VIII GEFENOL Summer School on Statistical Physics of Complex Systems

IFISC, Palma de Mallorca, July 2-13, 2018

Poster abstracts

Alejandro Alés

Anomalous scaling in discrete growth models

A. Alés[1], J.M. López[2], and D. Pazó[2]

[1]Instituto de Física de Mar del Plata, IFIMAR, Universidad de Mar del Plata-CONICET, República Argentina

[2] IFCA (U. Cantabria-CSIC), Santander, Spain

Abstract: Many and varied phenomena of surface growth have been modeled through discrete systems and it has been possible to find their associated critical exponents. This has classified growing surfaces into certain classes of universality. A particular case is the ballistic deposition model, studied since the 60s of the last century; when stimulated with white noise, its critical behavior falls on the universality given by the KPZ equation. In contrast, when the noise has a temporal correlation this gives rise to the modification of the critical exponents and the formation of facets, which require a new spectral roughness exponent (within the so-called generic dynamic scaling) to be able to characterize the roughness scaling of the obtained surface. We have studied and characterized this exponent, comparing with the results obtained from the continuous KPZ model.

Itay Azizi

Composition, morphology, and growth of clusters in a gas of particles with random interactions

Itay Azizi, and Yitzhak Rabin

Physics Department, Bar-Ilan University, Ramat-Gan, Israel

Abstract: We use Langevin dynamics simulations to study the growth kinetics and the steady-state properties of condensed clusters in a dilute two-dimensional system of particles that are all different (APD) in the sense that each particle is characterized by a randomly chosen interaction parameter. The growth exponents, the transition temperatures, and the steady-state properties of the clusters and of the surrounding gas phase are obtained and compared with those of one-component systems. We investigate the fractionation phenomenon, i.e., how particles of different identities are distributed between the coexisting mother (gas) and daughter (clusters) phases. We study the local organization of particles inside clusters, according to their identity—neighbourhood identity ordering (NIO)—and compare the results with those of previous studies of NIO in dense APD systems.

Reference: The Journal of Chemical Physics **148**, 104304 (2018)

Ernesto Berrios

Multi-drug resistance in bacteria: theoretical and numerical approaches

Ernesto Berrios-Caro, Danna Gifford, and Tobias Galla

School of Physics and Astronomy, The University of Manchester

Abstract: A theoretical and numerical study is presented of multi-drug resistance (MDR) in bacteria, supported by experiments of Escherichia coli (str. K-12 substr. BW25113), submitted to a combination therapy of two antibiotics. Using simple numerical simulations based on binomial probability distributions, we can predict the temporal evolution of bacteria which have developed MDR to one or two antibiotics (single and double resistant bacteria, respectively), under different drug concentrations applied. Further, with the initial condition of no resistant bacteria at the therapy initiation, we can estimate the probability of single and double resistant bacteria appearance, as a function of time. This probability has been verified numerically. Moreover, including a hypermutator derivative, i.e., bacteria with higher mutation rates, we study the dependence of single and double resistant bacteria with the initial proportion of hypermutators. Partial results show good agreement with experimental data.

Davide Botto

Dynamical transition in TASEP with Langmuir kinetics: mean-field theory

D. Botto[1], A. Pelizzola[1], M. Pretti[2], and M. Zamparo[3] (Politecnico di Torino)

[1]Politecnico di Torino, INFN Torino

[2] Politecnico di Torino; CNR-ISC

[3] Politecnico di Torino

Abstract: Working within the mean-field framework, we study the dynamical transition in the Totally Asymmetric Simple Exclusion Process with open boundaries. This phenomenon is signalled by a singularity in the slowest relaxation rate, that is the smallest eigenvalue of the relaxation matrix. In the high-density phase, at a critical value of the injection rate, such eigenvalue becomes independent of this parameter, the same holds in low-density at a critical value of the extraction rate due to the particle-hole symmetry. This behavior does not coincide with any static transition related to the steady state. We provide rigorous bounds for the slowest relaxation rate that become tight in the infinite size limit. We generalize these results to the TASEP with Langmuir kinetics, where particles can also attach to an empty site and detach from an occupied one at given rates. We restrict the analysis to the symmetric case of equal binding/unbinding rates and show that a dynamical transition occurs in this case as well.

