a model for the correlation of traffic flow vs pollutants and climatic variables and propose scenarios of change.

Magali Arellano and *Hector Benitez-Perez*

Routing in temporal networks

SPEAKER: *Magali Arellano*

ABSTRACT. A temporal network (TN) can be described as a set of devices capable of computing and communication, interacting amongst each other for varying time periods, ie, since nodes are mobile it is possible that new nodes join, meanwhile others leave the network. To establish a route between a pair of nodes of this temporary network is not a trivial matter, classical algorithms choose the route as a large and computationally expensive static trajectory, nevertheless, in a Temporal Network, a chosen node may not be available for communication in a period of time. One strategy is that for a specific instant, the route may be represented as graph describing the configuration that a local network can adopt in current time. Therefore, it is not suitable to use traditional routing algorithms for TN since they are designed for static topologies in which it is necessary to know about the whole network in order to be able to determine any optimal route. Traditional routing algorithms use a path discovery algorithm each time the topology changes, it requires the generation of a global state of TN continuously.

In this research, it is proposed an algorithm for routing discovery, whose objective is to decrease network flooding. The algorithm is named Consensus Routing Algorithm (CRA). CRA accounts the characteristics of the TN, such as idle time in the scheduler, network's availability, mobility, and the distance between nodes. Idle time in the scheduler node is a significant feature because the path is considered broken if there is not enough time in node's scheduler to transmit a message.

The algorithm obtains a route through a dynamic topology, by establishing successive consensus among nodes. Inside a local group, each node gets routing information from its neighbors while exists an active connection. This provides resilience to local changes of the dynamic topology: any change is kept at a local scale.

When some change occurs (a mobile node entering, moving, or leaving), it does not affect the overall state of the TN, but it only involves the local group of the implicated nodes. Then, it is not necessary to recalculate the entire route, but only those groups of nodes affected by the change. The union of the local states of the nodes forms the local network status at a given time T. To determine the cost of sending a message between two nodes, it's defined a metric in terms of how long it takes to deliver a message over a given route.

The route obtained by the CRA is represented as a sequence of nodes with the best conditions for transmitting like a router and thus reducing the communication efficiency of such a route. By using a limited neighborhood, the number of active connections is significantly reduced, particularly when compared with flooding. However, the flooding algorithm obtains a route in less time, but this route is more likely to be inefficient compared with the route calculated by the CRA.

Juliana S. Silva and Antonio Mauro Saraiva

The Proposal of a Methodology for Applying Social Network Analysis Metrics in the Biodiversity Informatics Domain

SPEAKER: Juliana S. Silva

ABSTRACT. In the last decade, several researchers have used Interaction Networks for analyzing the role of species in network structure, focusing on the factors that have contributed and influenced biodiversity maintenance. The concepts, algorithms, metrics and computational resources commonly used in this field are the same as those in Social Network Analysis (SNA), which uses the graph theory concepts, computing techniques and resources to analyze the interdependencies among nodes in the network. Therefore, we propose a methodology to guide researchers to apply SNA metrics to biological Interaction Networks, in the Biodiversity Informatics domain. The methodology is formalized by means of Business Process Modeling Notation (BPMN) and structured in four steps: (i) mapping the data types and the interactions available; (ii) defining the key-questions to be answered and the analysis variable; (iii) choosing the SNA metrics appropriate to the context of the research; and (iv) performing the biological analysis with the support of SNA. As material resources, a set of computational (such as R packages, Dieta, Pajek and Ucinet software) and Statistical Analysis (Exploratory and Multivariate Data Analysis) tools were used, as well as the SNA metrics. This proposal was born at the Research Center on Biodiversity and Computing at the University of São Paulo (BioComp-USP), by means of the collaboration with researchers from different areas (Ecology, Genetics, Microbiology, Social Network Analysis, Statistical and Data Analysis). To assess the suitability of this methodology, it was submitted to pollinator-plant and microbiological Interaction Network case studies. The results show the benefits that providing a systematic method to guide the steps of a research can bring to a researcher – be it due to the support of the resources recommended, be it by the organization of the research activities. Furthermore, when a researcher has interaction data organized in a bipartite matrix, it is possible to apply SNA resources to identify clustering patterns and to discover new knowledge regarding the data. As an example, we can mention that, by means of the w-clique metric, it was possible to discover new knowledge regarding a simple interactions database (phylogenetic subgroups frequency in water bodies) – the water bodies were clustered in polluted and unpolluted sites; this pattern had not been revealed using classical grouping methods. Finally, as future work, we consider the possibility of applying this methodology as a complementary resource to underexplored knowledge areas (such as Agrobiodiversity and Molecular Genetics), in the identification of patterns to support decision makers.

Joseph D. Ramsey, Madelyn Glymour, Ruben Sanchez-Romero and Clark Glymour

Discovering high-dimensional functional directed networks of the human brain using the Fast Greedy Equivalence Search algorithm for up to a million variables.

SPEAKER: Ruben Sanchez-Romero

ABSTRACT. Effective connectivity inference algorithms applied to brain data from non-invasive imaging techniques, allow us to characterize the functioning brain as a dynamic and complex causal network of interacting regions that support motor, sensorial, and cognitive activity. New functional magnetic resonance imaging (fMRI) acquisition protocols, such as multi-band techniques, are producing data with increasingly higher temporal and spatial resolution. These new data demand inference methods that scale up well to high dimensional complex systems, in order to achieve novel and detailed mechanistic characterizations of functional brain networks, in terms of causes and effects. Here, we describe two modifications, based on parallelization and caching reorganization, that massively scale up the well-known score-based Greedy Equivalence Search (GES) algorithm for discovering directed acyclic graphs on random variables. The first modification, called the Fast Greedy Equivalence Search (fGES) algorithm is capable to recover with high precision and good recall high dimensional directed networks with up to one million variables. The second modification rapidly finds the Markov Blanket of any node (ie. the minimum set of nodes needed to fully predict the behavior of a node in a network) in a high dimensional system. These two modifications are tools to obtain global and local detailed mechanistic descriptions of high dimensional complex systems, such as the human brain. But they are general enough to be applied to other domains, such as genome data for cancer drivers discovery, or macroeconomic policy. We illustrate the fGES algorithm with a high resolution human resting-state functional magnetic resonance imaging (rs-fMRI) dataset for which the brain cortex was parceled out into 51,000 voxels recording blood oxygenation level-dependent (BOLD) time series of 10 minutes. We describe properties of the resulting rs-fMRI voxelwise network. Finally, we show how from the high resolution brain network produced by the fGES algorithm we can reconstruct brain networks at coarser spatial scales, such as the popular region of interest (ROI) mesoscale networks.

Francesco Pinotti, *Fakhteh Ghanbarnejad*, *Philipp Hoevel* and *Chiara Poletto*
Interplay between cooperative and competitive effects in multi-pathogen interaction systems
SPEAKER: *Fakhteh Ghanbarnejad*
ABSTRACT. Pathogens do not spread alone and share their host with other pathogens often interacting with each other in non-trivial ways. Both cooperative and competitive interactions have been observed. These two mechanisms have been mainly studied separately and non-trivial dynamical effects like hysteresis and bistability have been shown to arise from them [1-3]. Here we consider two pathogens competing with each other for hosts in presence of a third pathogen cooperating with both of them, mimicking in this way ecological mechanisms observed in bacterial infections [4], see Fig. (1). We address the impact of cooperation on the outcome of the two-pathogen competition, defined in terms of dominance of one competing pathogen or the co-circulation of both of them. Stability theory within the mean field approximation is combined with computer simulations assuming different contact networks among hosts.
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Akira Ishii, *Kana Fukui*, *Ayaka Miki*, *Nozomi Okano* and *Yasuko Kawahata*
Analysis of social epidemic phenomena on SNS using social physics approach
SPEAKER: *Akira Ishii*
ABSTRACT. In the present age where consumer behavior remains on record through the Internet, purchase records and action records for huge quantities of consumers are left. In this paper, we propose a method based on social physics for analyzing and forecasting social phenomena, and possibly applying it to marketing etc. by using the voices of society's people recorded by blogs and Twitter as data. Social physics is a new frontier of physics alongside economic physics, but if there is a huge amount of data, the methodology of physics that has been the subject of experimental data on natural phenomena can also be applied to social science. The approach using this article will be one of significant approach in computational social science. In this paper, we focus on social epidemic phenomena and consider how break and convergence can be measured on the theory of social physics. The social outbreak mainly treated in this research is Piko t aro and hydrogen water[1]. Both are rapidly prevalent, and convergence abruptly in the case of the hydrogen water in Japan. The theory used for analysis is a mathematical model of the hit phenomena. This theory was submitted by Ishii et al. In 2012[2], supposing that humans advertise the opportunity to be interested in a certain topic, a review from a friend and rumors heard in town. This theory is the theory of social physics that quantitatively treats breaks and convergence of people's interests. It is a theory that can analyze breaks and convergence of reputation such as movies, music concerts, social incidents. Analysis shows that fashion breaks and convergence correspond to the strength of rumors that can be measured from the theory in social media.
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Jesús Andrés Arzola Flores and *Esmeralda Vidal Robles*
Sincronización en Sistemas Químicos
SPEAKER: *Esmeralda Vidal Robles*
ABSTRACT. En el presente trabajo se muestra la sincronización entre sistemas químicos de distinta naturaleza mediante la construcción de modelos matemáticos de los mecanismos de reacción de dichos sistemas. Se emplea un acoplamiento unidireccional simétrico. Se muestra que mientras el parámetro de acoplamiento crece, la sincronización aparece, además, para cierto valor del parámetro de acoplamiento emerge un estado de caos intermitente, el cual puede ser una ruta a la sincronización en sistemas químicos. Se cuantifico la evolución de la dinámica de sincronización mediante el cálculo de la dimensión fractal de las series temporales obtenidas de la solución numérica del sistema de ecuaciones diferenciales no lineales. Los modelos matemáticos obtenidos podrían ayudarnos a entender la compleja dinámica existente en la regulación hormonal en humanos.

