BOOK OF ABSTRACTS

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COMPLEXITAT

SIRIS ACADEMIC

INVITED TALKS

PLENARY TALK

Dr. Mariano Marzo – *Catedràtic d'Estratigrafia i professor de Recursos Energètics i Geologia del Petroli a la Facultat de Geologia de la Universitat de Barcelona.*

Reflections on the complexity of the energy transition

The energy system responds to the demands of a growing number of people in the world with aspirations to make life materially better for themselves and their children. Meeting this demand will probably require approximately doubling the size of the global energy system over the course of this century. And that means the potential growth of atmospheric CO2 and other greenhouse gases unless something is done at the same time to reduce these emissions so that there are no net additions. The big question is: how could the energy system evolve from now to provide a better life for all with a healthy planet? But in order to answer that question we should begin with a profound reflection on "where we are now and why", recognizing the complex nature of the challenges that face society.

THEMATIC TALKS

Dr. Pietro Tierno – *Departament d'Estructura i Constituents de la Matèria, Facultat de Física de la Universitat de Barcelona.*

Emergent Hydrodynamic Bound States Between Magnetically Powered Active Micropropellers

We study the hydrodynamic interactions (HIs) between colloidal micropropellers [1] confined above a plane and driven in a viscous fluid via application of a circularly polarized rotating magnetic field [2]. The applied field torques the particles, which translate close to the surface due to the HIs with the bounding plate. At high driving frequencies, the strong flow generated by the spinning particles makes HIs dominating over magnetic dipolar ones, and close propelling particles form bound states by temporarily adjusting their translational speed in order to optimize the transport of the couple.
We develop a theoretical model which shows quantitative agreement with the direct experimental data. In dense suspension, these bound states can be extended to metastable 1D array of particles assembled by the sole HIs. Our results also demonstrate the importance of the boundary surface in the interaction and dynamics of con fined propelling microswimmers.

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Dr. Albert Solé-Ribalta – *Grup de Recerca en Sistemes Complexesde l'IN3, Univeristat Oberta de Catalunya.*

Congestion phenomena in urban transportation networks

The rapid growth of population in urban areas is jeopardizing the mobility and citizen health worldwide. Amidst the urban management problems there is a prevalent one: traffic congestion. Complex networks are good abstractions of the intricate connectivity of urban transportation networks and are essential to model dynamical processes occurring over them. I will discuss several mechanisms to identify congestion hotspots in the urban environment in both, individual and multimodal transportation networks. In addition, I will show how simple mechanisms, locally applied where required, can alleviate congestion without affecting social welfare, neither in the economical or temporal aspect.

Dr. Laurent Brodeau – "*Research Scientist" al Barcelona Supercomputing Center.*

Scientific & Computing challenges in Climate Modeling

The audience will be reminded about the basic facts, features, and figures regarding present-day state-of-the-art numerical climate models, as well as the main issues climate modelers face nowadays. Improving the quality, reliability, and accuracy of climate simulations carried out using these climate models has become a real challenge in terms of various aspects; such as HPC requirements (CPU and data storage), scalability improvement, numerical methods (and parametrizations) used to solve (sub-grid) physical processes, experimental approaches (ensemblist/stochastic vs deterministic), inclusion of biogeochemical processes, diagnostics and data analysis. These aspects will be discussed and illustrated.

RESEARCH IN COMPANIES

Ignasi Vilajosana – *Worldsensing*

Operational Intelligence:
A new approach to making City Mobility Management more responsive

From a growing urban population, to urbanization or climate change and related environmental disasters: in the coming decades, cities will need to be able to respond to unexpected situations quicker and more efficient than ever. And, they will need to be enabled to manage the increasing complexity of inner-city traffic and related issues.

Most cities share common challenges: fragmented work processes, disconnected departments and siloed data which keep them from creating efficient urban operations. For a long time, the goal of cities around the globe was to gather an understanding of how citizens move by means of IoT technology. But up to now, city services, such as traffic and first responders, have been merely reactive to what is happening and have not had the means to plan proactively and foresee unexpected situations.

To address this, multiple Smart City products have become available in recent years. Most vendors collect large data sets with the aim to aggregate data of multiple sensors and present insights in dashboard centric platforms. While coloured dashboards provide insights into decision-making processes, they don't necessarily change the way decisions are made. Due to the rising complexity of urban operations cities will need to move from data visualization to decision-making support tools which recommend actions and show potential outcomes before operational decisions are made.

In this talk, we will take a closer look at how cities can introduce operational intelligence systems and integrate them in their prevalent structure and will illustrate the implementation process by means of a real world city mobility example from the Colombian capital Bogotá.

Pascal Weinberger – *Telefonica Alpha Research*

Presentation of Telefonica Alpha Research lines and goals.

CONTRIBUTED TALKS

Hybrid Optimization Methodologies for Stochastic and Dynamic Systems

Laura Calvet, Angel A. Juan, David Masip

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Abstract

A large number of decision-making processes in strategic sectors such as transport, production, finance, computing and telecommunications involve NP-hard optimization problems. Trends such as globalization make systems larger and more complex. Typically, managers are required to take crucial decisions in real time. Designing routes to quickly provide medical assistance after a natural disaster, rescheduling flights because of some delays caused by unexpected circumstances, or reducing the risk of some savings in the stock market being affected by unpredicted events are a few examples. Often, these problems are characterized by high levels of uncertainty and dynamism.

Despite the fact that exact methods exist for addressing deterministic problems, they usually require a high amount of time to solve real-sized problem instances. As a consequence, approximate methods are widely implemented. Metaheuristics have become predominant methods for solving challenging optimization problems in reasonable computing times. However, they usually assume that the inputs, the objective functions, and the set of optimization constraints are deterministic and known in advance. These constitute strong assumptions that lead to work on oversimplified versions of real-world problems. As a consequence, the solutions obtained may have a poor performance when implemented. Processing times in scheduling, or travelling times and customer demands in routing constitute classical examples of variables presenting high degrees of stochasticity. Simheuristics (Juan et al., 2015) integrate simulation and metaheuristics to solve stochastic optimization problems in a natural way. Similarly, learnheuristics (Calvet et al., 2017) combine machine learning and metaheuristics to tackle optimization problems in dynamic environments, where inputs may depend on the structure of the solution. For instance, in the distribution business, whenever a supplier operates from multiple depots it needs to decide two things: *(a)* which set of customers will be served from each depot; and *(b)* the vehicle routing plan for the given assignment. If depots are heterogeneous in terms of their commercial offer, customers show different willingness to consume depending on how well the assigned depot fits their preferences. Thus, a hybrid methodology (Figure 1) is needed to solve this problem. The aim of this talk is to review hybrid optimization methodologies for stochastic and dynamic problem, showing a number of realistic applications.

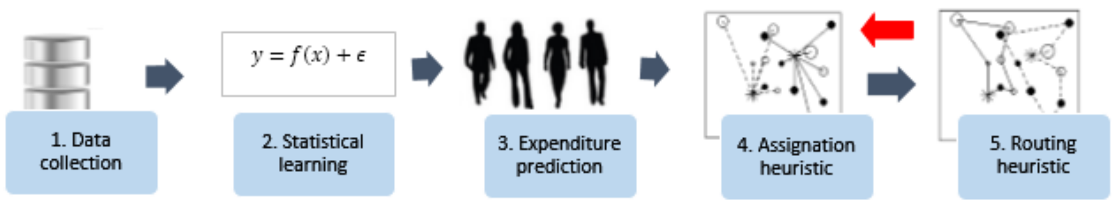

Figure 1. *Hybrid methodology for urban freight transportation considering preferences.*

Calvet, L.; De Armas, J.; Masip, D.; Juan, A. (2017): "Learnheuristics: hybridizing metaheuristics with machine learning for optimization with dynamic inputs". Open Mathematics, 15: 261–280, DOI: 10.1515/math-2017-0029.

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Undercooled and arrested dynamics in currency exchange markets

J. Clara-Rahola[1,2], *A.M. Puertas*[1], *M.A. Sánchez-Granero*[3], *J.E. Trinidad-Segovia*[4], *and F.J. de las Nieves*[1]

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Undercooled and arrested dynamics are observed in many physical systems, such as colloidal and molecular correlated fluids or glasses, granular matter, polymers or atomic systems among others. All of them are featured by displaying distinct separation between local microscopic dynamics and longer ranged structural relaxations [1]. Such systems are as well featured by particle displacements depicting non-Gaussian distributions, where structural relaxations are responsible of tailed distribution profiles [2]. In this work we have considered the field of financial markets and have studied such discipline within an approach typically employed in undercooled and arrested systems. We consider currency exchange markets focused on the Euro -US Dollar in the time range 2010 – 2015 resolved at the minute, and study such pair employing a hopping model from structural glasses by Chaudri, Berthier and Kob [2]. We find that when tuning such model appropriately, thus by considering Ornstein-Uhlenbeck distributions to the short time dynamics instead of Gaussian ones, Euro – US Dollar price change distribution functions (pdfs) are correctly depicted as indicated in Fig. 1(a). Despite non-Gaussian tails in the pdf, the corresponding mean squared displacement averaged over all years is linear with time, apparently indicating free diffusion [3]. However, when data is deaggregated appropriately by considering a reference time, the typical behavior of undercooled fluids, featured by a separation between microscopic dynamics and structural relaxation is observed as shown in Fig. 1(b). By considering the reference time at the opening or closure of the NYSE, diffusive or glass dynamics is respectively resolved. Similarly, price correlation functions show the typical two-step decay, and the non-Gaussian parameter develops a peak in the time range when the price is caged [3]. This phenomenology is similar to that shown by physical glasses, posing an interesting analogy between fields originally considered to be far apart. Furthermore, we have found that such behavior and description is as well characteristic to other currency pairs and markets.

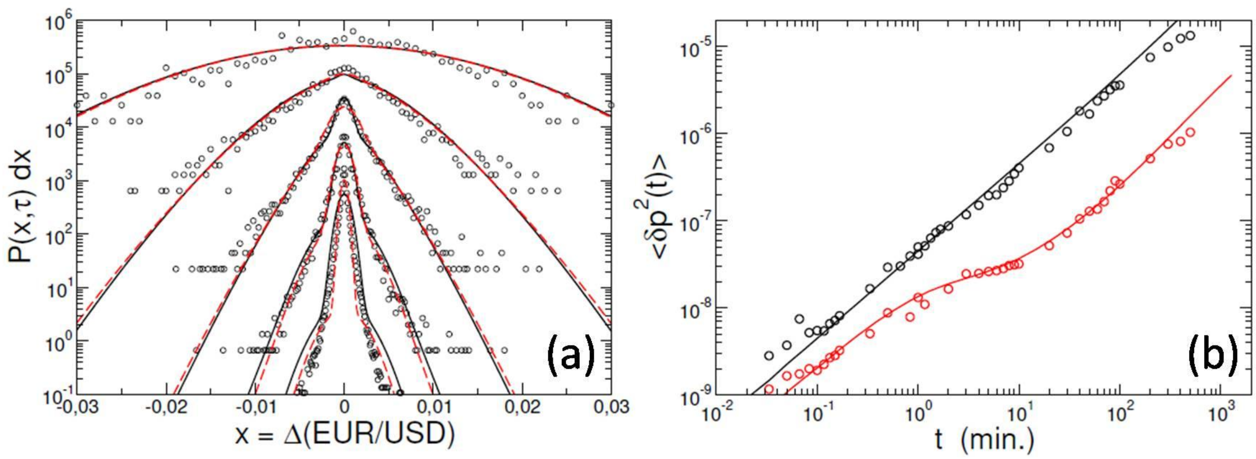

Figure 1: (a) price fluctuation distributions of the Euro – US Dollar for time intervals t = 5, 25, 125, 625 and 3125 minutes, from bottom to top, shifted vertically for clarity. Data belongs to 2010-2015. The lines are theoretical description according to [2], where Gaussian and Ornstein-Uhlenbeck approximations are considered. (b) Mean squared price displacements at different time origins: 9.30 am ET (black circles) and 6 pm ET (red circles). The lines are the fits obtained from the pdf model.