References:

[1] de Gier J and Essler F H L 2005 Phys. Rev. Lett. **95**, 240601.

[2] de Gier J and Essler F H L 2008 J. Phys. A: Math. Theor. **41**, 485002.

[3] Pelizzola A and Pretti M 2017 Eur. Phys. J. B **90**, 183.

[4] Parmeggiani A, Franosch T and Frey E 2004 Phys. Rev. E **70**,046101.

Jorge Calero Sanz

On a graph-theoretical structure of real numbers

Jorge Calero[1], Bartolo Luque[1], and Lucas Lacasa[2]

[1]Department of Applied Mathematics and Statistics, EIAE, Technical University of Madrid

[2]School of Mathematical Sciences, Queen Mary University of London

Abstract: In this work, we study properties of real numbers through a set of graphs named Farey graphs, which we show are in bijection with real numbers in [0, 1]. The Farey graphs can be navigated by an operator R. This operator induces a dynamics and we make a classification of dynamical attractors (fixed points, periodic or aperiodic orbits and chaos) which has a correspondence in the real numbers. Furthermore, we can define an entropy on Farey graphs, and its maximization connects with the previous dynamical classification.

Jan Chołoniewski

Modelling of temporal fluctuation scaling in online news with independent cascade model

Jan Chołoniewski[1], Julian Sienkiewicz[1], Gregor Leban[2], and Janusz Hołyst[1]

[1]Faculty of Physics, Warsaw University of Technology, Warsaw, Poland

[2]Artificial Intelligence Laboratory, Jožef Stefan Institute, Ljubljana, Slovenia.

Abstract: An abundance of online news outlets enables a large scale statistical analyses of news circulation. The EventRegistry (www.eventregistry.org, the global media monitor) not only aggregates articles from over 30,000 sources in 15 languages but extracts semantic information about mentioned entities and concepts. Our results indicate that a number of news items mentioning given keyword published by observed news sources follows the Temporal Fluctuation Scaling law (TFS) with different regimes for three timescales (below 15 mins, 15 mins - 1 day, over 1 day). The TFS exponents provides an insight about a temporal synchronization of the news outlets activity indicating that the correlations are present in the intermediary and the large timescales. We show that it is possible to model the observed fluctuation scaling using the independent cascade model (IDC). The IDC is an information propagation model similar to SIR with the difference that it can be run on a directed network with heterogeneous edge weights. Network of content correlations of the news outlets has been recovered with natural language processing methods and the Leydesdorff's fractional counting approach, and used as one of media for the numerical experiments.The simulations of IDC in tested network models (extracted network, random graph, Barabasi-Albert) indicate TFS with a trivial exponent (alpha=0.5). Introducing a time-varying parameter controlling a news item popularity in each model macrostep allowed us to obtain TFS with exponents similar to those observed in the empirical data.

Rafael Diaz

Improving randomness characterization through Bayesian model selection

Rafael Díaz Hernández Rojas[1], Aldo Solí[2], Alí Angulo Martínez[2], Alfred B. U'Ren[2], Jorge G. Hirsch[2], Isaac Pérez Castillo[2], Matteo Marsili[3]

[1] Sapienza Università di Roma

[2] UNAM, Mexico

[3] ICTP, Trieste

Abstract: Random number generation plays an essential role in technology with important applications in areas ranging from cryptography to Monte Carlo methods, and other probabilistic algorithms. All such applications require high-quality sources of random numbers, yet effective methods for assessing whether a source produce truly random sequences are still missing. Current methods either do not rely on a formal description of randomness (NIST test suite) on the one hand, or are inapplicable in principle (the characterization derived from the Algorithmic Theory of Information), on the other, for they require testing all the possible computer programs that could produce the sequence to be analysed. Here we present a rigorous method that overcomes these problems based on Bayesian model selection. We derive analytic expressions for a model's likelihood which is then used to compute its posterior distribution. Our method proves to be more rigorous than NIST's suite and Borel-Normality criterion and its implementation is straightforward. We applied our method to an experimental device based on the process of spontaneous parametric downconversion to confirm it behaves as a genuine quantum random number generator. As our approach relies on Bayesian inference our scheme transcends individual sequence analysis, leading to a characterization of the source itself.