Gabriela Durán-Meza and José Luis Del Río-Correa

Escort distribution of order q and its implications in multifractals.

SPEAKER: Gabriela Durán-Meza

ABSTRACT. A multiplicative cascade can be characterized by p, a probability vector defined on the unitary interval. This can be possible using the Halsey's measure H(M,q,τ), this measure consider the geometric and the probabilistic properties of a optimal cover of the unitary interval, the first associated with τ and the second with q. We use the fact that the condition for obtain a non-degenerate value of the measure H implies the existence of a function between the τ and q parameters, i.e. τ = τ(q). We show the relationship between τ(q) and the Halsey partition function, and prove how H(M,q,τ(q)) generates a multiplicative cascade with the escort probability introduced by Beck and Schlögl. The statistical multifractals are characterized by their dimension spectrum D(α) in terms of the Holder exponent α. We analyze how is distributed the measure generated by the escort distribution of order q on the different sets J(Δ), and show that this measure is concentrated on a particular set with a Holder exponent α*(q) which define the condensation set of the measure.

Giuliano Punzo and Dario Bauso

Compartmental analysis of infrastructures

SPEAKER: Giuliano Punzo

ABSTRACT. Networked engineering systems are often referred to as complex engineering systems (CES), as much as human beings and social communities. Some CES have a large social component. In an electric network, for example, the load is defined by the individuals' demand, which is highly dependent on the individuals' routine. Cascade failures are a common problem to CES, which mirror in the spread of epidemics for socio-biological systems. While biological systems can usually count on immune systems to avoid infection or to heal, there is not such a thing in CES. Compartmental models are mature tools used in epidemiology to track the spread of diseases across populations (see for example [Longini 1988]). However application to technological fields has only recently been attempted, and only for validation purposes, using unmodified epidemiological models as in [Mehrpouyan et al. 2015]. This study assesses the feasibility of applying specifically designed compartmental models to complex engineering systems, with a particular focus on infrastructures, to anticipate the cascade failure risk and, most importantly, define immunization strategies to minimize their likelihood. In CES different components have different probability of failure and different failure modes. Most importantly, these are often strongly dependent on the age of the component and its load in the time domain. We shall hence define a compartmental model for complex systems where node susceptibility to infection is based on their load and age. As such they have to take into account non-deterministic variables such as the users load and its shifts due to external factors (e.g. traffic congestions following public transportation strikes. What part of a road network will jam first and how will the congestion propagate? Is this going to have long term consequences such as road degradation?). First the literature is surveyed searching for compartmental model features that best adapt to be translated from immunology onto complex engineering systems. Attention will be put on network systems with non-uniform node. We shall introduce an explicit time dependency, a novel aspect in compartmental models [Huang et al. 2016], well suited for the case of CES, mirroring the concepts of "births and deaths" from epidemiological models [Liu 2004]. These features are included in a mathematical model and their effect is explored through numerical simulations. Wherever possible an analytical, steady state solution is offered. The model seeks to provide quantitative indicators of the network resilience and allow performing stability analysis.

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Katya Perez Guzman, Oscar Córdoba Rodríguez, Ana Belén Ríos Carmona and Fernando Ramírez Alatriste

Mapping the carbon curse with system dynamics modeling for Mexico, 1965-2000

SPEAKER: Katya Perez Guzman

ABSTRACT. Climate change mitigation is for many a chimera, primarily due to the unsuccessful attempts at emissions reductions over the long term, evident already by the beginning of the twenty first century, when the first complying periods of international regulations were expected. There are many reasons for the emissions' obstinacy at negating hopes for curving down, but fossil fuel producing countries can be an excellent unit of analysis to begin to inquire. The carbon curse has emerged from the natural resource economic literature to underscore the possible structural drivers of emissions in countries whose economic, social and political machinery has historically been built around, or parallel to, oil production. This article maps a system dynamics model of the carbon curse, where CO2 emissions do not stem solely from the direct consumption of fossil fuels, but from indirect structural forces that place government contracts to the most energy intensive sectors of the economy in the center of the problem. With the resulting systems of differential equations, we compare three different periods of Mexican history: that when oil was used mainly for internal production (1965-1975), a second one when Cantarell is discovered and the country starts an intensively extractive period that continues until today (1975-1985) and the third one, when oil is Mexico´s primary export commodity (1985-1995), and the most energy intensive sectors of the economy (cement and steel) account for an important part of the highest levels of carbon intensity in the history of Mexico. The resulting scenery does imply a relationship between government investment and contracts, which do appear to have a causal relationship with carbon intensity. The importance of such findings lies in the fact that such indirect forces are not taken into account on emission accounting, much less into climate mitigation policy. A further comparison between oil producing countries, looking to duplicate the results and for additional drivers behind the carbon curse, can give light to the structural drivers behind an oil producing economy. It is only when these barriers are taken into account that the societies will be able to follow a consistent and permanent future low carbon development path.

Herman Geyer

Determining the micro-effects of dimensionality on agent mobility in Polycentric City Regions using fractal scaling

SPEAKER: Herman Geyer

ABSTRACT. The metaphor of fractals is thus the repetition of patterns at different scales, both as the repetition of a form in a subsystem nested within a system and between autonomous subsystems of different scales. However, it is expected that there will be a very real variance between real discrete structure of the city and predicted effects. Fractals serve to illustrate that within the perceived randomness and unpredictability in systems, structure emerges. Applied to the problem of complexity theory and polycentrism, the main research question in fractal scaling is this: if change occurs in the city region as a discrete in reality, should it correspond to changes in the fractal simulacrum, being the idealised representation of city regions in terms of a static maximum of equilibrium economic model. The paper attempts to analyse the self-similarities in fractal geometry by creating a model of change in South African cities.

Ana María Aguilar Molina, *Alejandro Muñoz Diosdado* and *Fernando Angulo Brown*

Fractal and multifractal analysis in time series of ECG

SPEAKER: *Ana María Aguilar Molina*

ABSTRACT. Fractal and multifractal analysis represents a mathematical theory and a method to analyze and identify a wide variety of natural phenomena. Such analyzes have recently been used to study time series of physiological systems and other systems.

A standard technique for diagnosing heart disease is the electrocardiogram (ECG). The heartbeat time series obtained from ECG aren't stationary, and according to many researchers, multifractal characteristics are present in healthy individuals and monofractal in patients with chronic heart disease. Fractal dimension provides information about changes in the internal dynamics of the time series. Various "multifractal formalisms" have recently been developed to describe the statistical properties of these measures in terms of their singularity spectrum f(α), this spectrum provides a mathematically precise and naturally intuitive multifractal description with singularity strength α, whose fractal dimension is f(α) for each value of α. In this thesis the method of Chhabra and Jensen is used. They developed a simple and accurate method for direct calculation of the singularity spectrum. To analyze the multifractal spectrum, the parameters of symmetry, and the degree of multifractality Δα, which depend on the values of $\propto$max, $\propto$min and $\propto$0, give us a description of the time series.

In this work we used multifractal formalism for the analysis of time series of heartbeat obtained from the databases of the Physionet website, and time series of 24 continuous hours (Holter) of patients with metabolic syndrome.

The time series were previously treated to eliminate artifacts and two segments of six hours were obtained: one was obtained when the subjects were asleep and the other when the subjects were awake. The three parameters that describe the multifractal spectrum were calculated for each one. However, both the degree of multifractality and the asymmetry of the multifractal spectrum do not provide sufficient information about the health status of the study populations. For this reason, we introduce more variables to provide more information on the people health state. The proposal of this work is to measure the curvature of all multifractal spectra and introduce another parameter "r", called "the symmetric parameter" which identifies the preferential inclination of the multifractal spectra. We found that the parameters of curvature and the symmetric parameter of the multifractal spectra provide a correct assessment of the health status of the individuals.

Matías Daniel Fernández

Confirmatory bias as incommensurability. Micro-grounding the contrarian effect

SPEAKER: *Matías Daniel Fernández*

ABSTRACT. The possibility of working with increasingly complex models led to the detection of emerging patterns difficult to explain and even to interpret, demonstrating that simple models still have significant explanatory potential. One of the emerging patterns with the greatest impact in the social sciences has been, perhaps, the revelation that polarization seems to have a greater role in our world than it has consensus. The contrarian effect, as a macroscopic phenomenon, is nothing more than the presence of agents who are "against the flow", that is to say, that base their own personal assessments in the antipodes of the hegemonic constructions of the society, making possible explanations to these generalized phenomena. From presidential elections (United States, Spain, Austria, Argentina, France) and Brexit, to public opinion formation in our contemporary societies, lot of examples are repeated and have gained strength during the last ten years The present work seeks to approach another possible interpretation on the microscopic behavior of the contrarian effect, starting from the incommensurability of the paradigms as a concrete manifestation of confirmation bias. Therefore, there is no longer a proportion “p” of agents behaving like contrarians, but now, there is a probability “p” that any agent can show difficulties in the language mechanisms and behave in that particular case as a contrarian. Our model consists of N agents, which interact in groups of two people during T consecutive periods. Each of the agents can ascribe to the paradigm A or B with an intensity for each agent that we will call a and b, respectively, in such a way that a=-b (that is, the paradigms are symmetrically opposed). The agents send the signals α=a, when they ascribe to the paradigm A, and β=b, when they ascribe to the paradigm B. Although there are no problems in the emission of the message, we contemplate a certain tendency towards a confirmation bias at the moment of the reception, which makes possible the polarization within the system without this being a deterministic phenomenon. Using these agent-model based simulations, whether we consider this an endogenous or an exogenous probability, we can see how the system can generate language problems that makes it impossible for agents to reach consensus scenarios, or to do so with greater difficulties. In fact, agents with a neutral position are ultimately key to achieving, in some cases, consensus scenarios.