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The origins of Zipf's meaning-frequency law

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In his pioneering research, G. K. Zipf observed that the number of meanings of a word grows as the square root of its frequency [1]. He derived this meaning-frequency relationship from two assumptions: Zipf's law for word frequencies, i.e. a power law dependency between the frequency of a word and its rank, and Zipf's law of meaning distribution, a power law dependency between number of meanings and frequency rank (Fig. 1). Here we show that a single assumption suffices to derive Zipf's meaning-frequency law. The assumption is that the joint probability of a word and a meaning that are connected is proportional to the product of their degrees. This can be justified as the outcome of a biased random walk where the entropy rate of the paths is maximized [2], suggesting that the meaning-frequency law could be a manifestation of optimal processes of mental navigation. We also explain how to improve a family of models of Zipf's law for word frequencies exhibiting a linear relationship between number of meanings and frequency [3] so that they can reproduce the actual power law.

Keywords: random walks, Zipf's laws, language.

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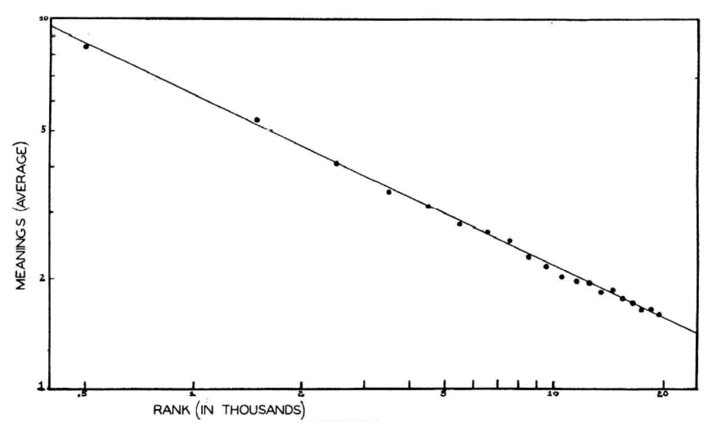

Figure 1: The relationship between the number of meanings of a word and its frequency rank in double logarithmic scale. Reproduced from [1].

Food-pairing, Food-bridging a new perspective on the principles of cooking

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March 29, 2017

Abstract

In this manuscript we propose, analyse and discuss a possible new principle behind traditional cuisine: the Food-bridging hypothesis and compare it with food-pairing hypothesis using the same dataset employed in the study of Ahn et al. [1] about food-pairing.

Since the introduction from Francois Benzi and Heston Blumenthal of the Food-pairing hypothesis, a debate on this hypothesis has been risen in gastronomy science and cuisine. Originally it states that, if two ingredients share important flavour compounds, it has a good chance to result in a good combination, [1, 2]. In the last few years,

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this hypothesis got the attention of foodies, many cuisine chefs and scientists. If food-pairing is one of the main principles behind our taste preferences, scientifically this would allow us to predict and build many successful new ingredients affinities based on the flavours they are composed of.

In Ahn et al. [1], it is presented a study of the food-pairing hypothesis across several regional cuisines, employing a set of tools, which derives from the new science field named complex networks, a sub-field of complex systems [3, 7, 8]. These mathematical techniques were applied to several regional cuisines, encoding from ingredients and flavour compounds relation an ingredient network (nodes) based on flavours sharing (edges), this manuscript denominated as the flavour network. The authors had observed that Western cuisines showed a tendency towards the food-pairing hypothesis (pairs of ingredients that share many flavour compounds) and Eastern Asian cuisines tend to avoid compound sharing between ingredients. After this work , the study of food-pairing has been applied to other specific regional cuisines [4, 5, 6].

Food-bridging hypothesis, assumes that if two ingredients do not share a strong molecular or empirical affinity, they may become affine through a chain of pairwise ingredients affinities.

Food-pairing and Food-bridging are different hypothesis that may be possible mechanisms behind traditional cuisines recipes. Food-pairing intensifies flavour with similarty flavoured ingredients and food-bridging smooths contrasted flavoured ingredients in a recipe, respectively. Both hypothesis food-pairing and food-bridging, jointly are observed in traditional cuisines, as shown in this work.

We observed four classes of cuisines, where East Asian cuisine in one extreme tends to avoid food-pairing as well as food-bridging and Latin American cuisine in the other extreme follows both principles. The other middle classes are represented by Southeastern Asian avoiding food-pairing and following food-bridging, and Western cuisines (Southern, Eastern and Western European with North American) following food-pairing and avoiding food-bridging, respectively. See Figure.

References

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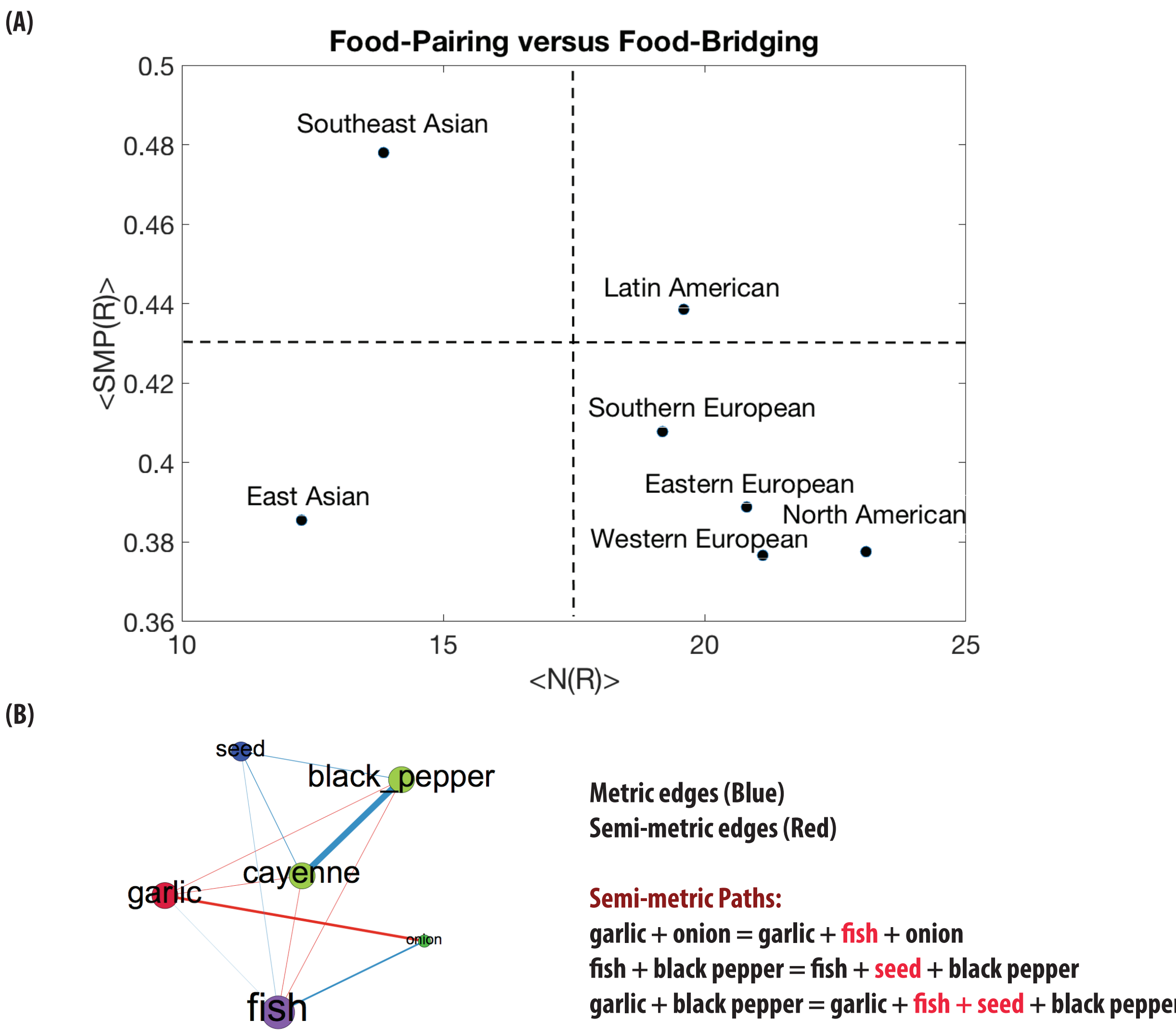

Figure 1: (A) Average Food-pairing versus average Food-bridging (B) Semi-metric analysis of a Southeast Asian cuisine six ingredients. The semi-metric path or food-bridge is the shortest path that connects indirectly two nodes, that is, in the path ”garlic + fish + onion” is a semi-metric path, with ”fish” the intermediate ingredient that potentiates the affinity between ”garlic + onion”, the semi-metric edge. Other semi-metric paths may exist. Some of the possible semi-metric paths or food-bridges are also represented.

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

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For a long time, the Markovian assumption has been at the core of the modeling of stochastic dynamics governing many natural and technological systems, due to its mathematical tractability. Nevertheless, a new wealth of time-resolved data on different interactions, from human dynamics to natural phenomena, revealed that this modeling framework needs to be overcome. Here we introduce a general formalism to allow the steady state of non-Markovian (NM) processes on networks to be reduced to equivalent Markovian processes on the same substrates [1]. We consider the NM Susceptible-Infected-Susceptible (SIS) epidemic model [2] and show that its steady-state is equivalent to a Markovian one with an effective infection rate λ_{eff}, thus encoding all the NM effects into a single parameter. Interestingly, this result is independent of the underlying network topology.

In SIS dynamics, nodes are either susceptible or infected. An infected node decays spontaneously to the susceptible state after a random time t distributed as $\psi_R(t)$. A susceptible node, connected to a an infected one, becomes infected after a random time t has elapsed since the infection was initiated, with t distributed as $\psi_I(t)$. Distributions $\psi_R(t)$ and $\psi_I(t)$ allow us to evaluate the (time-dependent) hazard rates, defined as $\delta(t) = \psi_R(t)/\Psi_R(t)$ and $\lambda(t) = \psi_I(t)/\Psi_I(t)$, where $\Psi_R(t)$ and $\Psi_I(t)$ are the corresponding survival probabilities. In Markovian dynamics, both distributions are exponential and the corresponding hazard rates are constants.

Our mathematical formalism demonstrates the existence of an effective infection rate λ_{eff}, defined as

$$\lambda_{eff} \equiv \int_0^\infty \phi(\tau_{ji})\lambda(\tau_{ji})d\tau_{ji}, \qquad (1)$$

where $\phi(\tau_{ji}) \equiv \lim_{t\to\infty} \text{Prob}(\tau_{ji}; t|n_j = 1, n_i = 0)$ is the probability density of τ_{ji}, where τ_{ji} is the time elapsed since the start of the infection process from a node j to a node i, given that node i is susceptible and node j is infected and $\lambda(\tau_{ji})$ is averaged over all active links $i - j$ in the network. We are also able to derive an approximate analytic expression λ_{app}, in very good agreement with λ_{eff}.

We check the validity of the effective infection rates, λ_{eff} and λ_{app}, by means of extensive numerical simulations of the non-Markovian SIS dynamics. We consider a Markovian recovery process with rate δ, that is, $\psi_R(t) = \delta e^{-\delta t}$, and an infection process with a Weibull inter-event time distribution, $\psi_I(t) = \frac{\alpha_I}{b}\left(\frac{t}{b}\right)^{\alpha_I-1} e^{-(t/b)^{\alpha_I}}$ with parameter α_I controlling the infection inter-event time distribution.

Fig. 1 shows the prevalence of the disease ρ^{st} at the steady state as a function of λ_{eff} and λ_{app}, for different network substrates: a two dimensional lattice,an Erdős Rényi (ER) graph,a random degree regular (RDR) network and a scale-free (SF) network with exponent $\gamma = 2.5$. One can see that different curves of the prevalence, corresponding to different forms of the infection inter-event time distribution, collapse onto one another when plotted as a function of λ_{eff} or λ_{app}. This result is particularly noteworthy since two infection processes with the same average infection time but different forms of $\psi_I(t)$ are known to behave very differently [3] showing huge differences in the prevalence ρ^{st}.