Enrico Fengler

Self-organized noise resistance in networks of chemical oscillators with spike timing-dependent coupling weights

Enrico Fengler, Jan Frederik Totz and Harald Engel

Institut für Theoretische Physik, Technical University Berlin, Berlin, Germany

Abstract: Recent work has shown that applying noise on networks of nonlinear oscillators can increase their level of synchronization. This, on the first glance, counterintuitive behavior was observed in numerical simulations with networks of noisy phase- and relaxation oscillators. The key is to allow for a time-dependent link weight evolution, that implements a form of Hebbian learning via spike timing-dependent plasticity. This forces the network to increase its coupling dynamically in response to larger noise intensity. However, there exists an optimal noise level, where the coupling strength and the synchronization level attain a maximum. These findings are of relevance to the treatment of neurological impairments such as Parkinson and Tinnitus [1-3]. We have experimentally validated this self-organized noise resistance in large populations of neuromorphic chemical oscillators. Beyond this finding, our experimental setup allows for further networks of relaxation oscillators with desired distributions of natural frequencies, phase response curves, network topology and time-dependent coupling weights [4-6].

References

[1] O. V. Popovych, S. Yanchuk, P. Tass, "Self-organized noise resistance of oscillatory neural networks with spike timing-dependent plasticity", Sci. Rep. **3** (2013)

[2] L. Self, Synchronization of chemical oscillators in the presence of noise", BSc-Thesis, TU-Berlin, (2017)

[3] D. Hebb "The organization of behavior. A neuropsychological theory" New York: Wiley & Sons (1949)

[4] J. F. Totz, J. Rode, M.R. Tinsley, K. Showalter, H. Engel, "Spiral wave chimera states in large populations of coupled chemical oscillators", Nat. Phys. **14** (2017).

[5] J. F. Totz et al. Phase-lag synchronization in networks of coupled chemical oscillators, Phys. Rev. E **92**, 022819 (2015).

[6] J. F. Totz, "Synchronization and Waves in Confined Complex Media", Springer-Thesis (2018), in press

Antonio Fernández Peralta

Analytical and numerical study of the non-linear noisy voter model on complex networks

A. F. Peralta[1], A. Carro[2], M. San Miguel[1], and R. Toral[1]

[1]IFISC (UIB-CSIC), Palma de Mallorca, Spain

[2] Institute for New Economic Thinking at the Oxford Martin School, University of Oxford, Oxford, UK

Abstract: We study the noisy voter model using a specific non-linear dependence of the rates that takes into account collective interaction between individuals. The resulting model is solved exactly under the all-to-all coupling configuration and approximately in some random networks environments. In the all-to-all setup we find that the non-linear interactions induce "bona fide" phase transitions that, contrarily to the linear version of the model, survive in the thermodynamic limit. The main effect of the complex network is to shift the transition lines and modify the finite-size dependence, a modification that can be captured with the introduction of an effective system size that decreases with the degree heterogeneity of the network. A non-trivial finite-size dependence of the moments of the probability distribution is derived from our treatment, nevertheless mean-field exponents are obtained in the thermodynamic limit. These theoretical predictions are well confirmed by numerical simulations of the stochastic process.