Víctor Mijangos, *Gemma Bel-Enguix*, *Julia B Barrón Martínez* and *Natalia Arias Trejo*

Comparing Adults' and Children's Lexicon Structure with Graph Modeling from WAN Corpora

SPEAKER: *Gemma Bel-Enguix*

ABSTRACT. Semantic relations allow us to explore which traits -functional, categorical, or phonological- determine the distance between words in the lexical space. An interconnected lexicon allows for rapid and efficient word processing, as well as reference and meaning anticipation. A lexical space with large distances between words would imply slow linguistic processing. Research has shown that stronger semantic connections correlate with greater language proficiency (Kotz & Elston-Guttler, 2004).

NLP needs an efficient method for capturing semantic relations, commonly represented in Psycholinguistics with graph structures. Distributional Space Models (DSM) have been adopted in the latter field as a way to represent word meaning in linear space (Baroni et al., 2014).

DSM representations are generally useful for analyzing the semantics of natural language. Recently, Biemann (2016) proposed an understanding of the DSM structures as sparse graph-based representations of word relations. With this vision in mind, we seek to connect the tools of Natural Language Processing with the analysis of semantic relations in the lexical space.

In this paper, we expand the ideas of Biemann (2016) such that the tools developed for DSMs can be applied to the analysis of graphs and used to study lexical relations in the cognition of adults and children. We present a study of Word Association Norms (WAN) graphs obtained from psychological experiments with 6 to 11-year-old children (Arias-Trejo & Barrón-Martínez, 2014) and young-adults (Arias-Trejo et al., 2015). For the analysis and comparison of these networks, we propose an architecture based on spreading-activation and the use of a linear transformation between graphs to predict unseen words (Itawari et al, 2016). This is performed in order to observe the behaviour of the words in a corpus where they are not present.

The adoption of the graph structure perspective allows us to understand DSM in new ways; at the same time we can look semantic relation graphs with new eyes and combine the methods of graph theory and DSM's in order to understand better the language behaviour. Evenmore, this architecture is useful for analyzing the semantic correlation between words in the mental lexicon.

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Amparo Salcedo, *Alejandro Muñoz* and *José A. Zamora*

Analysis of heartbeat intervals time series realizing stress tests using the DFA method

SPEAKER: *Amparo Salcedo*

ABSTRACT. Heartbeat intervals time series can be analyzed to look for long-term correlations in the functioning of the heart and to identify a pathology. The Detrended Fluctuation Analysis (DFA) which is a method that eliminates the local trends in time series providing information about the long term fluctuations and the existing scale relations it, in addition is a suitable method for the analysis of non-stationary signals. The ECG records obtained from a Holter monitor, which records the electrical activity of the heart, were determined the heartbeat intervals time series, while the subjects were doing stress tests. These tests are low cost, non-invasive and are of great importance to detect changes in the cardiovascular function after an exercise program, the objective is that the effort test will show electrocardiographic changes that not are evident in a patient at rest. In this work, we analyzed R-R series of healthy young subjects performing stress tests on a commercial treadmill in which the speed, the duration time and the inclination were changed. With the DFA method were found correlations between the DFA exponent and the parameters of the stress test, so that it is possible to determine at least qualitatively the stress to which the heart is submitted during the different tests.

Mi-Hwa Lee

Network analysis on government R&D projects performing inter-firm in Korea

SPEAKER: *Mi-Hwa Lee*

ABSTRACT. The Korean government is expanding the portion of support for R&D tasks centered on SMEs in order to support R & D capabilities of companies(Government R&D support portion: 10.7% in 2008 → 18.0% in 2015). This way will contribute to productivity improvement and job creation of SMEs. Due to lack of internal resources such as human resources, funds, and R&D capability, SMEs can increase their productivity by enhancing synergy through acquisition of external resources. Therefore, it can be assisted that inter-firms cooperation tasks of government R&D projects can lead to synergy creation rather than individual tasks of government R&D projects. The purpose of this paper is to identify the level of strategic network for mutual cooperation and to find out whether the cooperation company has a concentration on specific companies. To do this, we extracted the subjects with relatively strong relationships with the companies participating in the R & D task simultaneously, and confirmed that they have significant relationship characteristics with the growth and productivity indicators of the company. In addition, the Korean government's R & D projects are led by SMEs, but it is confirmed that there is a strong relationship between large companies and specific industry sectors in terms of cooperation. In Korea, SMEs account for 99% of the total companies, but at the level of global competitiveness, a small number of large companies are leading. It is difficult to confirm directly visible effect of the government R & D project by supporting SMEs that are lacking in competitiveness, but it can be confirmed that they actively make efforts through cooperation with external cooperation.

Mahdi Jalili

Cascaded failures in complex networks: what's the role of centrality measures in initial seeds?

SPEAKER: *Mahdi Jalili*

ABSTRACT. In complex networks, different nodes have distinct impact on overall the functionality and resiliency of networks against failures. Hence, identifying vital nodes is crucial to limit the size of the damage during a cascade of breakdowns triggered by single component failure. This information enables us to identify the most vulnerable nodes and take solid protection measures to deter them from failure. In this work, we study the correlation between the cascaded failures and centrality measures in complex networks. The failure starts from a seed node, and propagates through the network. This research study investigates how the centrality of a node (in terms of different centrality measures) affects the outcome of the failures started from that node. For each node, we obtain its cascade depth, which is the number of removed nodes when that node fails; the larger the cascade depth of a node, the higher its centrality from the point of view of cascaded failures. The cascade depth is correlated with a number of centrality measures including degree, betweenness, closeness, clustering coefficient, local rank, eigenvector centrality, lobby index and information index. Networks behave dissimilarly against cascading failure due to their different structures. Interestingly, we find that node degree is negatively correlated with the cascade depth, meaning that failing a high-degree node has less sever effect than the case when lower-degree nodes fail. Betweenness centrality and local rank show positive correlation with the cascade depth indicating the higher the betweenness centrality or local rank of a node, the more the number of removed nodes by failing that node.

Ruben Jaramillo, Jöns Sánchez, C. Alberto Ochoa-Zezatti, J. Jesus Nieto, Ricardo Perez and Nancy Sánchez

Evaluation of Partial Discharge Using Artificial Intelligence

SPEAKER: Jöns Sánchez

ABSTRACT. In electrical engineering, the partial discharge (PD) is a common phenomenon which occurs in insulation of high voltage. PD can occur in a gaseous, liquid or solid insulating medium. The partial discharges are in consequence of local stress in the insulation or on the surface of the insulation. In PD diagnosis test, is very important to classify the measures of PD, since PD is a stochastic process. The occurrence of PD depends on many factors, such as temperature, pressure, applied voltage and test duration. Moreover, PD signals contain noise and interference. This paper is an approach for a diagnosis selecting the different features to classify measured of partial discharges (PD) activities into underlaying insulation defects or sources that generate PD. Self Organizing Maps (SOM) is a type of artificial neural network (ANN) that is trained using unsupervised learning to produce a low-dimensional (typically two-dimensional), discretized representation of the input space of the training samples, called a map, and is therefore a method to do dimensionality reduction. The SOM has been used for nonlinear feature extraction as PD. The results present different patterns using a hibrid method with Self Organizing Maps (SOM) and Hierarchical clustering, this combination constitutes an excellent tool for exploration analysis of massive data like partial discharges on underground power cables for CFE. In the cases analyzed, the original dataset is one million of items, was used a U-matrix of 20×20 cells to extract features and detect patterns. We have tested 63 dataset of diagnostic test at power cables, obtaining a very fast data representation and 95% confidence in the discrimination of partial discharge source, considering noise and combined sources. Therefore, this new approach has been fast, robust, and visually efficient.

Vicente Estrada-Gonzalez and Markus Müller

DOES EXPOSURE TO COMPLEX VISUAL ART IMPROVE COGNITIVE ABILITIES?

SPEAKER: Vicente Estrada-Gonzalez

ABSTRACT. Exposure to some complex aesthetic expressions (classical music) can improve cognitive abilities (Rauscher, Shaw, & Ky, 1993; Rideout & Taylor, 1997). Moreover, works of art lacking complexity do not achieve the same effect (Rauscher, Shaw, & Ky, 1995).

Since music and visual art share physic dynamics such as a universality of rank-ordering distributions (Martínez-Mekler, G; 2009), this brings up the question: Could an acute exposure to complex visual art improve cognitive abilities as well as music does?

We hypothesize that complexity in visual art can produce a similar effect on the cognitive abilities such as that produced by classical music.

Goals: Evaluate the cognitive effect of exposure to complex computer-generated paintings.

Method: In the frame of dynamic systems, we have created computer-generated paintings with a stochastic model based on the fact that complexity appears in a phase transition of the dynamic elements of a given phenomenon (Solé, Manrubia, Luque, Delgado, & Bascompte, 1996). We will test the participants with a Paper Folding and Cutting task from the Stanford-Binet Test.

Results: Behavioral data to be obtained.

Eric Sanchis

Second-Order Complexity - An Example

SPEAKER: *Eric Sanchis*

ABSTRACT. Although there does not exist a definitive consensus on a precise definition of a complex system, it is generally considered that a system is complex by nature. The presented work illustrates a different point of view: a system becomes complex only with regard to the question posed to it, i.e. with regard to the problem which has to be solved. According to the asked question, the same system may be considered as being simple, complicated or … complex. Because the number of questions posed to a given system can be potentially substantial, complexity does not present a uniform face. Two levels of complexity are clearly identified: (1) a first order complexity centred on its measuring or on the system dynamics, (2) a second-order complexity related to the system composition. First order-complex systems are well-known because they have been studied by the scientific community for a long time. They profit from specialized institutes and take advantage of universal tools essentially provided by physics or mathematics. In second-order complex systems, complexity results from the system composition and its articulation that are partially unknown. The term vagueness is the key word characterizing this kind of systems. Therefore, the purpose of modelling is to circumscribe the inherent complexity of the system in one or more precise places and to identify components and relations that can be caught. The tools used to study second-order complex systems are not universal anymore but are specific to a particular complex system. The human cognitive system will be the starting point making it possible to illustrate the aspects previously mentioned of a second-order complex system. According to the objective of the modelling, questions asked to the human cognitive system can be addressed to different levels: (1) the physical level (brain), (2) the functional level (cognitive architecture) (3) the level of its productions (concepts, ideas and mental states). The modelling of one of these productions, the property of autonomy, is a typical example of second-order complex system when this property has to be implemented in a software agent (indistinct components, fuzzy relationship between components). The described method makes it possible to model properties of the same type as autonomy such as free will but also to categorize them (autonomy and free will as complex properties, mobility or replication as simple properties). The final outcome is an implementable computational object that distinguishes the solid aspects of the model from those that are uncertain. It is also an invaluable tool which permits a critical analysis of the models produced by the method itself but also of the models found in the specialized literature. The weakness of the tool is that it strongly depends on the nature of the studied system, or more precisely on the nature of the question asked to the system.