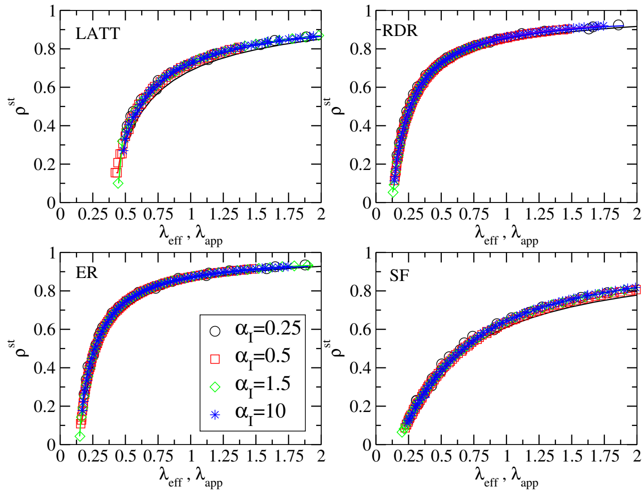

Figure 1: Steady-state prevalence ρ^{st} as a function of the effective infection rate, for different values of the exponent α_I. Symbols represent λ_{eff}, extracted by numerical simulations, continuous lines represent λ_{app}.

Interestingly, the approximate infection rate λ_{app} is expected to converge to λ_{eff} close to the epidemic threshold, and therefore the critical point and the set of critical exponents of the NM SIS dynamics, when expressed in terms of λ_{app}, are the same of those of the Markovian case. By means of a finite size scaling analysis, we obtain the epidemic threshold λ_c and the set of critical exponents for a NM SIS dynamics with $\alpha_I = 0.5$ and $\alpha_I = 2$, on top of two-dimensional lattice and RDR networks, showing that they are in very good agreement with the corresponding ones known in literature for Markovian SIS dynamics.

It is worth remarking that our formalism is not restricted to the SIS model and can be easily extended to any NM dynamics with a finite set of discrete states, allowing to determine the extent to which such dynamics can be reduced to a Markovian equivalent or whether the NM dynamics are fundamentally different. This simplification of the temporal nature of discrete-state processes promises to find application in the wide variety of areas where non-Markovian aspects are recognized as increasingly influential.

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Optimal entrainment of the spikes emitted by a semiconductor laser with feedback

J. Tiana-Alsina, C. Quintero-Quiroz, M. C. Torrent and C. Masoller
Universitat Politècnica de Catalunya, Departament de Física, Colom 11, 08222, Barcelona, Spain

The nonlinear dynamics of a semiconductor laser induced by optical feedback has been intensively studied in the last three decades, not only because these lasers are important practical devices, but also, because of the wide range of complex regimes that can be induced by optical feedback. The chaotic optical output generated has found various applications (secure communications, information processing, LIDAR, random number generation, etc.). In this contribution we focus on a dynamical regime known as *low frequency fluctuations* (LFFs), in which the laser emits an spiking output with dynamical properties that resemble the spike sequences of biological neurons. Operating in this dynamical regime, semiconductor lasers can be building blocks of ultra-fast information processing systems inspired in the way biological neurons process information. To use the laser as an information processing unit, it is crucial to understand how the information of a weak input signal is encoded in the output sequence of optical spikes.

In this contribution we consider the simplest situation of a weak periodic signal which is applied to the laser via direct current modulation. We present an experimental study of the role of the signal waveform and laser operation conditions in the entrainment of the output spikes to the periodic input. We propose several measures to quantify entrainment (inter-spike-interval distribution, spike success rate and ordinal spike correlations [1, 2]) and use them to analyze which waveform (at a given mean value and oscillation amplitude) produces optimal entrainment.

Figure 1 displays the ISI distributions for a semiconductor laser subject to an optical feedback and an external current modulation. Two periodic waveforms have been used. In Figure 1a we show the ISI distribution when a pulsed signal is applied while in Figure 1b illustrates the ISI distribution under a sinusoidal waveform. In both cases, four different modulation frequencies are choosen to show up the first four locking scenarios displayed by the dynamical system.

In the case of pulsed modulation, locking 1:1, 2:1, 3:1 and 4:1 (revealed by a high and narrow peak in the ISI distribution at $n \cdot T_{mod}$) are observed at modulation frequencies $f_{mod} = 7$, 14, 25 and 35 MHz respectively. On the other hand, for the sinusoidal test, a much broader ISI distributions are observed at low modulation frequencies which reveals an heterogeneous distribution of the power dropouts (i.e. poor entrainment). At higher frequencies the ISI distribution becomes narrower and the dynamical response of the system approches to the one observed with the pulsed modulation. Therefore, our results indicate that, for entraining the power droputs, the pulsed waveform is more efficient than the sinusoidal waveform..

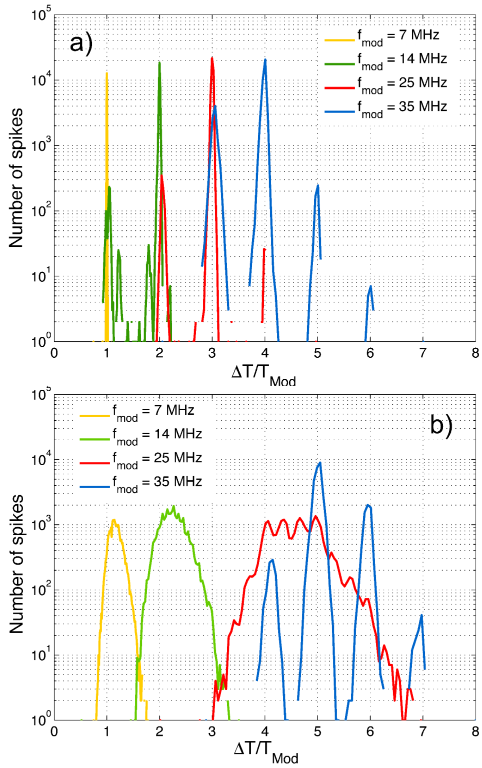

Figure 1: Experimental inter-spike-interval (ISI) distribution. The modulation amplitude is choosen to be 2.0% of I_{DC} and the modulation frequency is 7 MHz (yellow line); 14 MHz (green line); 25 MHz (red line); 35 MHz (blue line).

Acknowledgments: This work was supported in part by European Commission through the FP7 Marie Curie Initial Training Network NETT (289146), Spanish MINECO/FEDER (FIS2015-66503-C3-2-P) and ICREA ACADEMIA, Generalitat de Catalunya.

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The relation between structure and function in complex networks: trivial answers for an old problem?

Gorka Zamora López, Ruggero G. Bettinardi, Nikos E. Kouvaris, and Gustavo Deco.

For almost two decades many efforts have been devoted to investigate the impact of different network features, e.g., hubs, clustering or communities, on the collective behaviour of dynamical processes on complex networks such as spreading phenomena and synchronization. However, a unique answer to the relation between the network structure and its function is not possible, because the emerging network activity is a product of the interplay between several ingredients. Thus, the network topology shapes, but does not determine the network dynamics. At most, we can aim at making a rough estimate of what is the contribution of the structure alone in sculpting the emergent functional relations. To answer that question, we have proposed a network measure, *topological similarity* $\mathcal{T}$, based on simplest axiomatic assumptions. Topological similarity represents the direct relation between the structure of a network and the patterns of functional relations that it *tends to* produce.

From a practical point of view, it has to be recognised that most real systems operate far from the synchronised state, a circumstance that has received less attention in the literature. Although chimera states represent a fascinating phenomenon of a system away from global synchrony, their emergence are restricted to very strict conditions which can be hardly met in real systems. Based on the fact that the structure of real networks are heterogeneous in many ways, we could show how such heterogeneities may lead real networks into chimera-like states and other complex phenomena, which trigger the relation between the structure and its function even more complicated. For example, our observations indicate that the inverse problem, that is, to estimate the underlying structural connectivity from observed network dynamics may be an unsolvable problem. Finally, we show the application of the theoretical tools introduced to help understand the relationship between structural and functional connectivities in the human brain.

POSTERS

A Simheuristic Approach for the Uncapacitated and Stochastic Hub Location Problem in Smart Cities

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Abstract

Smart cities represent rich and dynamic environments where the use of information, digital and telecommunication technologies are used to improve the city's operations more flexible, efficient and sustainable. The increasing trend of urbanization and mobile connected cities focus on strengthening network infrastructures, optimizing traffic and transportation flows, decreasing energy consumption and supplying innovative services. Due to their complexity related to the number of users, heterogeneous services and specific requirements, smart cities can significantly benefit from a network design as it can be used to improve system performance. In this context, the most common problem in design and usage of telecommunication networks is the hub location problem (HLP) as illustrated in Figure 1, in which the objective is to determine the number of hub facilities, their location and allocation of demand to facilities so that the transfer of all the commodities in the network is ensured, while the total cost of providing service are minimized. There are several kinds of HLP: the number of hubs may or may not be established beforehand, the node allocation may be either single or multiple, there may be constraints on the capacities, etc. Nonetheless, standard HLP models treat inputs as known and deterministic. We investigate the application of a previous proposed simheuristic algorithm [1] for solving the stochastic uncapacitated HLP in which uncertainty is associated to transportation costs.

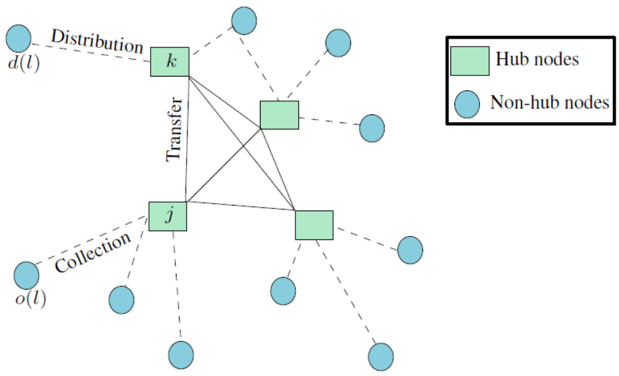

Figure 1: Illustrative example of the Hub Location Problem. The hub nodes are assumed to be fully connected.

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Network-based study of comorbidity

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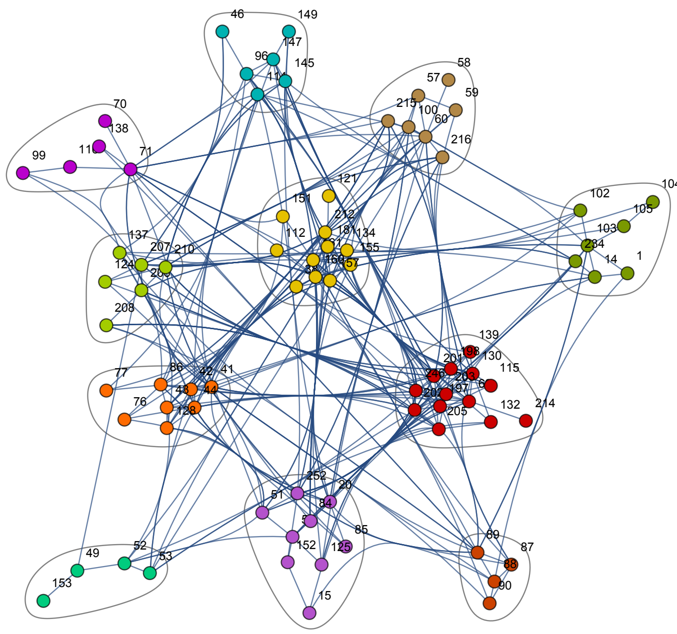
Abstract

Epidemiological studies have demonstrated the existence of different types and levels of comorbidity and multimorbidity (presence of one or more diseases, respectively, added to a primary disease in the same individual). The Institute for Research in Primary Care (IDIAP Jordi Gol) has described the existence of clusters (i.e. epidemiological groups) of patients with comorbidity and multimorbidity in the Catalan population. Here, we expand on these results by applying a network-based analysis of comorbidity/multimorbidity data. Nodes represent diseases and they are connected by edges according to their degree of co-occurrence based on the Jaccard's similarity index values and/or relative risks. An ongoing analysis describes central diseases across these settings, major node communities, and disease trajectories across time/gender. Subsequently, we aim to integrate biological data that may reveal fundamental molecular features underlying specific comorbidities. Collectively, this multidisciplinary project aims to decipher the systems-level patterns of comorbidity/multimorbidity and to predict their causal molecular basis.



Preliminary results on revealed node communities for a given age group and gender.