Harrison Hartle

Projective vertex-removal procedures for sparse, exchangeable random graph ensembles

Harrison Hartle, Dmitri Krioukov, and Pim van der Hoorn

Network Science Institute, Northeastern University, Boston MA, USA

Abstract: We construct and study vertex-removal schemes for ensembles of random networks, primarily in the context of a model of random directed acyclic graphs constructed by connection of an average of N vertices whose coordinates are in causal contact when sprinkled Poissonianly into a de Sitter spacetime, with the intent to be left with an ensemble of smaller-sized graphs whose probability distribution matches that of the same model but of smaller expected size N'<N. In particular, we seek a resolution to the difficulty of combining into a single random network model the properties of exchangeability (isomorphism symmetry of the graph probability distribution), sparsity (a fraction of edges relative to the total possible number vanishing on expectation in the limit of large graphs), and projectivity (the existence (and in our case, construction) of a vertex-removal scheme (a subgraph identification procedure) resulting in a graph ensemble equivalent to that produced by the same network model at the smaller (subgraph) size).

Linard Hoessly

Mean field repulsive Kuramoto models: Phase locking and spatial signs

Corina Ciobotaru, Linard Hoessly, Christian Mazza, and Xavier Richard

University of Fribourg, Fribourg, Switzerland

Abstract: Self-synchronization in populations of oscillatory units appears naturally in neurosciences and is often described by the Kuramoto model. We study a repulsive mean-field Kuramoto model that describes the time evolution of n points on the unit circle, which are transformed into incoherent phase-locked states. Such systems can be reduced to a three-dimensional system, whose mathematical structure is strongly related to hyperbolic geometry. The orbits of the Kuramoto dynamical system are then described by a flow of Möbius transformations. We show this underlying dynamic performs statistical inference by computing M-estimates of scatter matrices and data processing: the initial configuration of the n points is transformed by the dynamic into a limiting phase-locked state that surprisingly equals the spatial signs from nonparametric statistics.

Arkadiusz Jedrzejewski

Pair approximation for the q-voter model with independence on complex networks

Arkadiusz Jedrzejewski

Department of Theoretical Physics, Wrocław University of Science and Technology, Wrocław, Poland

Abstract: We investigate q-voter model with stochastic noise arising from independence on complex networks. Using the pair approximation, we provide comprehensive, mathematical description of its behavior and derive formula for the critical point. The analytical results are validated by carrying out Monte Carlo experiments. The pair approximation prediction exhibits substantial agreement with simulations, especially for networks with weak clustering and large average degree. Nonetheless, for the average degree close to q, some discrepancies originate. It is the first time the presented approach has been applied to the nonlinear voter dynamics with noise. Up till now, the analytical results have been obtained only for a complete graph. We show that in the limiting case the prediction of pair approximation coincides with the known solution on a fully connected network. In the work, we were mainly interested in the time evolution and stationary values of

the up-spin concentration. It turns out that the qualitative behavior of a system on studied weakly clustered complex networks is similar as on a complete graph and depends on the model parameter q, that is to say, for $q < 6$, the system undergoes continuous phase transitions, whereas for $q > 5$, phase transitions are discontinuous. However, the quantitative behavior also depends on the average node degree of an underlying network. What is interesting is that networks which have very different arrangements of edges and node degree distributions lead to the same results when they have the same value of the average node degree.

Reference:

A. Jedrzejewski, Phys. Rev. E **95**, 012307 (2017).

Stefan Landmann

Phase transitions in resource-competition models: an alternative approach

Stefan Landmann and Andreas Engel,

Carl von Ossietzky Universität Oldenburg, Bremen, Germany

Abstract: Complex ecosystems generally consist of a large number of different species which in turn utilize a large number of resources. While a lot of work has been done on models comprising only a few species and resources it is not clear to which extent these results are applicable to large systems. Recent work has demonstrated that methods from statistical mechanics can be successfully applied to systems consisting of an infinite number of species and resources. Within this scope, Tikhonov and Monasson [1] showed that a high-dimensional realization of MacArthurs resource competition model exhibits a phase transition from a 'vulnerable' phase to a 'shielded' phase in which the species collectively shield themselves against disturbances of the environment. Here, we provide an alternative approach to the same problem and show that the phase transition can be understood by considering the space of positive solutions of large random linear equation systems. The problem is tackled using methods from statistical mechanics revealing that for infinitely large systems a phase transition in the solution space exists which coincides with the transition observed in the resource competition model. This reveals that the transition is a generic feature surprisingly independent of the precise dynamics of the model.