Matthew Jackson, *Hao Xu*, *Joanna Chustecki*, *Daniel Kierzkowski*, *Zijun Yang*, *Soeren Strauss*, *Richard Smith* and *George Bassel*

A complex systems approach to modelling multicellular self-organization in the plant stem cell niche

SPEAKER: *Matthew Jackson*

ABSTRACT. Individual cells within multicellular tissues communicate in order to self-organise into complex organs. In plants, development is continuous and modular, where new tissues arise from groups of self-organising stem cells in the meristem. Plant cells cannot move, so physical interactions with their neighbours are fixed. To model the role of these associations, a complex systems approach to capturing, modelling and predicting the self-organising outputs of multicellular organisation was used. Using live 3D imaging and image analysis, cellular connectivity networks were extracted, describing all cell-cell interactions in the meristem. Network analysis was used to identify features in the cell connectivity network, and revealed a counter-optimised global topological feedback across the multicellular system, regulated though cell division. A classical study of cell division by Errera in 1888, shows that the shortest wall that bisects the cell equally is often observed. In a comparison to this rule, predictions of division plane orientation were made using topology based division rules, and simulated topological cell divisions mostly conformed to, or outperformed Errera's rule. The local geometric property of individual cell divisions in fact encodes a global topological property of the multicellular system.

Gerrit-Jan Zwenne, *Kunbei Zhang* and *Aernout Schmidt*

Agent-based Models to Comprehend the General Data Protection Regulation

SPEAKER: *Gerrit-Jan Zwenne*

ABSTRACT. In the EU, differences in personal-data protection levels were an early concern. Such differences would induce a “race to the bottom.” In 1980, the OECD established harmonizing principles. In 1995, Directive 95/46/EC set a uniform minimal protection level for EU member states. Recently the General Data Protection Regulation (GDPR) was adopted in the European Commission, to succeed the Directive after 22 years of service. The GDPR is in 88 pages. It has 173 considerations that explain the why and how of its 99 Articles. This document is/contains our data.

By establishing the GDPR the EU shows sensitivity to a complexity concern. The scope of personal-data use is widening. Currently almost everyone is connected and forms networked communities. Zhang (2014) coined the community that nurtures on personal data the PDC (for personal-data user community, a complex adaptive system which includes consumers, social-media providers and digital government services as its agents.) The GDPR aims to domesticate the PDC. We focus our research on one new element brought to the fore by the GDPR: the right to data portability. We are afraid that the concept will be understood differently by IT-scholars, economists and legal scholars. This leads to our research question: “can the right to data portability (as formulated in GDPR art. 20) be understood, coherently and concurrently, by professionals from respectively the law, the economy and information technology?”

Agent-based models create toy worlds. Our pont of departure is this: we cannot reasonably discuss the capabilities of the law to help a complex social system survive in the real world without having a model of how a toy complex system will react to internal and external adaptations in technology, economics and law. No single discipline will find a `best solution.' Working examples of adequate mechanisms are the next best thing.

Our approach is a new one. We use the 88-page GDPR as source material for our pilot study. We harvest the requirements for two agent-based models through two different disciplinary filters: alpha and beta (for arts and sciences) in a manner that takes de Marchi [2005] seriously. Running these models leads to repeatable stochastic encounters between agents. The encounters translate into working towards the selection of the best strategy sequence, conditional to the “political season” these evolve in. Inspired on Alexander [2007] the games that can dynamically form in this manner are prisoner’s dilemmas, stag hunts and bargaining games. “Political seasons” reflect stable political periods as presented in the considerations. The two (alpha, beta) collections of available strategy-payoff combinations are also harvested from the document.

Our results show that we can use the GDPR to design working toy versions of mechanisms that realise the right to personal-data portability as seen through both perspectives. And that the evolutionary-game-theoretic simulation approach allows for blending these perspectives' expectations in a rational manner.

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Antonio Bensussen and *José Díaz*

HIV gene regulatory network dynamics

SPEAKER: José Díaz

ABSTRACT. In the present work, we built the gene regulatory network (GRN) of the HIV-1 from the data reported in the specialized literature. We proposed a Boolean and a continuous mathematical model of this GRN to analyze the dynamics of the molecular interactions that regulate gene expression of latent proviruses in resting CD4+ T cells. Both models reproduce several in vitro and exvivo observations of provirus gene expression and indicate that the GRN operates in a critical regime. We found that the network architecture restricts the dynamics of the HIV-1 to just two states: latency and activation. The ODEs model shows that the GRN exhibits bistability, which restricts the conditions to switch on the provirus and favors latency over activation. Virus activation occurs though a transcritical bifurcation in which the NF-kB availability is the bifurcation parameter. The results obtained from the models can be used to design new latency reversing agents (LRAs) to reactivate latent viruses in infected cells. The analysis of the network with perturbation methods revealed unexplored LRAs synergies that can maximize viral reactivation in resting CD4+ T cells.

Alberto Ochoa, Jöns Sanchez, Angelica Badillo, Fernando Montes and Alberto Hernadez

Imperialist Competitive Algorithm to determine energy needs in a planning horizon for a high marginality zone and using a reactive model with high uncertainty

SPEAKER: Alberto Ochoa

ABSTRACT. The Imperialist Competitive Algorithm (ICA) use a basic system of knowledge source to determine the better situations under uncertainty using a model of countries, each one related to the knowledge observed in several aspects of social behavior. These knowledges are combined in order to direct the decisions of the individual agents to solve optimization problems or in the solution of distribute resources in different communities. In the present research, we simulated a reactive model under uncertainty to distribute energy resources in the Southwest Chihuahua using a reactive model under uncertainty to integrate these diverse sources of knowledge to direct the population of the agent. The different phases of solution of the problem emerge combining the use of these source of knowledge and these phases give rise to the appearance of individual rolls within the population in terms of leaders and followers to each country (group of agents). These rolls give rise to an exit of organized grouping or organized groups in the population level and knowledge groups or knowledge grouping in the social belief space. This application optimizes a function revalued in the design of problems of social modeled of social modeling, allowing illustrating a better reactive model under uncertainty

María Teresa Barbato Epple, Ricardo Guzman, Daniel Sznycer and Leda Cosmides

Rational Moral Intuitions

SPEAKER: María Teresa Barbato Epple

ABSTRACT. The human cognitive architecture should contain many domains of human social interaction: (consider, e.g., exchange, kin altruism, mating, cooperative foraging, warfare). These different types of social interaction require different concepts, inferences, sentiments, and judgments to regulate behavior adaptively. Therefore, the different domains require specialized subsystems of moral cognition that takes into account many moral considerations that are often contradictory (e.g., incompatible duties). If we consider that the selection produced adaptations designed to weight conflicting moral sentiments to produce judgments the subjects choosing which option they “feel is morally right” will produce judgments that are internally consistent. We experimentally explored the design of the integrative psychological process that weighs the different moral considerations to produce all-things-considered moral judgements. Specifically, we wanted to know whether the subjects produced rational moral judgments in the sense of GARP (general axiom of revealed preferences), and whether they responded to relevant moral categories (such as motivations) in a consistent way. Using three moral dilemmas involving warfare, we quantitatively varied morally-relevant parameters: Each dilemma presented 21 scenarios in which sacrificing C civilians would save S soldiers ($0 \leq C < S$), varying S, C, and S/C (soldiers saved per civilian sacrificed). Judgments were highly consistent. Bootstrapped choices would violated aprox GARP 50 times, yet there were no GARP violations for 49% and 64% of subjects (unwilling conscripts vs. willing warriors). Of the >250 who sacrificed some, but not all, civilians, 55% and 62% made 3 or fewer GARP violations. Fewer civilians were sacrificed when soldiers had volunteered.

Iván Martínez Ocampo and Fernando Ramírez Alatriste

Self-organized traffic lights: A comparison of spatial arrangement

SPEAKER: Iván Martínez Ocampo

ABSTRACT. In the cities there are several problems trying to solve, most of the limitations to the solution of these problems are due to the high degree of interaction between components in they and the number of components that they have, It is so we can only provide some degree of estimation but not of prediction of the phenomena they present. From the systemic point of view the current attempt to address problems from perspectives involving as many possible components in the study and treatment of certain problems. Among these ways to address the problems we found the selforganization, which is a property of complex systems, which can be used to build adaptable and robust systems, so the system builds the solution to a problem at a particular time in which is required. The objective of the present work is to show that the interaction with a different spatial configuration, such as hexagonal, allows an improvement in the efficiency of the processes of the algorithm of selforganization of semaphores in comparison with the classic quadric scheme. Although studies have been carried out on the best use of space through different forms of space tessellation, there are currently no approaches to the dynamics related to the flow that can be developed on this type of hexagonal tessellation, and more specifically on vehicular traffic. In addition to the fact that using agent-based modeling gives the proposed model a better approach to the reality of the problems of cities; because the entities of social systems can be modeled as autonomous agents that interact with each other and with their environment. The methodology is implemented with the NetLogo, an ABM tool, this tool allows us to do computer simulations of self-organization algorithm of traffic lights at the intersection of different types of models proposed cities. Through ABM is used the property of self-organization of complex systems that allows to develop efficient and high degree of adaptability the solutions to specific problems in time, as in the case of vehicular traffic, the solution may be an adaptation to change traffic flow. For improving flow efficiency it has been proposed the idea of allowing efficient spatial arrangements do flows, one of these spatial arrangements is hexagonal. In this research, an amendment is proposed regarding the implemetation of the algorithm of self-organization of traffic lights in patterns of abstract cities, for it takes into account a hexagonal spatial arrangement with respect to the quadrangular classical spatial arrangement, the results show that the difference in efficiency is significant.