Unsupervised feature detection in ocular image databases

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Abstract

Unsupervised organization of big data sets containing complex data according to relevant features is a challenging task. Here we test different methods in two ocular image databases showing that carefully choosing a dissimilarity measure to compare two objects in the data base is essential to obtain meaningful results. A large database of over 1000 OCT images of the anterior chamber and a small retinal fundus image database of 45 entries were analyzed. We show how both sets can be unsupervisedly ordered in a two dimensional space with axis that represent meaningful high level features.

Synchronization Transitions Induced by Topology and Dynamics

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The synchronization of coupled oscillators is a paradigmatic example of the emergence of complex behavior in a dynamical system with local interactions. It is an ubiquous phenomena in nature, where most of the systems present a complex underlying structure. Much research has been done in the last decades to understand the interplay between dynamics and topology, obtaining successful results in the inference of the structure from the response dynamics [1, 2] and the prediction of the synchronization onset for several topologies [3, 4, 5]. However, a general theory for synchronization in complex networks is still missing and there are many theoretical and empirical challenges to face towards a complete understanding of the process [6, 7].

In this work, we study the dynamics of Kuramoto oscillators in evolving complex topologies. We construct functionally equivalent networks by constraining the distribution of coupling strengths in the nodes in order to show that the same evolution of the global order parameter in a quasi-static process can be observed due to changes either in the underlying connectivity of the network or in the dynamics of the interactions. In this framework, an explicit analogy between topological and dynamic transitions is made by using simple mean-field arguments.

We consider that the dynamics of any sparse but connected network is driven by a reduced effective coupling strength between oscillators, K_{eff} depending only on the current coupling strength of the network K and its distribution over the nodes space. For instance, for an Erdös-Rényi $G(p, N)$, the homogenitiy of the network leads to the scaled coupling $K_{eff} = pK$, where p is the global fraction of existing edges, and the structural transition occurs at a critical connectivity $p_c = K_c/K, \forall K \geq K_c$ (K_c is the critical coupling for the all-to-all limit case). This result closely agrees with numerical simulations, and the mean-field approximation [4, 5] converges to it for large and highly connected systems. Beyond the prediction of the synchronization onset, we suggest that the whole evolution in the dynamic response due to structural changes is analogous to the evolution of an static structure under changes in the coupling strength among oscillators.

In order to quantify these effects, we use a model of network formation that interpolates between Erdös-Rényi and Scale-Free [8] to generate networks with increasing average connectivity constrained to the given degree distribution. For each network, we iterate the system towards the steady-state for a range of supercritical coupling strengths (for the all-to-all case), measuring the global degree of synchronization with the usual macroscopic order parameters.

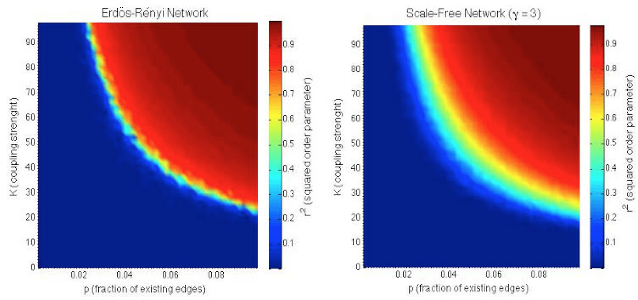

Figure 1: Steady-state of synchronization measured by the squared order parameter r^2 for both ER and SF networks in the plane (p, K), with $N = 10^3$ nodes and a uniform distribution of natural frequencies $g(\omega) = 1/\pi$, as fixed parameters in each realitzation. Isochrome regions represent functionally equivalent networks that preserve the global coupling strength and the clear analogy between structural (increasing p) and dynamic (increasing K) transitions is shown for both ensembles. For the ER case, we observe the same behaviour as in the all-to-all case, where a discontinuos phase transition occurs at $K_c = 2$, and the critical connectivity $p_c(K)$ matches our theoretical prediction. For SF networks, the transition appears earlier and becomes smoother, as expected [6, 7], but the studied analogy remains present.

This work presents some analytical and numerical evidence on the close relation between topological and dynamic transitions to synchronization. We aim to shed some light on the nature of these transitions in real systems, where one can usually measure their response dynamics, but there is very little information about the underlying topology, its evolution, and the specific local interaction mechanisms.

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CHARACTERIZATION OF THE GAME STYLE FROM THE DISTRIBUTION IN THE LENGTH OF FOOTBALL PASSES

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Most living beings move creating patterns that consist of alternating a series of random motions with varying lengths. Depending on the system and constraints inpinging on it, it may take a form of Brownian motion, subdiffusion, superdiffusion or for some cases even a Levy flight distribution. These patterns have been detected in numerous phenomena as diverse as geophysics, financial mathematics, astronomy, physics or biology, and have been found in different animal species, from sharks to bees. The objective of this study is to determine if the distribution in the length of the passes in a match respond to mathematical patterns of this type. The passing score has allowed characterizing the performance during the match or the style of game of a team using indicators like the percentage of ball possession, the number of passes by possession or the order of intervention in sequences of passes. However, pass lengths have barely been subject to investigation. Brillinger et al. (2007) identified in a sequence of 25 passes that finalized in goal, where the shortest pass was 5.6 meters and the longest was 27.9 m., suggestive of a long-tailed distribution. This suggests the hypothesis that the distribution in the length of the passes during a match may be characterized by a large number of short passes, lower number of mid passes and a small number of long passes. Therefore, the exponent of the distribution in the length of the passes would allow to characterize the game style of a football team.

Key words: complex systems, Levy flights, Brownian motion, football.

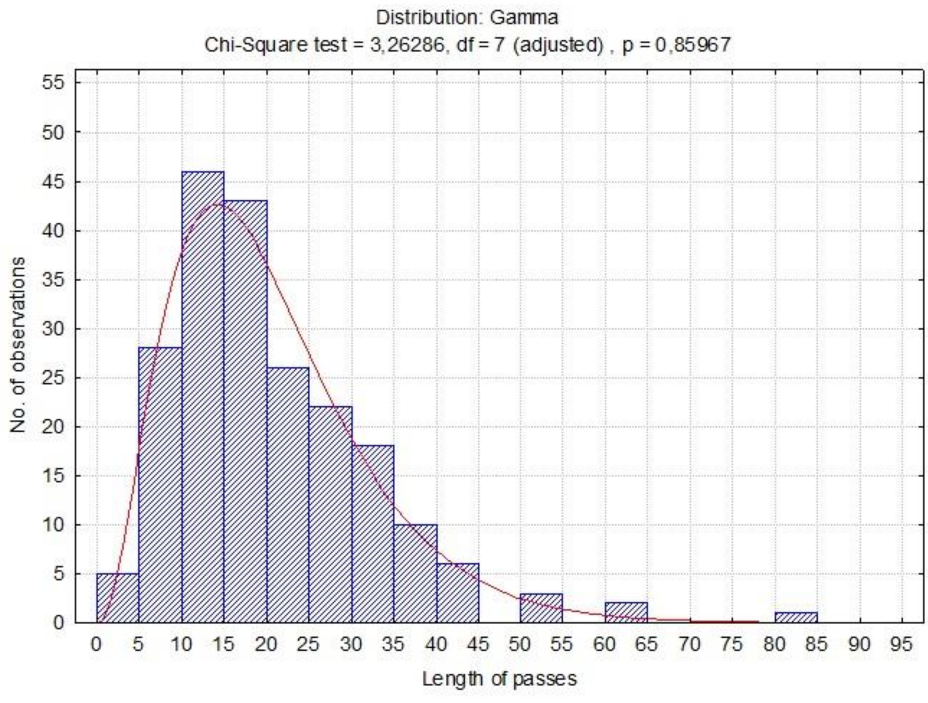

Figure 1. Probability density function

Statistical inference in social dilemmas

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Abstract

Our investigation focuses on the predictability of human beings when confronted to simple decision-making scenarios, as those considered in Game Theory. The data for this study is provided by a social experiment in which participants played different types of one-on-one games. Our approach to the problem classifies both participants and games in groups. Players and games are grouped together according to their respective similarity as observed in the data. Using this methodology, we build a predictive model. Finally we improve its predictive power by imposing the requirement that similar games should belong to the same group.

Experiment and Model

Participants played an average of 14 consecutive rounds against different opponents (i.e., other participants). A randomly selected game was played in each round. In total, there were 121 games grouped into 4 categories: Harmony Game (HG), Snowdrift Game (SG), Stag Hunt (SH) and Prisoner's Dilemma (PD). Each of these games is characterized by its payoff matrix (see Fig. 1).

The Stochastic Block Model approach groups up players or games in configurations according to the similarity in the observed actions. Our algorithm explores a landscape of configurations and looks for the optimal one in terms of energy.

Game Theory and Model

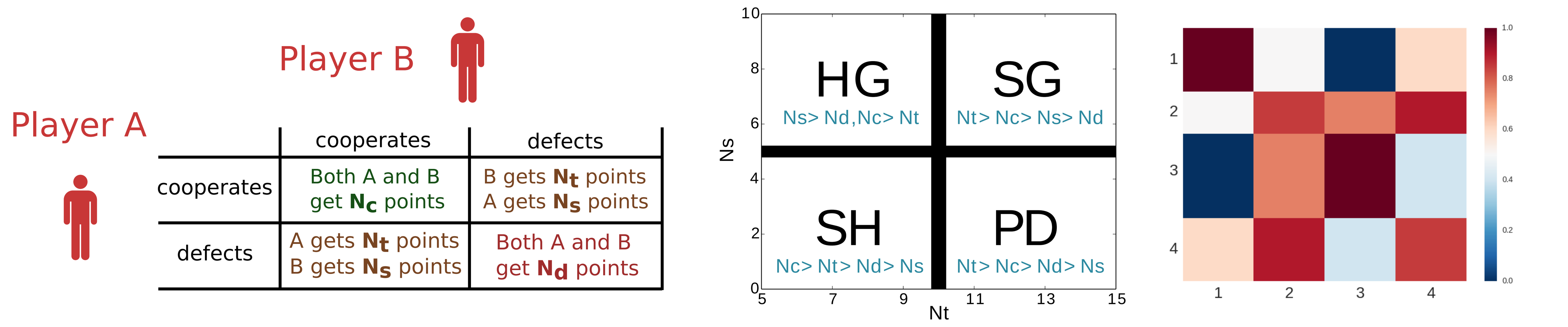

Fig. 1: Subjects played 121 different games grouped into 4 different types. Each game is characterized by the Nt and Ns payoffs. We consider a Stochastic Block Model approach to study the problem.

Methods

Our goal is to detect and predict the participants' strategies. Therefore, we want to compute the probability $p(a_{pg} = a|R^O)$ that the **player p**, chooses the **action a** in the **game g**, given the observations R^O:

$$p(a_{pg} = a|R^O) = \int_{\mathcal{M}} dM p(a_{pg} = r|M)p(M|R^0)$$

In SBMs this probability is exclusively determined by the groups to which p and g belong, such that the previous equation transforms into:

$$p_{SBM}(a_{pg} = a|R^0) = \frac{1}{Z} \sum_{\substack{P_U \in \mathcal{P}_U \\ P_p \in \mathcal{P}_g}} \frac{n^a_{\sigma_p \sigma_g} + 1}{n_{\sigma_p \sigma_g} + 2} \quad e^{-\mathcal{H}(p_p, p_g)}$$

Simulated Annealing

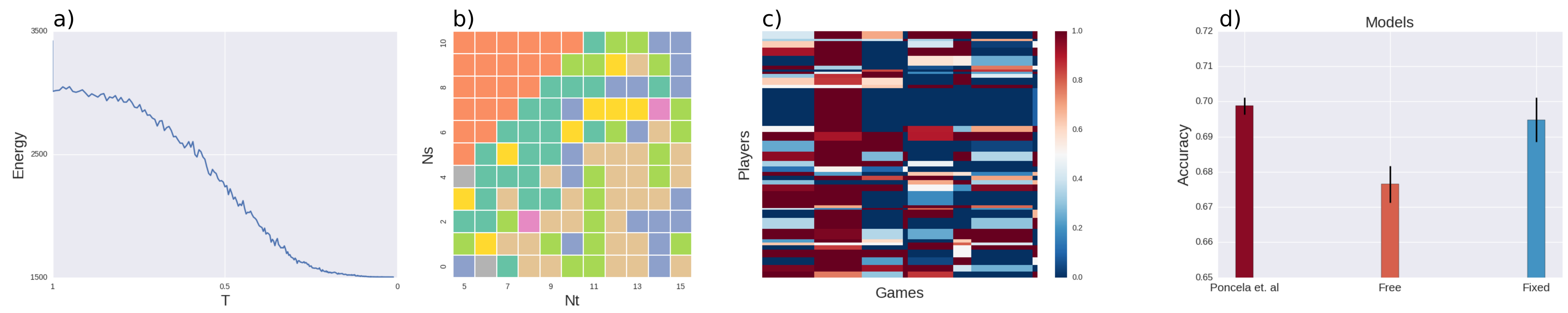

Fig. 2: (a) Energy vs. temperature, (b) distribution of games groups, (c) groups of players vs. groups of games and (d) performance of the three different models considered.