References:

[1] Mikhail Tikhonov and Remi Monasson. “Collective Phase in Resource Competition in a Highly Diverse Ecosystem”. In: Phys. Rev. Lett.**118** (4 Jan.2017), p. 048103.

Felipe Le Vot

Mixing properties of diffusion as a tool to describe irreversible coalescence on a 1d growing domain

F. Le Vot, S. B. Yuste, and E. Abad,

Dpto. de Física. Grupo de investigación SPhynX. Universidad de Extremadura, Badajoz, Spain

Abstract: Diffusion-controlled processes in growing domains are relevant for many natural phenomena, notably in Biology. In general, mixing properties are strongly affected by the domain growth, resulting in a drastic modification of the behavior with respect to the case of a static domain. We will present an exact solution for the case of encounter-controlled coalescence reaction and explain the behavior by means of the PDF for the interparticle-distance.

References:

[1] S. B. Yuste, E. Abad, and C. Escudero, Phys. Rev. E, 94 032118 (2016).

[2] F. Le Vot, E. Abad, and S. B. Yuste, Phys. Rev. E, 96 032117 (2017).

[3]F. Le Vot, C. Escudero, E. Abad, and S.B. Yuste, arXiv:1804.03213 [cond-mat.stat-mech] (2018).

Nataniel Martinez

A nonequilibrium-potential approach to competition in neural populations

N. Martínez[1], J.I. Deza[1], R.R. Deza[1], J.F. Mejías[2], and H.S. Wio[3]

[1]IFIMAR (UNMdP-CONICET), Mar del Plata, Argentina.

[2]Swammerdam Inst. Amsterdam Univ., the Netherlands.

[3]IFISC (UIB-CSIC), Palma de Mallorca, Spain

Abstract: Energy landscapes are a useful aid for the understanding of dynamical systems, and a valuable tool for their analysis. Here we derive a global Lyapunov function for a broad class of rate models of neural networks, which provides an energy landscape without any symmetry constraint. This newly obtained "nonequilibrium potential" (NEP) predicts with high accuracy the outcomes of the dynamics in the globally stable cases studied here. Common features of the models in this class are bistability - with implications for working memory and slow neural oscillations - and "population burst", also relevant in neuroscience. Instead,

limit cycles are not found. Their nonexistence can be proven by resorting to the Bendixson-Dulac theorem, at least when the NEP remains positive and in the (also generic) singular limit of these models. Our finding opens the door to the use of generic rate models in gradient descent methods, a widely employed technique in deep learning and artificial neural network training.

Mattia Mazzoli

Equilibria, information and frustration in heterogeneous network games with conflicting preferences

M. Mazzoli[1,2] and A Sánchez[3,4,5]

[1]IFISC (UIB-CSIC), Palma de Mallorca, Spain

[2] Dipartimento de Fisica, Università degli Studi di Torino, Torino, Italy.

[3] Grupo Interdisciplinar de Sistemas Complejos (GISC) Dpt. Matemáticas and Institute UC3M-BS for Financial Big Data, Universidad Carlos III de Madrid, Leganes, Spain.

[4] Instituto de Biocomputación y Física de Sistemas Complejos (BIFI), Univ. Zaragoza, Zaragoza, Spain.

[5] Unidad Mixta Interdisciplinar de Comportamiento y Complejidad Social (UMICCS) UC3M-UV-UZ,

Abstract: Interactions between people are the basis on which the structure of our society arises as a complex system and, at the same time, are the starting point of any physical description of it. In the last few years, much theoretical research has addressed this issue by combining the physics of complex networks with a description of interactions in terms of evolutionary game theory. We here take this research a step further by introducing a most salient societal factor such as the individuals' preferences, a characteristic that is key to understanding much of the social phenomenology these days. We consider a heterogeneous, agent-based model in which agents interact strategically with their neighbors, but their preferences and payoffs for the possible actions differ. We study how such a heterogeneous network behaves under evolutionary dynamics and different strategic interactions, namely coordination games and best shot games. With this model we study the emergence of the equilibria predicted analytically in random graphs under best response dynamics, and we extend this test to unexplored contexts like proportional imitation and scale free networks. We show that some theoretically predicted equilibria do not arise in simulations with incomplete information, and we demonstrate the importance of the graph topology and the payoff function parameters for some games. Finally, we discuss our results with the available experimental evidence on coordination games, showing that our model agrees better with the experiment than standard economic theories, and draw hints as to how to maximize social efficiency in situations of conflicting preferences.