Adela-Maria Isvoranu, Denny Borsboom, Jim van Os and Sinan Guloksuz

A (Data Driven) Network Approach to Schizophrenia

SPEAKER: Adela-Maria Isvoranu

ABSTRACT. In recent years, network models in the field of public health (e.g., psychopathology, psychiatry) have gained considerable attention and recognition. In such network models, psychological processes are conceptualized as complex systems in which observable psychological behavior, such as the critical transition to a psychotic episode, is assumed to arise from interactions between symptoms and other psychological, biological, and sociological agents rather than reflective of an unobserved disorder. The access to large datasets investigating symptoms of mental disorders led to the advancement of the network methodology, allowing scientists to disentangle potential causal pathways towards a disorder, directly from the data. Network models can therefore provide key insights into the complex system of mental disorders. In order to provide an example of how network models can be used in the field of public health, we investigated the association between schizophrenia and environmental exposure. We constructed a network model of data from a prospective study investigating vulnerability and risk factors for onset and progression of psychopathological syndromes. We analyzed the relation between three environmental risk factors (cannabis use, developmental trauma, and urban environment), dimensional measures of psychopathology (anxiety, depression, interpersonal sensitivity, obsessive compulsive disorder, phobic anxiety, somatizations, and hostility), and a composite measure of psychosis expression. Results indicate the existence of specific paths between environmental factors and symptoms, most often involving cannabis use. In addition, the analysis suggests that symptom networks are more strongly connected for people exposed to environmental risk factors, indicating that environmental exposure may lead to less resilient symptom networks.

Fernando Fernandes

COMPLEX SYSTEMS, REAL MARKETS AND LONG MEMORY: AN INTERESTING CONNECTION

SPEAKER: *Fernando Fernandes*

ABSTRACT. The aim of this work is to present an interesting connection between the behavior of economic agents and long memory features - as an emergent phenomenon, that generally occur in a wide set of time series found in economic/financial problems.
Why is it relevant? Because the incorrect specification of stochastic processes can provide misleading conclusions. If the stochastic process exhibits or not long memory directly affects the description of the autocorrelation structure of a wide range of problems, such as asset pricing, macroeconomic modeling and other time series phenomena.
Hence, the misspecification of such features may induce very different results in long term, affecting the way that optimal policy making may be conducted, since these effects last longer than short memory.
It is shown that heterogeneity between agents, large deviations from the equilibrium points (in conjunction with the laws of motion) and spatial complexity are very important in the emergence of long memory features, by means of extensive usage of computational multi-agent based models, stochastic analysis and Monte Carlo simulations.
Keeping that in mind, three different computational models are presented and simulated in this work, showing that long range dependency may simply arise from the interactions between the agents, establishing what can be called “long memory emergence”.
On the other hand, none of these models were developed for this work. Their respective authors separately made them for specific purposes and that is why the present author have decided for such strategy (of picking models made by third parties). Instead of building models (which usually takes a considerable amount of time to make them work properly) that might contain biases in terms of finding such long memory properties – as a consequence of the present work idea – they were chosen, simulated (in their respective platforms) and analyzed using the R Statistical Package.
Despite the fact that heterogeneity is a widely known characteristic that affects the rise of long memory in complex systems, the other two factors are not. It is also important to state that there may be several other kinds of factors that are present in a complex system that potentially can lead to the emergence of this phenomenon.
Moreover, when a long memory filter is applied over time series with such properties, interesting information can be retrieved.

Jennifer Perez-Oregon, *Alejandro MuÑoz-Diosdado* and *Fernando Angulo-Brown*

Study of seismicity as a self-organized critical system.

SPEAKER: *Jennifer Perez-Oregon*

ABSTRACT. In this work a study of synthetic seismology of the Gutenberg-Richter relationship is carried out. This relation links the frequency of seismic events with their magnitudes. For this, we use a cellular automaton that follows the Olami-Feder-Christensen model based on the spring-block. From the generation of synthetic events we make an analysis of the properties and conditions of the parameters of this model that seem to be more related to real seismicity. Furthermore, based on a study of the relation between the frequency of events (y-intercept) and the slopes that are generated when plotting the Gutenberg-Richter relationship, an analysis of this approach was performed with the cellular automaton mentioned for synthetic seismicity. In particular, we are interested in the examination of seismicity as a self-organized nonlinear system.

Paola Vanessa Olguín, *Markus Müller* and *Julieta Ramos Loyo*

Rhythms, collectivity and interpersonal synchronization of brain dynamics

SPEAKER: *Paola Vanessa Olguín*

ABSTRACT. Hyperscanning is the simultaneous registration of the electrical brain activity of two or more subjects. In the present study we investigate possible interpersonal synchronization of male and female couples performing a coopertive task within a particular acoustic environment. In a first pilot study we found a pronounced gender difference for the interpersonal synchronization, extended between zero and 25Hz. Furthermore, different tempos of the rhythmic acoustic stimuli imprint slightly different characteristics of the interpersonal synchronization pattern. Most surprising, the synchronization between monozygotic male twins is more pronounced than other male couples.

Veronica Alexandra Rojas-Mendizabal, Arturo Serrano, Roberto Conte-Galvan and Anamaria Escofet

A Complexity Perspective for Quality of Experience (QoE) estimation: The Case of e-Health in rural contexts

SPEAKER: Veronica Alexandra Rojas-Mendizabal

ABSTRACT. Information and Communication Technologies (ICT) have become an important tool with potential to improving living conditions. ICT are immersed in practically all human affairs; under these circumstances, technology and society are inseparable. By the same token, technology developers must understand the conditions and requirements of the users, as well as the nature of the context. They must understand that technology development also involves human aspects, i.e., people must be considered the central element and purpose of technology design. In this regard, Quality of Experience (QoE) has been used as an important tool for assessing the usability and user acceptance of a particular device, service or technology application. International standard setting agencies, technology manufacturers, as well as academic groups have relied on QoE estimations to understand the interactions of technology and human behavior. In this contribution, we draw on complexity science to incorporate in the estimation of QoE the interplay of the ecosystem, the behavior, and the interactions among the agents. We provide a platform to estimate QoE to assessing the relationship between technology and human factors involved in e-Health projects. Our proposal is focused on a rural environment, given that e-Health interventions have been useful to respond to critical sustainable development needs in these contexts. In this paper, we apply a heuristic procedure to incorporate complexity principles for estimating QoE using Fuzzy-Logic simulations in order to understand the influence of human factors in a gynecology intervention intended for a rural setting. The results of our simulation show that the applications of complexity principles in our e-Health intervention may contribute to develop integrated design strategies of devices and systems, thus providing, a balance of technology performance and human behavior, i.e., a balance between QoS, Quality of Service (technology performance metric) and QoE (human and technology performance metric). In other words, QoE offers valuable information for developing and designing devices and equipment taking into account factors involving emotions and other variables of human nature associated to a particular context. Likewise, it is relevant to stress that our ecosystemic approach was also key to identifying and analyzing complexity traits in the resulting simulation scenarios. Furthermore, complexity was an important enabler to refine the estimation of QoE in the e-health intervention studied. Hence, complexity is immersed in QoE as well as in e-Health, we argue then, that they inherently behave as dynamic complex systems. This realization is fundamental for: a) to refine the problem statement; b) to avoid doing more of the same; and c) to develop a holistic vision with solutions tailored to society as a whole when plaining and implementing e-Health interventions.

Dayani Loaiza-Monsalve and *Alejandro Pérez-Riascos*

Spatial and temporal patterns in bike sharing systems: Modelling using a gravity law

SPEAKER: *Alejandro Pérez-Riascos*

ABSTRACT. With a high proportion of the world's population living in cities, the study of mobility and the coupling between different transportation systems in urban areas is of utmost importance. Most of the studies on public transportation systems have been performed considering: taxis, subway, bus and trams. The case of bike sharing systems, although facilitates mobility for a important fraction of inhabitants, has been less explored.

In this work, we analyze spatiotemporal patterns in bike sharing systems in the cities of Chicago and New York. In the first part we characterize the temporal dynamics of users, we found similarities in the time day use of public bicycles in both cities. In addition we identify an inverse power-law relation for the probability distribution of the time that users employed the bicycles. Then, by using a origin destination matrix we are able to characterize the spatial structure of travels in the whole bike sharing system. We found the same inverse power-law relation for the probability distribution of traveled distances in both cities.

An important fact in the study of bike sharing systems is that the locations of stations are fixed and in this way we can describe the information about the statistics of travels by means of a origin destination matrix. In order to explain the obtained results we introduce a gravity law model to describe the spatial dynamics. In this case, the mass of each station is associated to its importance in the whole system, we also use the geographical distance between stations. Then, via Monte Carlo simulations we recreate the system assuming a Markovian dynamics and the introduced gravity model; the obtained results fit very well with real data revealing that the this model captures important aspects of the global dynamics in bike sharing systems.

Our analysis and results introduce new ways to process the data available for bikesharing systems. This approach can be implemented for different existing bicycle sharing systems to identify temporal and spatial patterns associated to human mobility in urban areas.