Priors

In order to increase the predictive power of our model, we make the plausible assumption that games with similar payoffs should fall into the same group (i.e., players play similarly to similar games). The strength of this requirement is controlled by the parameter α. It is observed that there is an optimal range of values for this parameter, for which statistical fluctuations are ruled out, therefore yielding higher accuracies.

Conclusions

We find that the subjects in the experiment tend to classify games according to the difference between the Temptation and Sucker payoffs (N_t -N_s). This appears clearly when we include an *a priori* assumption in our algorithm, namely that games with similar payoffs should be played similarly. Moreover, this assumption yields models with an overall lower number of groups and a better performance.

Results

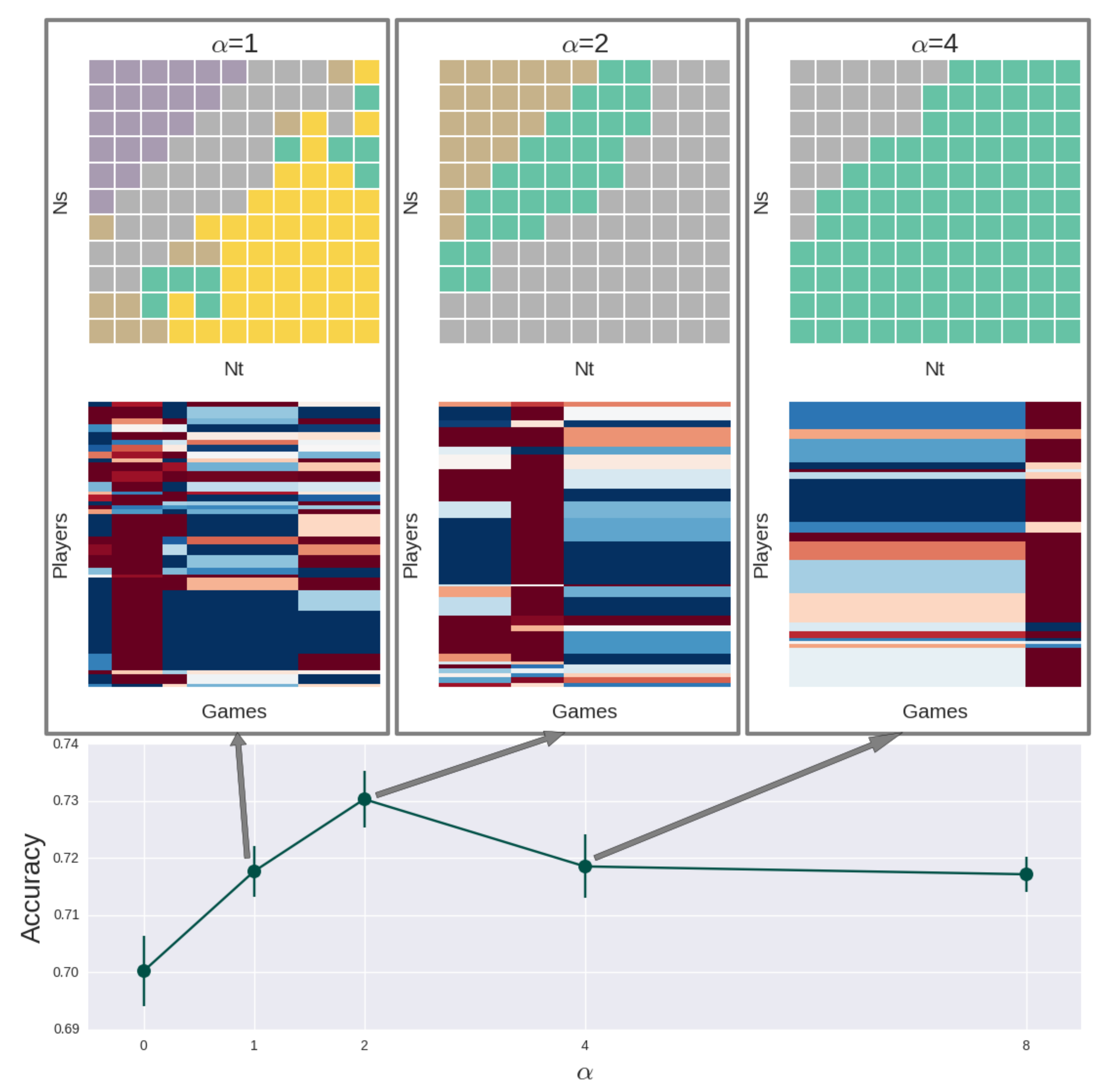

Fig. 3: Accuracy for different values of the prior parameter α. Inset: distribution of games groups (up) and Stochastic Block Model (bottom) for $\alpha = 1$ (left), $\alpha = 2$ (center) and $\alpha = 4$ (right).

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Acknowledgments

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SEESLAB Science and Engineering of Emerging Systems

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Phase transition and event-size distribution in finite-size random walks and branching processes

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By means of a mapping with random walks, we study critical phenomena in branching processes with a finite-size constrain. We derive the behavior of several order-parameter quantities as well as the event-size distribution, extending the results of Font-Clos and Moloney [PHYSICAL REVIEW E 94, 030102(R) (2016)] to include non-percolating events. We obtain the exact finite-size event-size distribution in Laplace space in the subcritical, critical, and supercritical cases, showing the fulfillment of finite-size scaling.

Author: Elisenda Ortiz Castillo

Title: Efficient navigation of temporal networks embedded in hyperbolic metric spaces

Abstract: We study the efficiency and robustness of the routing of information packets in time-varying complex networks whose nodes can be inactive at certain points in time. For this purpose we analyze real data of five different topologies, and consider their complex network representations embedded in a hidden hyperbolic metric space. The underlying geometry defines distances between nodes that we use in a greedy forwarding strategy for the transport of packets combined with a random activation-inactivation dynamics of the nodes. Interestingly, we find that the dynamic changes in the topology of the networks can contribute to an increase in the number of successful paths. For long-enough lived packets, there is an optimal value of activation which gives the best trade-off between the increase in the number of successful paths and the unavoidable increase in their length. Finally, the results are robust even when the most connected nodes activate with very low probability. Lastly, we find that a reduced and well-defined core sustains the highest contribution to the increase in success rate. Our results provide hints towards the development of better routing protocols that take into account the evolving nature of complex networks.

Geometric renormalization of real complex networks

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Renormalization has proven to be a very powerful tool for a systematic investigation of systems–from condensed matter to quantum field theory–as viewed at different scales. In the field of complex networks, some topological renormalization schemes based on shortest paths between nodes have been proposed in the past [1]. However, the collection of shortest-path lengths, albeit a well-defined metric space, is a poor source of length-based scaling factors in networks due to their homogeneity and the small-world property.

We present empirical evidence that real-world complex networks are invariant under geometric length scale transformations when embedded in an underlying hidden metric space. We prove analytically [2] that the embedding model [3, 4] is also renormalizable in the same framework and take it as new evidence supporting our conjecture that hidden metric spaces underlie real networks. The congruency between real networks and the geometric model enables to define a multiscale unfolding of complex networks that allows the study of their self-similarity properties.

As applications, this geometric renormalization scheme yields a natural way of building smaller-scale replicas of real networks while simultaneously preserving their statistical properties, which can be extremely useful in the study of dynamical processes on large networks. The hidden metric space renormalization group can also be applied to design a new greedy routing protocol in hyperbolic space which exploits the multiscale unfolding of complex networks increasing the success rate of single-scale versions.

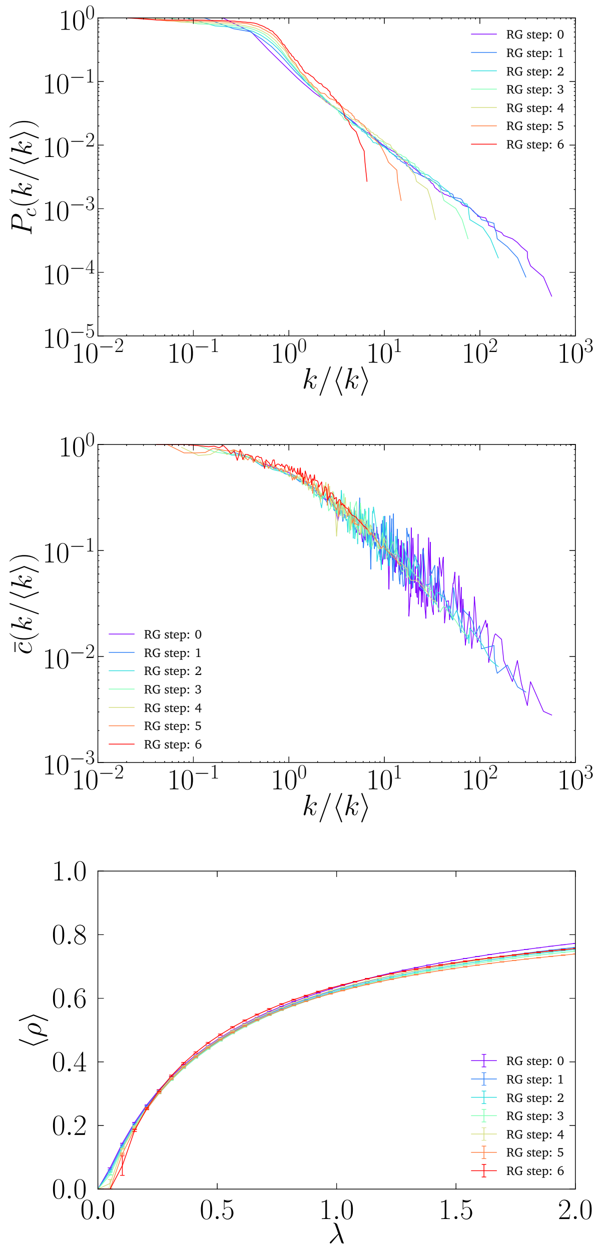

Figure 1: **Geometric renormalization of the Internet AS network.** The plots compare the networks obtained from the geometric renormalization transformations. At every renormalization step, the number of nodes is reduced by a factor 2. **Top:** Rescaled complementary cumulative degree distributions. **Middle:** Rescaled clustering coefficient spectra. **Bottom:** Average prevalence as a function of the infection rate in the SIS dynamics on the original network and its smaller-scale replicas.

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BIPARTITE METAPOPULATION MODEL FOR EPIDEMIC SPREADING DYNAMICS OF STUDENTS IN U.S. CAMPUSES

CLARA GRANELL

The spreading of infectious diseases has been studied in the complex networks literature in a great variety of forms. Models range from the simplest assuming homogeneous mixing of individuals, to epidemics spreading on quenched networked structures, to even multilayer scenarios. Significant progress has been made, and up to date we are able to understand the critical behavior of spreading dynamics in global scenarios, but the outcome of more realistic and localized environments is still a challenge.

In particular, we are interested in studying the interplay between the spreading dynamics of influenza-like illnesses (ILI) and mobility of students inside university campuses. In most U.S. universities, a great part of the students live in the university residence halls, specially freshmen and second year undergrads, who in some cases are even required to reside in the university dorms. Their mobility dynamics is cyclic, i.e. they live in a dorm, they go to classes and do other activities where they meet with other students, and return to the same dorm. This particular aspect of mobility, along with the fact that students' contact patterns tend to be endogenous, make university settings very interesting scenarios for studying the spreading of ILI and testing the efficacy of measures for prevention of infection.

To do so, we propose a model, based on the well-known metapopulation models for epidemic spreading in networks, that account for the interplay between mobility and disease contagion for this particular scenario. The model works as follows: there are two types of nodes (populations): *dorms* and *classes*. These populations are connected in a bipartite fashion, i.e. there is no connection among dorms or among classes. Each individual belongs to a dorm to which they return after their academic activities are over. The dynamics work as follow: every day, each individual residing in a dorm decides to go to class with probability p, choosing randomly one of the class nodes as its destination. In the class the individual encounters other individuals and interact with them according to the Susceptible-Infected-Susceptible (SIS) spreading dynamics, in a well-mixed fashion. After that, all students synchronously return to their respective dorms, where they interact with other residents following the same SIS dynamics.

Synergistic cumulative contagion in epidemic spreading

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Epidemic modeling has proven to be a powerful tool for the study of spreading and contagion phenomena in biological, social and technical systems. The addition of numerous compartments and the incorporation of complex contact topologies has yielded evermore accurate models, prompting their use as real-time predictive tools. Notwithstanding, most approaches assume memoryless and independent processes, an approximation partially invalidated by empirical evidence [1]. We propose an alternative, cumulative infection mechanism, and study its effects in the susceptible-infected-susceptible model.

In our description, susceptible agents accumulate pathogens from all their infected neighbors and become infected following a given probability density. When the last infected neighbour recovers, the accumulated viral load starts to decay with a characteristic relaxation time ζ. Infected agents recover spontaneously following a given inter-event time distribution. Here we use a Weibull distribution for infections (with shape parameter α) and exponentially distributed recoveries. We study the limit cases $\zeta = 0$ (instantaneous decay) and $\zeta = \infty$ (long-term memory) in random degree regular networks.

Performing extensive numerical simulations we obtain the bifurcation diagrams (Fig. 1) and critical properties of the absorbing phase transitions. Our results [2, 3] show a variety of phenomena, including loss of universality and, counterintuitively, an apparent memory-loss in systems equipped with long-term memory. These features arise from different combinations of infection distributions and relaxation times, evidencing a crucial role of non-Markovian effects.

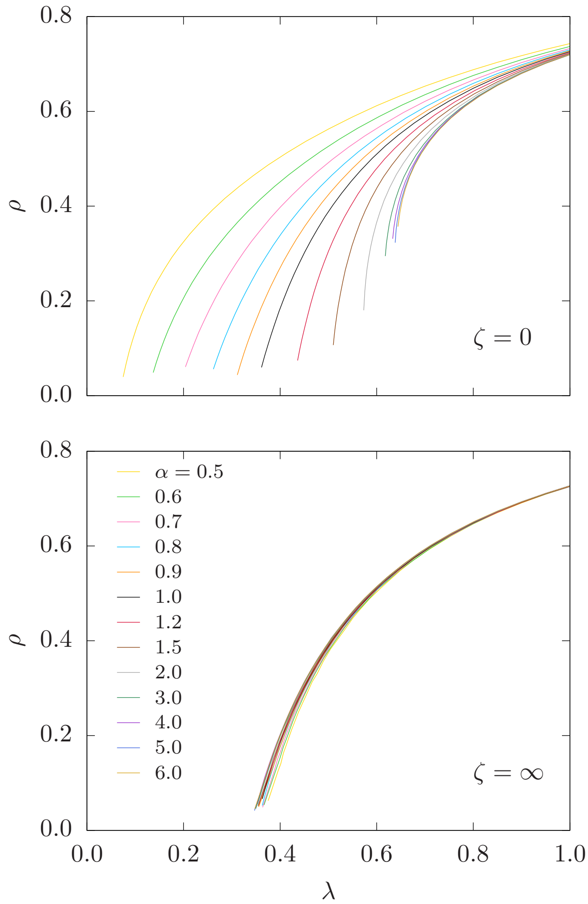

Figure 1: Fraction of infected agents, ρ, as a function of the effective spreading ratio, λ, for various infection distributions (α indicated in legend). **Top**: Instantaneous decay of viral load (short-term memory). **Bottom**: Viral load does not decay (long-term memory).

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Reconstructing Networks of Neuronal Connections

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Abstract

We aim to grow functional neuronal circuits for damage repair in diseases such as Sanfilippo's, Huntington's and Parkinson's, by guiding the growth of cultures of neurons derived from induced pluripotent stem cells (iPSC) [1].

We use calcium fluorescence imaging to record neuronal activity, which allows the simultaneous monitoring of hundreds of neurons with high spatio-temporal resolution [2]. Starting from these recordings, we use the Transfer Entropy approach to reconstruct the directed and weighted functional network between neurons [3]. Simulations of realistic networks allow us to validate this approach and provide complementary details which are difficult to extract from experiments [4]. We present observable network properties and their evolution upon ageing of the culture with a view to characterize and model network growth and disease development.

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Álvaro Martínez

Darwinian theory of biological evolution has two main features: variability and selection. Evolutionary processes occur across all spatial and temporal scales, from species and organisms down to the molecular level. Quantifying variability and disorder is, therefore, essential to understand how molecular ensembles of mutants evolve in time. In this work we show how, building on the most recent developments in thermodynamic inference in stochastic thermodynamics, we can extract the intrinsic information of a disordered ensemble of DNA hairpins using single-molecule force spectroscopy.

Subthreshold signal encoding and transmission in coupled FitzHugh-Nagumo neurons

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In sensory neurons the presence of noise can facilitate the detection of weak signals, which are encoded and transmitted via temporally correlated sequences of spikes. In a recent work [1] the dynamics of a stochastic FitzHugh-Nagumo (FHN) neuron was studied, when a weak periodic signal was applied to the neuron (the amplitude of the signal was kept below the excitable threshold, such that by itself, in the absence of noise, it did not generate spikes and the response of the neuron was a subthreshold oscillation). In the presence of noise, spikes trains were generated, and by using a symbolic method of time-series analysis known as ordinal analysis [2] applied to the sequence of inter-spike-intervals (ISIs), it was shown that the interplay of noise and the periodic signal induced the emergence of relative temporal ordering in the timing of the spikes, i.e., induced temporal correlations among several consecutive ISIs. Different types of temporal ordering were found, in the form of preferred and infrequent ordinal patterns that depended on both, the strength of the noise and the period of the input signal. A resonance-like behavior was also found, as the probabilities of the preferred/infrequent patterns were maximum/minimum for certain periods of the input signal and noise strengths. In contrast, the spike rate was found to be nearly independent of the period of the input signal. These results suggest that single sensory neurons in noisy environments might encode information about weak stimuli in the timing of the generated spikes ('temporal coding'), captured as more/less frequent ordinal patterns in the ISI sequences, and not in the spike rate ('rate coding').

Here we analyze under which conditions the coupling to a second neuron, which is assumed to be mutual, linear and instantaneous, can further enhance the temporal ordering in the spike sequence of the first neuron, improving the encoding of the weak, subthreshold external signal. As in [1], we apply the method of ordinal analysis to the output sequence of inter-spike intervals of the first neuron. We find that for certain periods and amplitudes of the external signal, the coupling to the second neuron changes the preferred (and also the infrequent) ordinal patterns. A detailed study of how the ordinal probabilities vary with the coupling strength is performed. In a second step, we analyze which coupling conditions enhance temporal order in the spikes of the second neuron, improving the transmission of the signal.

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Interplay Between Human Mobility and Telecommunication

Manlio de Domenico, Joan T. Matamalas and Alex Arenas

Understanding how people move within a geographic area, e.g. a city, a country or the whole world, is fundamental in several applications, from predicting the spatio-temporal evolution of an epidemics to inferring migration patterns. The possibility to gather information about the population through mobile phone data —recorded by mobile carriers triggered a wide variety of studies showing, for instance, that mobile phones heterogeneously penetrated both rural and urban communities, regardless of richness, age or gender, providing evidences that mobile technologies can be used to build realistic demographics and socio-economics maps of low-income countries, and also provide an excellent proxy of human mobility, showing for instance, that movements exhibit a high level of memory, i.e. the movements of the individuals are conditioned by their previous visited locations.

However, the precise role of memory in widely adopted proxies of mobility, as mobile phone records, is unknown. We have used 560 millions of call detail records from Senegal to show that standard Markovian approaches, including higher-order ones, fail in capturing real mobility patterns and introduce spurious movements never observed in reality. We introduce an adaptive memory-driven approach to overcome such issues. At variance with Markovian models, it is able to realistically model conditional waiting times, i.e. the probability to stay in a specific area depending on individual's historical movements, Figure 1.

Our results demonstrate that in standard mobility models the individuals tend to diffuse faster than what observed in reality, whereas the predictions of the adaptive memory approach significantly agree with observations. We show that, as a consequence, the incidence and the geographic spread of a disease could be inadequately estimated when standard approaches are used, with crucial implications on resources deployment and policy making during an epidemic outbreak.

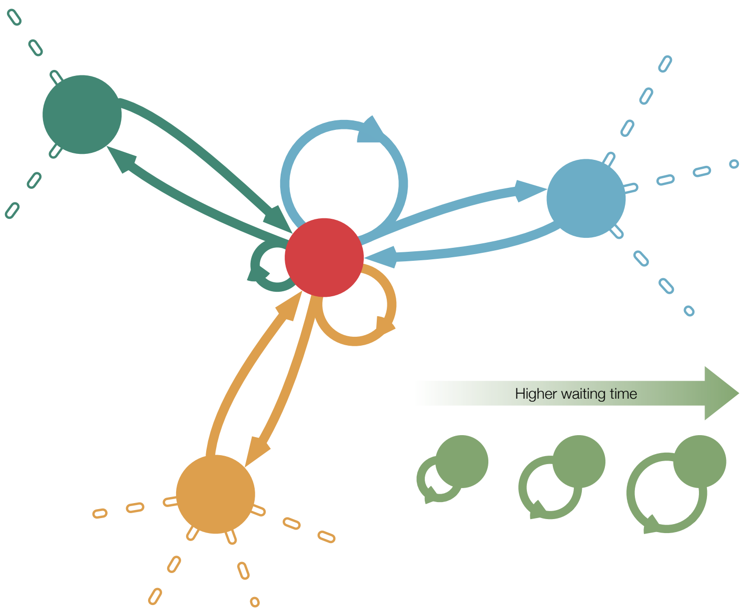

Figure 1. An example of human mobility between four different places. Individuals from green, blue and orange nodes move to the red central node and, after some time, go back to their previous location. The amount of time spent in the red node by individuals coming from the other nodes depends on their previous location, and it is represented by self-loops of different size.

Ensembles of Sisyphus processes with self-triggered resets

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During the last few years, the interest in the stochastic resetting of processes has drastically grown. The genuine apparition of power law tails and the extensive presence of these kind of processes in nature, as in animal food search or in computer random algorithms have made them a usual tool to model a vast number of processes. Resets usually appear as an external input, i.e., the resets are triggered by a source which is independent of the system itself. Among these processes, the Sisyphus process has been recently studied as a simple yet interesting process involving resets. It consists in a walker who at each step can either advance one position in a discrete, one-dimensional grid or restart to the origin with a given probability [1].

Lately, a two-walker system has been studied where the trigger of the reset is their relative position being 0 (i.e., they reset their position if they collide) which is an internal property, not depending only on the studied walker and its environment but also on the state of the other walker [2]. In this direction, we study a system composed by two different Sisyphus processes (a bi-Sisyphus process) which now can either jump to the immediately upper level or stay at their position. The whole system resets whenever one of the two walkers hits a target placed in a given level h.

This model could describe different systems in nature. In neuroscience, it can be seen as a discrete generalisation of the so called integrate-and-fire model for neurones that studies the evolution of the increasing voltage in the neurone which suddenly discharges when a certain voltage threshold is reached [3]. The model analysed here pretends to describe what happens with binary interactions in neurones, where the discharge of one of them can trigger the discharge of the other when also the evolution of the inter-reset voltage is stochastic. In social sciences, the model studied in this work could be used as the basis to describe leadership formation (e.g., world power countries) or as a model for opinion dynamics.