Ángel José Martínez Salinas and *Fernando Ramírez Alatriste*

A model of social interaction from complexity; Dissemination of Culture, ENCUP 2012 in CDMX with Model Based Agents (MBA)

SPEAKER: *Ángel José Martínez Salinas*

ABSTRACT. Studying the opinion about citizen participation and democracy in Mexico City (acronym in Spanish CDMX) allows us to have variables to know how it spreads the socialization of perceptions, attitudes and behaviors, in a territory and how this process of interaction conforms the political culture, understood as a set of features conformed by traits, that finally gives us a panorama of what is the policy for the agents that interact in the most populated entity of Mexico. The objective of our research is to Implement the Model Based Agents (MBA) "The Dissemination of Culture: A Model with Local Convergence and Global Polarization", using nominal variables extracted from the “National Survey on Political Culture and Citizen Practices 2012” (acronym in Spanish ENCUP 2012) which extend on a map of the CDMX, the purpose is to visualize how the political culture is propagated in a territory, and to analyze the probability that a certain culture is dominant. The 3 variables we use are 1) the perception about democracy, 2) what is the level of dialogue and 3) the level of citizen participation in civil and social organizations, each one has 7 options, these represent the traits, together the 3 variables make up the features in the model. The model was implemented in NetLogo to perform 300 repetitions with 8000 agents. The purpose is to find the culture that dominates in the dynamic, the result of extending the model of Robert Axelrold, allows us to have a panorama on the political culture in the CDMX, at Interacting agents consider their degree of similarity and the boundary between neighborhoods, the result shows the aggregation of traits to features without a central address. The probability that a culture dominates presents a hierarchical structure in the frequencies of the surviving sets at the end of the experimentation, it approaches the "Beta-Like" function in semilogarithmic scale, also noticed three moments, a) increase b) decrease c) stagnation, when conforming the diversity of the sets during the process of the dynamics, this due to the aggregation of traits. The conclusions we have a diversity in the model tends to socialize pessimism about the practices of political and citizen participation in CDMX because the political culture that is more likely to dominate is the set 1) dissatisfied with democracy, 2) silent when someone says something that goes against their thinking, in other words there is no dialogue, and 3) it is difficult to organize with other citizens to work for a common cause, ie participation is low.

Sami Houry

Fractal Behavior in the Withdrawal of Program Students as a Potential Early Warning Signal

SPEAKER: Sami Houry

ABSTRACT. Education research has examined the program student withdrawal problem from multiple perspectives. Our research proposes a novel approach by examining the problem through the lens of fractal analysis. This approach is supported by a review of literature which suggest that one property for organizational emergence is its potential fractal-like form, i.e. self-similarity in patterns at multiple levels of observation. The patterns are termed fractals or fractal-like as per Mandelbrot who coined the original term and developed a mathematical theory of roughness to describe the natural world known as fractal geometry. After all, according to Mandelbrot, clouds are not perfect spheres and mountains are not perfect cones. He suggested that fractal geometry is a better model for the natural world than conventional geometric notions that assume smoothness of the shapes under study. In the business and organizational world, Thietart and Forgues's (1995) proposition 5 suggested that similar organizational structure patterns as well as process patterns could be identified at different organizational levels, such as the organizational, unit, group and individual levels. To this end, our research seeks to address the program student withdrawal problem at the individual level by investigating whether the emergence of the student's program withdrawal status is self-similar at multiple levels of observation, specifically the program level and the course level. In other words, whether the act of withdrawal at the program level is also present at the course level. Our research findings, based on analyzing data from a test group and a control group, moderately supported the presence of self-similarity or fractals. The significance of the finding is that this self-similarity of emergence at the program level and the course level could be an early warning signal in and of itself as withdrawal at the course level might be a predictor of what is to come at the higher program level. The self-similarity could potentially add a new generic early warning signal to the existing set of early warning signals identified in literature, which include rise in variance, skewness, autocorrelation, flickering and critical slowing down, pending further research and applications in other case studies.

Jesus Ernesto Cruz Martinez and Fernado Ramirez Alatriste

CO2 emission reduction, complex networks and world commerce network

SPEAKER: Jesus Ernesto Cruz Martinez

ABSTRACT. In 2009 Ostrom produced a conjecture of how to reduce world CO2 emissions based on polycentric approach, her paper offers an intuitive process in which a simple economical policy based on the execution of reducing to commerce based on the knowledge of goods/services origin - knowledge of CO2 footprint - and game theory applied to world market commerce. This work apply these ideas into world commerce network (WCN) - which we build and compare its topology with some other articles - and discovers how this conjecture could be right, due to a computer simulation which mixes complex networks, game theory and economy of ecology - theoretical knowledge of economy indexes and ecology calculation of CO2. Results from a series of simulation scenarios using both several coordination games and ecology scenario comparission - IPCC scenarios - verified with statistical analysis in results, are basic blocks for this work (formely Master Science thesis) which helps to understand how a policy can work on WCN and how Ostrom's polycentric approach can be implemented.

Julio César Amador Días López and *Carlos Adolfo Piña García*

Online Organized Political Participation of the Civil Society in Mexico

SPEAKER: *Carlos Adolfo Piña García*

ABSTRACT. We used survey data and collected data from the Online Social Network (OSN) Twitter between October the 5th and November the 9th 2016 (time window) to provide an overview related to political participation in Mexico. With the survey data we provided a qualitative assessment of political participation in Mexico by examining interest in politics and their sources of political information. With our collected data, we described the intensity of political participation in this OSN, we identified locations of high Twitter activity and identified political movements including agencies behind them. With this information, we compare and contrast political participation in Mexico to its counterpart through Twitter. We show that political participation in Mexico seems to be decreasing. However, according to our preliminary results political participation in Mexico through Twitter seems to be increasing. Moreover, we study the case of three online protests and how different actors of the civil society organized within the OSN to debate. In this regard, our research points towards the emergence of Twitter as a significant platform in terms of political participation in Mexico. Our study analyses the impact of how different agencies related to social movements can enhance political participation trough Twitter.We show that emergent topics related to political participation in Mexico are important because they could help to explore how politics becomes of public interest. The study also offers some important insights for studying the type of political content that users are more likely to tweet.

Given that our aim is to describe political participation in Mexico, we turn to survey data and collect data from Twitter to: firstly, explore and examine trends in traditional ways of political participation. Secondly, to spot shifts in sources of political information. Lastly, to assess and investigate trends in non-traditional ways of political participation. It is important to recall that we refer to political participation as any activity through which individual express their own opinion with the goal of exerting influence regarding political decision-making.

This study examines online and offline political participation in Mexico. Through the use of survey data, our research underscores the low levels of interest Mexicans have in politics. This level of interest reflected in the low level of political participation. In particular, we note that Mexicans receive political information mainly from television, with other sources of information such as newspapers, radio, the internet and online social networks well behind. In terms of political participation, we see that as the level of personal interaction needed to take part in political action increases, participation seems to decrease. On the other end, the emergence of new technologies such as Twitter facilitate social interaction to levels never seen before. Therefore, we considered important to examine the way in which political participation in Twitter compared to levels of political participation offline. In our sample of tweets, we found that the general level of online political participation seemed to increase. The analysis of this data allows us to study how the civil society uses Twitter to organize online protests.

Vincent Wong, *Daniel Cooney* and *Yaneer Bar-Yam*

Beyond Contact Tracing: Community-Based Early Detection for Ebola Response

SPEAKER: *Vincent Wong*

ABSTRACT. The 2014 Ebola outbreak in West Africa raised many questions about the control of infectious disease in an increasingly connected global society. Once the disease spread to dense urban areas, limited availability of contact information made contact tracing difficult or impractical in combating the outbreak. To address this, we consider the development of multi-scale public health strategies that specifically target epidemics in a highly connected and physically proximal society. We simulate policies for community-level response aimed at early screening of communities rather than individuals, as well as travel restrictions to prevent community cross-contamination.

Our analysis shows the policies to be effective even at a relatively low level of compliance. In our simulations, 40% of individuals conforming to these policies is enough to stop the outbreak. Simulations with a 50% compliance rate are consistent with the case counts in Liberia during the period of rapid decline after mid September, 2014. We also find the travel restriction to be effective at reducing the risks associated with compliance substantially below the 40% level, shortening the outbreak and enabling efforts to be focused on affected areas. Our results suggest that the multi-scale approach can be used to evolve public health strategies for defeating emerging epidemics.

Dániel Czégel, András Szántó, József Venczeli and László Kovács

Mezo-scale dynamics of the semantic space

SPEAKER: Dániel Czégel

ABSTRACT. Culturomics, the analysis of frequency changes of discrete semantic units of human language over historical time, has shed light on many intriguing social and cultural phenomena in the recent years. Here we propose a step towards a more comprehensive theory of semantic dynamics by defining different types of semantic interactions between these units (i.e., words, or more preferably, lemmas) based on their co-occurrence statistics obtained from large text corpora. In particular, we focus on two types of interactions: one is of cooperative nature, analogous to syntagmatic relations between words, and the other is a competitive one similar to paradigmatic relations. In order to understand global mechanisms governing semantic changes, we regard densely interacting clusters of units as basic building blocks of the semantic space. This allows us to focus on structural properties of these clusters, such as their size, coherence, or susceptibility to external disturbances. Furthermore, by using clustering algorithms that permits the death, birth, merge and split of the clusters, we are able to determine the types of interactions that are indeed realized between clusters in the function of their inner structure. This modeling scheme also has the practical advantage of being insensitive to actual word forms, making cross-linguistic comparisons and universal, language-free modeling possible.

Alejandro Pérez Riascos

Spatial structure of the distribution of land in urban areas

SPEAKER: Alejandro Pérez Riascos

ABSTRACT. A combination of rapid population growth and an accelerated demographic shift from rural to urban areas has resulted in a high proportion of the world's population living in cities, making of utmost importance the interdisciplinary study of cities from a complex systems perspective. In particular, cities are organized structures that evolve with a dynamics influenced, at different temporal scales, by economical, political, historical, topographical, among other phenomena. From this intricate set of interacting elements and situations that shape its structure, it has been shown in many cases, that cities present similar emergent patterns in, for example, their spatial morphology, size and number of inhabitants.

In this work, we explore the spatial structure of built zones and green areas in diverse western cities by analyzing the probability distribution of areas and a coefficient that characterize their respective shapes. From the analysis of diverse datasets describing land lots in urban areas, we found that the distribution of built-up areas and natural zones in cities obey inverse power laws with a similar scaling for the cities explored. On the other hand, by studying the distribution of shapes of lots in urban regions, we are able to detect global differences in the spatial structure of the distribution of land.

Our findings introduce new information about spatial patterns that emerge in the structure of urban areas, this knowledge is useful for the understanding of urban growing, to improve existing models of cities, in the context of sustainability, in studies about human mobility in urban areas, among other applications.