Concretely, we study global properties of the bi-Sisyphus, as the resetting time distribution of the whole system. Also, the first passage statistics of one of the two Sisyphus is determined, taking the other process as a mere reset trigger. Moreover, the one-by-one interaction defined by the bi-Sisyphus process is used as the generator of the interaction between elements in a discrete lattice. This is, when one of the Sisyphus in the lattice reaches h, this walker and its neighbours reset their position to the origin whilst the other parties continue climbing.

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Coordinated decisions and competing interests. How the first cities of Western Europe shaped their terrestrial transportation network

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We have developed a very simple deterministic model for proto-historical terrestrial routes that reproduces empirical networks with surprising accuracy. Such model connects a set of given geolocalized settlements (nodes) through paths (links) whose total lengths is derived from the empirical data. The only parameter in the equations weights the rich-get-richer bias when adding new links.

We are suggesting that the way the city-states shaped their communication infrastructure is related with the nature of the relationships they had with each other. By applying this model and determining the value of the parameter that produces the best fitting result, we should be able to answer question such as: To what extent did the city-states look for individual benefit instead of thinking for the good of the league? Were they trying to make the region work or were they just fighting to survive individually?

The goal we are pursuing is an ambitious one and the difficulties we are facing are many and... quite challenging. Surely many interesting things can be said about two case-studies in which the model has been applied successfully, but it looks like there are not many more good datasets out there.

Archaeologists are rarely able to infer the whole map, and without the information about the total length of the connections we do not know when to stop the growth of the network. Hence, we are looking for a criterion for stopping adding links that does not rely so critically on the completeness of the empirical information. We also wonder how reliable the recovery of the best fitting value of the rich-get-richer parameter is, both in ideal (synthetically generated) and in real (empirical) cases of damaged topologies.

We address all these issues trying to figure out how already existing techniques can help us dealing with this difficulties.
But most of all, we would like to know if there is any chance to make archaeologically-motivated network science that makes sense for both archaeologists and networks scientists.

Renormalization of correlated point-processes

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Abstract

The study of point processes is a cornerstone for the understanding of relevant properties in complex systems. The distribution of waiting-times corresponding to uncorrelated renewal point-processes renormalizes into two fixed points: a Poisson point-process if there is a finite mean waiting-time or a point-process characterized by a Mittag-Leffler distribution of waiting-times, if there is not [1, 2, 3, 4]. In this work we explore different ways to introduce correlations between waiting-times in order to study its effect in the renormalization of renewal point-processes.

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Simulation of hopping conductivity in electron glasses with the parallel rejection algorithm

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A common limitation of Markov-chain Monte Carlo (MC) methods is low acceptance. In equilibrium MC this problem can sometimes be circumvented with a clever choice of the MC moves, which can be chosen with a certain freedom as long as the Markov chain converges to the probability distribution of interest. Such freedom is not allowed in kinetic Monte Carlo (KMC), in which the MC moves are dictated by the physical dynamics to be simulated.

We recently introduced a general "parallel rejection" (PR) algorithm to address the problem of low acceptance, which is especially suitable for implementation on Graphics Processing Units (GPUs), easily available and inexpensive platforms for massively parallel computing [1].

We apply PR to the KMC simulation of the hopping conduction in disordered systems of localized electrons with long-range interaction, known as electron glasses or Coulomb glasses [3]. Simulations of these systems are plagued by the slow equilibration typical of frustrated systems, complicated by the long-range interaction and by the need to simulate very low temperature to access the variable-range hopping regime. They are thus plagued by very low acceptance.

For this particular application, PR can be seen as a parallelization of the "mixed" algorithm of Refs. [2], which can be further accelerated in GPUs by efficiently parallelizing the N local energy updates that, due to the long-range interaction, are required after each elementary MC move in a system with N sites.

We present here results in three dimensions which show that the parallel rejection algorithm outpaces the serial implementation of the mixed algorithm by several order of magnitude, thus allowing us to compute the conductivity down to very low temperatures. In particular, we provide evidence of a scaling relation for the relaxation of the conductivity at different temperatures.

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Title:
Chimera states in two globally coupled networks with chaotic dynamics.

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Abstract:

We consider a system consisting of two populations of identical chaotic oscillators, each having internal interactions, and globally coupled through their respective mean fields. We investigate the collective behavior of the system on its space of parameters, given by the strength of the global coupling (inter-population) and the strength of the internal coupling (intra-population). We find these collective states in different regions of parameters: (i) chaotic chimera states, where one population reaches a chaotic synchronized regime, while the other remains incoherent; (ii) complete synchonization, where both populations are synchronized internally and to each other; (iii) generalized synchronization, where each population is synchronized, but not to each other.; and (iv) incoherence, where both populations are desynchronized. These states are robust for different partition sizes and for different network topologies of the populations. We characterize the probability for the emergence of chimera states as a function of parameters. In addition, we find that chimera states arise even when the oscillators possess chaotic hyperbolic attractors, a relevant result since it has been recently shown that hyperbolicity prevents the occurrence of chimeras in the presence of nonlocal couplings.

Community detection in complex networks and graph invariants

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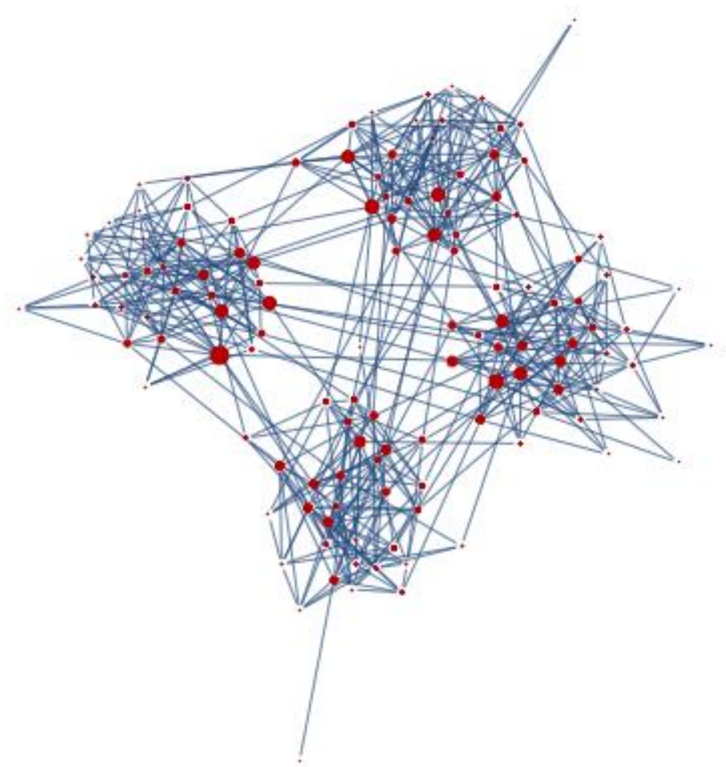
Abstract

Different community detection algorithms are applied to benchmark graphs and data from real social networks and the results related to several graph invariants. We study the relationship among the graph distribution of invariants like pagerank, communicability centrality, betweenness centrality, first passage and hitting times, etc. and the different communities of the network
We consider graphs with communities which have the same and different sizes to position nodes according to their graph centrality and we study their connections to each community.
We use standard benchmark community graphs: Girvan-Newman, LFR, regular graphs with community structure and available data from social networks.



Betwennes centrality and community structure. The size of nodes indicates the value of this parameter.

Identifying and characterizing dynamical transitions using nonlinear analysis tools.

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March 31, 2017

Identifying transitions to complex dynamical regimes is a fundamental open problem with many practical applications. Semiconductor lasers with optical feedback are excellent testbeds for studying such transitions, as they can generate a rich variety of output signals. Here we perform an experimental investigation of the onset of two well-known dynamical regimes: low frequency fluctuations (LFFs) and coherence collapse (CC) [1, 2]. We apply three nonlinear analysis tools to quantify various aspects of the dynamical transitions that occur as the laser pump current increases. The experimental setup is described in [3].

The first diagnostic tool is based in the analysis of the standard deviation, σ, of intensity time-series recorded with different oscilloscope sampling rate. For each set of (pump current, sampling rate), 10 time series with 10^7 intensity data points each were recorded. Fig. 1a displays the 10σ values vs. the laser pump current, for three sampling rates. In this plot we can identify different behaviours as the pump current increases: at low current the wide spread in the values of σ captures the coexistence between stable noisy emission and LFF dropouts [1]; for higher currents there is an almost linear increase of σ, which captures the increase of the depth and of the frequency of the LFF dropouts; at even high pump currents (above $I/I_{th} \sim 1.08$), σ saturates or decreases depending in the sampling rate, which captures the fact that the dropouts become irregular and allows to quantitatively identify the onset of coherence collapse [2].

The second diagnostic tool is based in the analysis of the number of threshold-crossing events: first, each time series is normalized to zero mean and $\sigma = 1$, then, in each time-series we count the number of times the intensity drops below a give threshold, and plot the number of threshold-crossing events vs the pump current, for various thresholds (see [3] for details). The results are presented in Fig. 1b where we can again distinguish different regions: at low and high currents the number of events depends on the threshold, which reveals that the intensity dropouts are irregular; in contrast, for intermediate currents the number of events is the same for the different thresholds, which captures the fact that the dropouts are of similar depth.

The third diagnostic tool is based in ordinal symbolic analysis [4], by which a time series y(t) is divided into non-overlapping segments of length L, and each segment is assigned a symbol, s, (known as ordinal pattern, OP) according to the ranking of the values inside the segment. For example, with $L = 3$, if $y(t) < y(t+1) < y(t+2)$, $s(t)$ is '012', if $y(t) > y(t+1) > y(t+2)$, $s(t)$ is '210', and so forth. In this way, the symbols take into account the relative temporal ordering of the values in the series. We apply the ordinal method to the sequence of time-intervals between consecutive threshold-crossing events. Specifically, we calculate the probability of consecutive intervals being increasingly shorter. The results are presented in Fig. 1c, where again one can identify well-defined regions, with $I/I_{th} \sim 1.08$ corresponding to maximum probability of the '10', '210', etc. ordinal patterns.

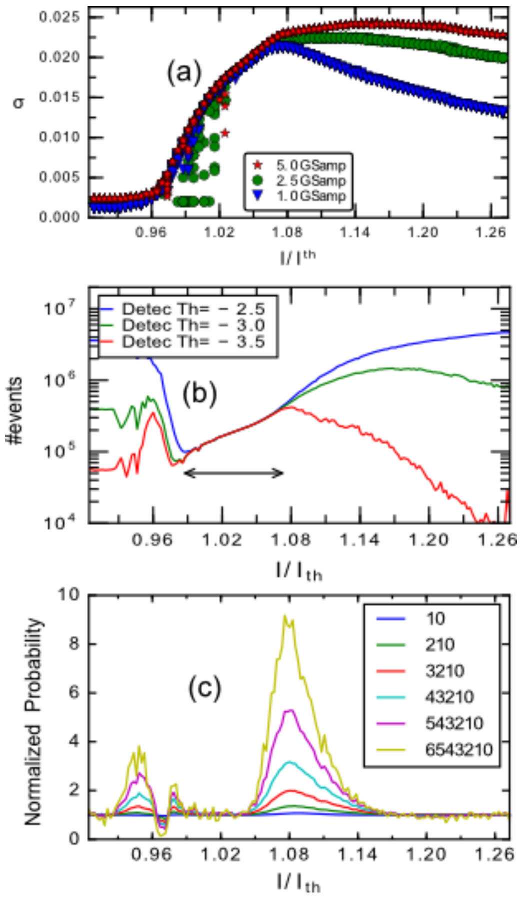

Figure 1: (a) Standard deviation, σ, of the intensity time series recorded with different oscilloscope sampling rate. (b) Number of threshold-crossing events, computed with different thresholds (in units of σ). (c) Probability of the decreasing trend ordinal pattern, normalized to the value expected if all the patterns are equally probable. In these plots different regions are observed with $I/I_{th} \sim 1.08$ indicating the onset of the CC regime.

Taken together, these three diagnostic tools allow delimiting the region of regular LFF dropouts, delimiting the region of coexistence LFF-stable emission, and allow identifying the onset of the CC regime. They can be used for characterizing dynamical properties of the laser output, which can be valuable for applications that exploit the complex output signals generated by semiconductor lasers with optical feedback.

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Role of centrality measures in a dynamic model of competences adquisition in time-dependent networks

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How humans learn has been an open question over centuries. And still it is. The secrets of competence and knowledge acquisition remain hidden despite the efforts of experts in many fields. Qualitative studies and noisy data is not enough to predict and improve the setting which optimize ability growth. We suggest a model of performance evolution which may help us describe, quantify and better analyse this open question. We cannot neglect the apparent connection between different factors within one single individual. Our starting point is a model [1] which considers the effect of variables interacting between each other:

$$\frac{\Delta x_i}{\Delta t} = \left(r_i x_i \left(1 - \frac{x_i}{K_i}\right) + \sum_{n.n} s_j x_i x_j \right) \left(1 - \frac{x_i}{C_i}\right) \quad (1)$$

Moreover, we want to stress the effect of the interactions between different individuals, which we also ought to consider. Therefore, a graph of graphs is naturally the best representation of this type of systems, considering these two type of networks, both characterized by its topology and temporal scale and evolution.

$$\frac{\Delta x_{ij}}{\Delta t} = \left(r_{ij} x_{ij} \left(1 - \frac{x_{ij}}{K_{ij}}\right) + \sum_{k \neq j} s_{kj} x_{ij} x_{ik} + \sum_{l \neq i} w_{li} x_{ij} x_{lj} \right) \left(1 - \frac{x_{ij}}{C_i}\right) \quad (2)$$

Equation (2), besides a logistic self-growing term, considers the effect of the network of individuals and the effect of the inner network of variables for each single individual. Furthermore, we have introduced two adjacencies matrices concerning the intensities of individuals influence and the intensity of variables influence. To start with a simpler system we focus on the system described by Equation (1). We aim to prove the connection between the topology of a network and its dynamics, described by a system of coupled non-linear differential equations. The main contribution is establishing a direct correlation of certain centrality measures and the optimal performance. Katz centrality or alpha centrality can be rewritten as the solution of one of the stable solutions of the dynamic system as long as certain conditions hold.

The stability of the system depends on both the topology and the dynamics. But, how general is this result? We want to study whether the effect of time in time-dependent networks allow us to stablish a similar connection between performance and centrality measures as well as allowing more freedom on parameters.

The relation of centrality measures and performance may lead us to predict the best achievements on the long run by just seeking the best configuration according to the centrality. However, when we relax some of the constrains the correlation with Katz centrality is no longer valid. We thus introduce a new centrality measure which takes into account not only topology but dynamics. This new centrality correlates with the new stable solutions.

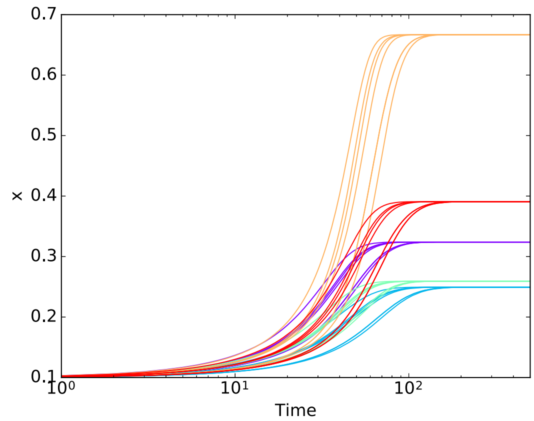

Figure 1: Temporal evolution of performance for 7 individuals and 5 inner variables

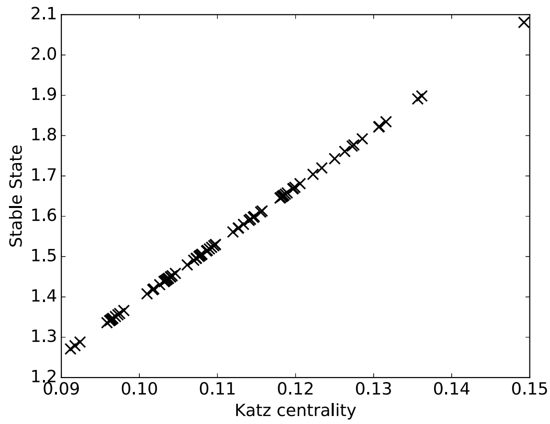

Figure 2: Stable state values as a function of the Katz centrality of the nodes, considering a random network of 80 nodes linked by 180 edges

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Characterization of human mobility patterns when wandering in an exhibition room

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The study of human mobility in the context of complex systems science has gained popularity over the last years [1] and has a wide range of applications, from epidemic spreading to the inference of census data in third world countries [2]. Recently, there has been a surge in the number of data sets related to human mobility thanks to the availability of massive digital traces of human whereabouts and the development of mobile GPS technology.

We developed a public experiment of human mobility with the collaboration of a cultural center of the city. The movement of the visitors in an exhibition room of the *CCCB* in Barcelona was tracked by six infrared depth camera sensors in order to study their movement patterns. The geometry of the room is shown in Fig. 1. In its center there is a short wall section that divides the room in two main spaces. The entrance is at the right of the room and the exit at the left, both closer to the upper space than to the lower one. The six cameras were placed on shelves on the central wall section, three on each side, with a combined field of view covering a wide extent of the rooms floor surface. Those cameras determine visitors positions in the room at any given time and track their movements through it. Furthermore, the cameras are able to single out the positions of a particular individual and keep track of the movement of each of them simultaneously. The uniqueness of this data set lies on both the location studied and on the actual amount of data collected. Indeed, we were provided with camera acquired data spanning four consecutive months (almost the actual time extent of the exhibition) and we estimate that, during this period, around 15000 people visited the exhibition.

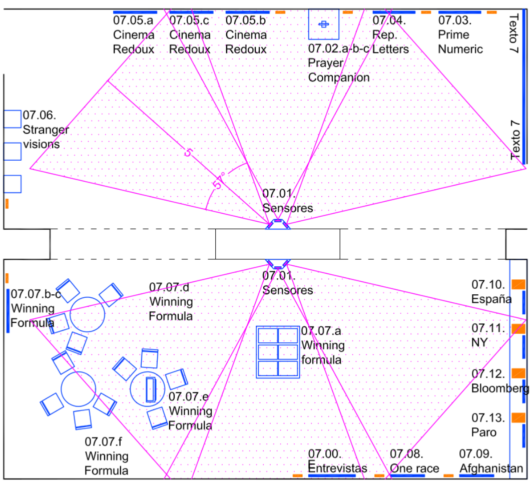

Figure 1: **Schematics of the room under study:** the field of view of each of the cameras is marked in purple and the exhibition objects are marked in blue.

We attempt to separate the data points of each visitor into two different classes. Stopped points, where the visitor is not moving, mostly correspond to the visitor watching one of the exhibition objects or points of attraction. Moving points are those where the visitor is moving from a point of attraction to another. Stopped points (see Fig. 2) are detected with a simple algorithm based on the distance between two consecutive data points [3]. The stopping statistics allow us to establish different characteristic stopping times, associated to diverse levels of attention of the visitor in front of an exhibition object, as well as the stopping patterns. From moving points, we compute the orientation of the trajectories, from which we can infer the preferred direction of exploration of the room, ie if a visitor is more likely to go left or right when they enter the room, and how many visitors leave the room without exploring a half of it.

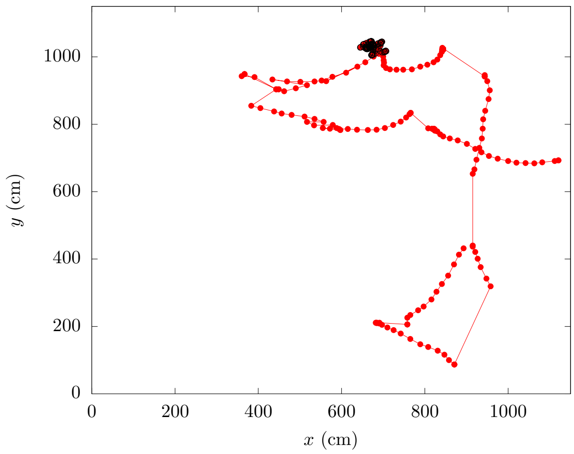

Figure 2: **Example of an individual trajectory in the exhibition room:** the origin is placed at the lower left corner of the room and stopped points are marked in black.

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Unveiling signatures of interdecadal climate changes by Hilbert analysis

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A recent study demonstrated that, in a class of networks of oscillators, the optimal network reconstruction from dynamics is obtained when the similarity analysis is performed not on the original dynamical time series, but on transformed series obtained by Hilbert transform. [1] That motivated us to use Hilbert transform to study another kind of (in a broad sense) "oscillating" series, such as the series of temperature. Actually, we found that Hilbert analysis of SAT (Surface Air Temperature) time series uncovers meaningful information about climate and is therefore a promising tool for the study of other climatological variables. [2]

In this work we analysed a large dataset of SAT series, performing Hilbert transform and further analysis with the goal of finding signs of climate change during the analysed period. We used the publicly available ERA-Interim dataset, containing reanalysis data. [3] In particular, we worked on daily SAT time series, from year 1979 to 2015, in 16380 points arranged over a regular grid on the Earth surface. From each SAT time series we calculate the anomaly series and also, by using the Hilbert transform, we calculate the instantaneous amplitude and instantaneous frequency series.

Our first approach is to calculate the relative variation: the difference between the average value on the last 10 years and the average value on the first 10 years, divided by the average value over all the analysed period. We did this calculations on our transformed series: frequency and amplitude, both with average values and standard deviation values. Furthermore, to have a comparison with an already known analysis methods, we did these same calculations on the anomaly series. We plotted these results as maps, where the colour of each site indicates the value of its relative variation. To give some examples, in Fig. 1 we report the map of average frequency during the first 10 years, in Fig. 2 the same map but during the last 10 years and in Fig. 3 the map of relative variation of frequency average between the two cases.

Finally, to gain insight in the interpretation of our results over real SAT data, we generated synthetic sinusoidal series with various levels of additive noise. By applying Hilbert analysis to the synthetic data, we uncovered a clear trend between mean amplitude and mean frequency: as the noise level grows, the amplitude increases while the frequency decreases.

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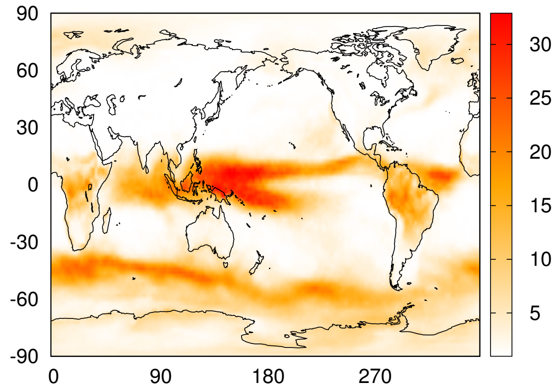

Figure 1: Average frequency during the first 10 years.

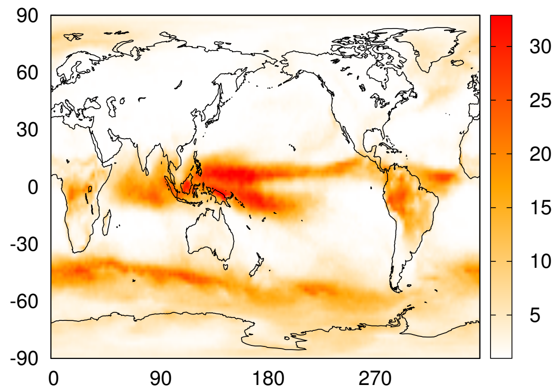

Figure 2: Average frequency during the last 10 years.

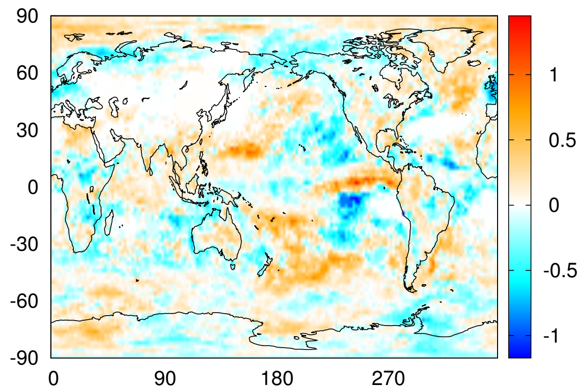

Figure 3: Relative variation of frequency average over the analysed period.