Antonieta Martínez and Markus Müller

Attention & Tempo: Stroop Effect Modulation by Auditory Stimulus

SPEAKER: Antonieta Martínez

ABSTRACT. Music is a human creation that implies many questions about how it is related to our cognitive processes. Music theory shows that music may be conceived as mathematical structures, as a complex organization of sounds and silences that can be traduced in rhythms, scales, modes and other arrangements, able to generate emotions and promote the appearance of different “mental states”. But, in which way music influences brain dynamics? And which features of the musical rhythm like tempo or pitch plays a major role in this interaction?

It is well known, that the auditory cortex is widely connected to other brain areas, beside of its strong link to the motor cortex. Therefore, musical stimulation might improve attention, visual-spatial imagination, working memory and verbal cognition. On the other hand, considering that brain is organized in a hierarchy of feedback loops with the ability to synchronize neural activity, it is conceivable that such synchronized oscillations have preferred frequency. The present study was conducted to provide evidence of a possible influence of music tempo on high level cognitive functions. We follow a resonance hypothesis as a potential explanation of our empirical results.

Josue Sauri

The Complexity of Child Labor

SPEAKER: Josue Sauri

ABSTRACT. Current Child Labor Policies focus on the issue treating it as a lineal problem, addressing it as the main cause of school dropouts, therefore affecting de development of children, since low education levels are highly related to poverty and deprivation of rights. However, in Mexico, data from the Child Work Module (CWM) collected by the National Institute of Statistics and Geography since 2007, suggest otherwise. According to the CWM of 2013 , at age 14, the legal age for working established by the Work Federal Law , occupation rates at 13.6% while school dropout rates at 8.6%, and by the age 17, occupation rates at 27.5% while school dropout rates 31.4%. Furthermore, reasons for work before age 14 have 59.3% of answers in work for pleasure or learning a job, while work for economic needs stands at 32.5%, after age 14, reasons for pleasure or learning drops to 30% while work for economic reason grow to 60%. In the other hand, just 5.2% children below age 14 are identified to dropout school because of work, while the same is true for 13.2% for children above 14 years old. Main reasons for dropping out of school are lack of interest or skill that stands at 37% in children above 14 years old and 13.7% below work age, followed by lack of economic income with 20.1% on children above 14 years old and 24.1% below work age. These results from the Child Work dynamic indicate that there is no real correlation between child work and school dropout. Parting from this hypothesis, this paper presents a summary of the third chapter of the research thesis presented for obtaining the Master Degree in Complexity Science at the Autonomous University of Mexico City , which explores the dynamic of the variables from the CWM using complexity tools to model relationships in data networks, analyzing these interactions on a Boolean Network. The model extracts thirteen variables from the CWM database making a correlation analysis and configures those variables into the Boolean Network, establishing the interaction relationships with a lineal regression model between variables and other statistical results of the data. This configurations results into 8 attractors on the Boolean Network that are then analyzed and categorized to match different dynamics of child work, identifying the properties that result in Child Labor and comparing to those that suggest a healthier dynamic of Child Work. With the results of the Boolean Network, the population measured on the CWM is classified into the network's attractors to probe the hypothesis of the research, suggesting that policies that treat the Child Work issue as a linear problem are doomed to fail.

Marcelo Del Castillo-Mussot, Pavel G. Soriano-Hernández, Ibzán Campirán-Chávez and Jorge A. Montemayor-Aldrete

Wealth of the world's richest publicly traded companies per industry and per employee: Gamma, Log-normal and Pareto power law as universal distributions?

SPEAKER: Marcelo Del Castillo-Mussot

ABSTRACT. Forbes Magazine published its list of leading or strongest publicly-traded two thousand companies in the world (G-2000) based on four independent metrics: sales or revenues, profits, assets and market value. Every one of these wealth metrics yields particular information on the corporate size or wealth size of each firm. The G-2000 cumulative probability wealth distribution per employee (per capita) for all four metrics exhibits a two-class structure: quasi-exponential in the lower part, and a Pareto power-law in the higher part. These two-class structure per capita distributions are qualitatively similar to income and wealth distributions in many countries of the world, but the fraction of firms per employee within the high-class Pareto is about 49% in sales per employee, and 33% after averaging on the four metrics, whereas in countries the fraction of rich agents in the Pareto zone is less than 10%. The quasi-exponential zone can be adjusted by Gamma or Log-normal distributions. On the other hand F orbes classifies the G-2000 firms in 82 different industries or economic activities. Within each industry, the wealth distribution per employee also follows a two- class structure, but when the aggregate wealth of firms in each industry for the four metrics is divided by the total number of employees in that industry, then the 82 points of the aggregate wealth distribution by industry per employee can be well adjusted by quasi-exponential curves for the four metrics.

Sara Najem

Solar potential scaling and the urban road network topology

SPEAKER: Sara Najem

ABSTRACT. Cities appear to have allometric laws which, when revealed and integrated in state policies, could help achieve or maintain sustainable growth. In this work we follow the solar potential of multiple cities in relation to their road networks' lengths and lengths distribution and found them to be governed by power laws; these we show to be valid down to the scale of a block. This is based on a simple observation: in an urban setting the rooftops solar potential depends on the number of erect buildings, which in turn is linked to the road length. In the process we identified a measure of social stratification according to which resources could be allocated based on common needs.

This is a first attempt at exploring the relation between a city's solar potential and its road network topology by drawing parallels with living systems' allometry and its dependence on the topology of the vascular network. More precisely, our findings raise the question about the existence of universal laws typifying rural and suburban areas' solar potential and serve as a tool for estimating metrics which are relevant to sustainability science and to cities economic development.

Joaquin Fernando Sanchez, Juan Pablo Ospina and Jorge Eduardo Ortiz

A programming language for the implementation of Ad-hoc networks through social-inspiration techniques

SPEAKER: Joaquin Fernando Sanchez

ABSTRACT. Ad-hoc networks can be considered as an open system [1], given their operating characteristics such as: decentralized control, dynamic topology, limited physical resources, no defined infrastructure. Considering these properties it could be said that also the behavior of this type of networks tends to be complex [2]. In order to deal with the complexity, techniques must be available that allow the adaptation of the systems to the environmental conditions [3]. In this research it is proposed as a means of adapting the systematic techniques of social-inspiration in computer systems. The idea of social inspiration is that, based on the solution of social dilemmas, we can have a basis for the creation of techniques and algorithms that solve computational problems [4]. This perspective is important to have, since conventional computing solutions can be set to generate the adaptability required in Ad-hoc networks.

Taking into account these arguments, it is proposed to develop a computational tool for the management of the elements that make up an Ad-hoc network. It is proposed the design of a programming language, which is oriented to contain native functions that effectively allow the implementation of an ad-hoc network. The design of the language is designed so that its first three layers, the lexical, syntactic and semantic part are in harmony with the needs of Ad-hoc networks. It is proposed that the language manages services through a multi-agent system which takes into account the necessary requirements of different applications. For the conception of language, the nature of the open systems must be taken into account, so that it may be possible to create adaptation functions for the Ad-hoc network to face the changing conditions of the environment in which it is located. One of the expected results is to define a multi-paradigm language, which would be the combination of object programming paradigm, functional paradigm and agent-oriented paradigm. It is noteworthy that language is part of the conception of a complete computational model [5], which considers the construction of a computer system on a dynamic system such as Ad-hoc networks

Jose Antonio Motilla Chavez and *J.Mario Siqueiros-García*

How complexity, clyodinamics and network science can offer a new narrative in the historical research

SPEAKER: *Jose Antonio Motilla Chavez*

ABSTRACT. The analytical approach of Complexity, and in particular Social Network Analysis (ARS), as a theoretical-methodological perspective applied to the study of historical processes, offers a wider and more articulated reading than the methodologies used in traditional historical research. In this sense, this approach allows to understand the structure, articulation, and different configurations of a concrete social system over time.

What at first glance could be read as issues of philias or phobias between political elite factions at any given time, can be explained from the analysis of how the structure of kin, and socio-economical networks have been configured and reconfigured over time. That is to say, the use of this approach allows to identify "evolutionary" processes, as well as the dynamics of social structures, for example, the emergence and decay of elites.

In this work we present the reconstruction through the analysis of social networks, of the emergence of an elite group in the Mexican state of San Luis Potosí, from 1787 to 1855. This elite was conformed by people from commerce, mining, agriculture, the army, and local politics. San Luis Potosí has a privileged geographic axis since it is a point of interconnection for the trade and transfer of goods with Mexico City, the north of the republic, the United States, and towards the Atlantic through the port of Tampico in the Gulf of Mexico.

For this analysis, it has been revised the composition of key social spaces, such as the city council, the local congress, the state government, the army, and commercial companies. For this purpose, data recovery has been done in primary sources, systematized in databases, and network analysis.

The network analysis has been done using Gephi and Cytoscape. The analysis performed allowed us to understand the emergence of groups within the elite, thanks to connections of kinship, friendship, and mutual collaboration in different institutions. Morover, it revealed the presence of characters with great centrality in the network. Although these characters importance was previously recognized according to the mexican historiography, it did not realize the great importance they had within the local elite when considering their whole network, which lead us to a new reading of the historical processes. It also revealed the existence of characters that served as a link between clearly defined sectors, such as the army or the city council, and others who had simultaneous presence over long periods connecting different generations. It also allowed to visualize the "evolution" of the network and to understand how the groups or networks within the local elite, managed to survive and maintain political influence over time. Finally, it raises the question that if armed uprisings and changes in political system, supposed an alteration or continuity within the studied network.

This paper seeks to contribute to the proposal of Turchin, who upholds that it is time for history to become an analytical and even predictive science. We propose this type of analysis for the study of the conformation and transformation of elites in different societies.

Lakshmi Charli-Joseph, Hallie Eakin, Rebecca Shelton, David Manuel-Navarrete, Beatriz Ruizpalacios, Abril Cid, Emilio Rodriguez and J. Mario Siqueiros-García

Agency Network Analysis (ANA) method for Social-Ecological Systems participatory modeling

SPEAKER: Lakshmi Charli-Joseph

ABSTRACT. Problems in social-ecological systems (SES) have been described as wicked because of their complex nature. Some of this wickedness is due to the intractable dependencies between the multiple interacting scales of the ecological and the social. Although the ecological component has been addressed abundantly, the social, cultural and subjective part of a SES is still seen as a black box. Moreover, there is a need for a better understanding of SES by incorporating the knowledge of diverse actors that are part of the SES. Addressing these gaps requires an active search for methods —i.e. Multicriteria Decision Analysis and Multicriteria Mapping— designed to capture stakeholders preferences and possible actions. Here we present a methodological approach developed in the context of our Transformation Laboratory or T-lab project that intends to foster collective agency towards the transformation of Xochimilco, the last remaining wetland of Mexico City. The method has been designed for capturing and modeling actors' agency related to environmental management, as subjectively perceived by the actors themselves. Our approach is based on the idea of participatory modeling in which actors are involved in the process of constructing and validating models. The method comprises and articulates three different techniques: a) ego-networks identifies an actor's (ego) networks of collaborators (social capital) around certain topics (e.g. farming), their perceived closeness, and how positive or negative is the the relationship beween ego and his collaborators, and the sectors to which collaborators belong (i.e., government, NGOs, Academia, etc.); b) action networks, which are bipartite networks connecting ego collaborators to a set of practices; where collaborators may converge in a practice (e.g. collaborator 1 and 3 participate in farming capacity building programs); and c) Fuzzy Cognitive Maps that capture ego's perceptions of a situation, problem or SES. The aim of integrating these diverse techniques is threesome: 1) to generate a comprehensive profile of the actor from its own subjective perspective. This is a relevant way of describing an actor's profile because it identifies the social capital of the actor, its place in the SES, its ecological and social role and the activities it performs in the SES. 2) Since our method integrates three forms of networks, ANA makes possible to identify pathways of action through the networks, from the activation of collaborators, through practices that finally have an impact somewhere in the system. 3) To assign probabilities to the different actionable paths. Future and ongoing developments of ANA include an implementation of a simulation strategy with stakeholders. This simulation has two objectives: 1) collaboratively generate alternative scenarios about the SES by mobilizing social acquaintances (social capital) in order to open-up and assess possible pathways for sustainable transformations, and 2) identify the route from perceptions to actions to be integrated in Agent-based Models on individual actions in response to social or environmental perturbations. Finally, a central motivation in designing this approach is to develop a method that would translate from qualitative and subjective information into quantitative data for a better understanding of SES dynamics.

Ludwig García Mata and *J. Mario Siqueiros-García*

Power relations in a socio-ecological system evolution

SPEAKER: *Ludwig García Mata*

ABSTRACT. Power relations have been a subject of recurring matter for social sciences in general and most particularly for anthropology. The present “paper” addresses the stated issue, specifically the different ways in which a regional elite duplicates, reproduces and diversifies its power. The proposed variant sought to carry out an analysis of the elite as a complex system from an anthropological perspective. However, different insights on power within the social sciences share one particular characteristic, and this is that most of them perceive power as a capacity, as a set of conditions, qualities and skills. All this prevent us from understanding how power emerges, reproduces and diversifies, that is why for most people power is the relative inequality that exists between two or more actors and / or groups immersed in a particular social relation, such inequality results from the control that certain participants of the relationship have on symbolic or material resources of interest to the participants. In this respect capacity means control and power an aspect of all social relations, without exception. This variation with regard to the perception about the power is the main difference between the classic analyzes of social sciences and the one we are presenting. This paper develops and proposes a model based on a network approach that allows describing, analyzing and understanding the evolution of power in a regional elite in Mexico, distinctively in the State of Guerrero on Mexico’s Pacific coast. The model is built on the basis of kinship relations of elite members and their interaction with three boundary constraints concerning the evolution of networks of power, namely World Bank recommendations, an amendment to Article 27 of the Political Constitution of the United Mexican States and the establishment of agribusiness in the region. The information that fed the model was obtained through anthropological field work: participant observation, in-depth interviews, genealogical construction, documentary research (literature, archive and hemerographic). Once the analysis was made, it was found that the evolution in the networks of power has moved from a state in which only conformed by ties of kinship has been a structure that bases its links in economic and political activity at local, regional and even national scale.

Carlos Rodríguez-Contreras, J. Mario Siqueiros-García, Pilar Galarza-Barrios, Carlos Piña-García, Eduardo Robles-Belmont, Carlos Gershenson and Fernanda Sánchez-Puig

The Role of Online Published Scientific Research on Online News Services

SPEAKER: Carlos Rodríguez-Contreras

ABSTRACT. Traditionally, medical coauthorship networks has been studied by many researchers using online medical literature. However, there has been an increasing interest in understanding how mass media obtain information to disseminate news and how “hot topics” propagates through population density. The purpose of this research is to assess to what extent the online news services talking about hot health topics, are supported on scientific research published online. We examine the case of Zika outbreak.

We selected the Zika disease as a case study due to the impact of Zika virus since its arrival to America Continent in 2014, causing a worldwide health crisis (more than one million people were affected in Brazil). In addition, malformations such as Microcephaly was found in some pregnant women who were exposed to the Zika virus. The Zika virus is considered as a global threat and requires a promptly intervention for its prevention. The World Health Organization (WHO) has declared it as a new health emergency.

The first phase of this study involves mining scientific research sites such as the Web of Science (WoS) aimed to get a significant amount of publications related to Zika. We also collect Online News Services such as: Yahoo News and Googe News. Moreover, to complement this study, we use a dataset of the World Data Atlas about Zika confirmed cases in 2015 and 2016 all over the World. The final phase involves a correlational statistical analysis to find relations between these sources of information.

From our perspective, Zika makes an interesting case study because before the 2016 outbreak there were 200 scientific publications approximately -from a total of nearly 2000 publications to date-, on the subject since the 1947 when the virus was first isolated from the serum of pyrexial rhesus monkey. 2016 as mentioned in the media news, was the year that the world came to know about Zika but also it was year that Zika epidemic came to an end as well. This aspect of Zika epidemic makes it specially interesting since it displayed a tracktable cycle from its outbreak to its end and in which more than the 90% of scientific publications were produced.

This research provides valuable information regarding online news services which address epidemic affairs. This study also provides an assessment of the role of online medical research as source of such services. Our findings indicate that the news sites on hot topics such as the outbreak of epidemics are seldom based on online scientific and medical literature. This indicates the preference of news services from other sources such as official speeches given by medical authorities, which can be sources of information of greater impact on the readers. Future and ongoing work is expect to find out more about how mass media obtains medical information to promote popular topics and acquire more readers of their online news.

Gustavo Carreón-Vázquez, Carlos Piña-García and J. Mario Siqueiros-García

Synchronization of a variation of the Kuramoto model on complex networks

SPEAKER: J. Mario Siqueiros-García

ABSTRACT. In this work we present a Kuramoto inspired model designed to capture group formation. Our model runs on a network where each individual is an oscillator whose frequency represents its individual behavior that when shared with other oscillators can become a group behavior. Our proposed model differs from the Kuramoto model in that we consider two types of dynamics affecting synchronization. 1) A local mean field (closest neighbors) that updates the oscillator positions. 2) A positive feedback process to couple in certain degree the oscillator frequency related to its closest position neighbor. Every link between any two oscillators in this network have a different value commonly referred to as a weight. For oscillator i, a specific constant value Ki_avg is provided and is the average of the weights of the connections between oscillators i and its neighbors. K_avg is the local coupling coefficient through which the position of oscillator i (θi) is updated. Each oscillator changes its own frequency according to the frequency of its best-coupled-neighbor (BCN) and also according to parameter A, that is defined as the closeness of the position of oscillator i regarding to the position of its neighbors. We implemented our model in a random Erdos-Renyi network, Watts-Strogatz small-world network and Ring grid network. In order to characterize the dynamics, we used the position of each oscillator and also the space of frequencies. The results of our model were the following: in the case of the Erdos-Renyi network, oscillators did not synchronized forming clusters and the frequency of each oscillator remains stable. For the ring grid network, we see the emergence of stable groups of coupled oscillators, and in the space of frequencies, there is a clear difference among the different regions -each with a different frequency- due to the topology of the network. The results in the small world network, instead, present formation of coupled oscillators groups. Each group oscillates with a different frequency. More precisely, in the space of frequencies two different dynamics can be identified, there are regions that converge to a fixed stable value, while there are others that are unstable, continually flipping from one region to another and that separate stable regions. Moreover, in the small world networks, we detected multiple-cascading effect through the network in which the frequency of a cluster spreads over some other parts of the network. We suggest that these results are the expected outcome when considering that, in terms of their clustering coefficient and long distant reach edges, the topology of small world networks is in the range between random and grid network topologies. Therefore, we suggest that high clustering coefficients must lead to the emergence of stable regions in both the grid and small world networks. On the other hand, the flipping regions in the small world network must be the effect of the long distance edges connecting different clusters. Also, we believe that the long distance reaching edges may be also causing multiple-cascading effect through the network.

Nancy G. Pérez López, Alejandro Muñoz Diosdado and José A. Zamora Justo

Crossovers determination in detrended fluctuation analysis (DFA) graphs of heartbeat intervals time series by using the curvature concept

SPEAKER: Nancy G. Pérez López

ABSTRACT. The detrended fluctuation analysis (DFA) is a very effective methodology to study the time series of complex biological systems, such as heartbeat intervals time series. This analysis helps to know a patient's health status and it has been determined that in healthy and young patients usually the DFA's analysis graphs are linear, whereas in the patients with cardiac problems the graphs present crossovers, these are points there the slope changes. The determination of the position of these crossovers and the involved slope change is relevant to support a possible diagnosis. The proposal of the present work is to use the geometric curvature concept to characterize these crossovers in heartbeat intervals time series obtained from patients with heart failure. A comparison was made with the subjects of a control group of healthy people and the method was validated by manually quantifying the positions and slope changes.