Katarzyna Oles

How long does it take to recovery? Power spectrum analysis of EEG signals during experiment with sleep restriction.

Katarzyna Oles and M. Smoluchowski

Institute of Physics, Jagiellonian University, Krakow, Poland

Abstract: The duration of sleep, wakefulness and dynamic changes in human performance are correla- ted by neural and genetic mechanisms underlying mutual interactions. Sleep deprivation and chronic restriction of sleep cause perturbations of circadian rhythmicity and degradation of waking alertness as reflected in attention, cognitive efficiency and memory. Neurobehavioral measures demonstrating sleep deprivation or sleep loss allowed us to analyse variations of those measures among healthy adult humans during 21 consecutive days divided into periods of 4 days regular life (a baseline), 10 days of chronic partial sleep deprivation and 7 days of regular (recovery) days. Every day the individuals undergo 30 minutes long Stroop test associated with the simultaneous EEG measurement quantified in resting states with eyes either open or closed. The novel observation is a slow relaxation to the original performance thus predicting that short periods of recovery sleep are insufficient to recover from prolonged periods of sleep restriction. Analysis of the EEG data reveal significant differences between signals during the three different periods, especially in the alpha waves range and can be quantified by patterns of the power spectrum.

Robert Paluch

Fast and accurate detection of spread source in large complex networks

Robert Paluch, Xiaoyan Lu, Krzysztof Suchecki, Bolesław Szymański, and Janusz Hołyst
Faculty of Physics, Warsaw University of Technology

Abstract: Spread over complex networks is a ubiquitous process with increasingly wide applications. Locating spread sources is often important, e.g. finding the patient one in epidemics, or source of rumor spreading in social network. The topic of the source detection is now very popular and many variants of this problem have been studied. However, current methods are too computationally expensive and they can not be use for a quick identification of the propagation source. Here we propose a new detector-based approach in which observers with low quality information (i.e. with large spread encounter times) are ignored and potential sources are selected based on the likelihood gradient from high quality observers. Our Gradient Maximum Likelihood Algorithm (GMLA) has computational complexity $O(\log(N)N^2)$ and is capable to process timely large networks consisting of tens of thousands of nodes. The accuracy of GMLA, which is comparable with other methods, strongly depends on the infection rate and network topology. Indeed, we found that scale-free topology, which facilitates the spread over the network, impede also the detection of the spread source.

Nirmal Punetha

Synchronization in networks of delay-coupled electronic clocks: effects of heterogeneity

Nirmal Punetha[1] and Lucas Wetzel[2]
[1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany
[2] Center for Advancing Electronics Desden, Technische Universität Dresden, Dresden, Germany

Abstract: The production process of CMOS integrated electronic circuitry inherently leads to large heterogeneities on the level of the electronic components. For electronic clocks, e.g., that means heterogeneity in the intrinsic frequencies, in transmission line and feedback delays, as well as loop filter cut-off frequencies. Here we study the effects of such heterogeneity on the dynamical properties of networks of mutually delay-coupled electronic oscillators, so called phase-locked loops. This is essential to enable self-organized synchronization as a novel concept for this technology. Using a phase model description, we show how the detuning of intrinsic frequencies and differences in the delay times associated to signal transmission lines as well as filtering change the synchronized states and their stability in such systems. The effects of the different types of delay times are discussed and we show how multistability and the frequency of synchronized states depends on the interplay of transmission line and feedback delay. The understanding of the consequences of such heterogeneity on the system dynamics is key to enable this synchronization approach for industrial application.

Domènec Ruiz I Batet

Asymptotic analysis of kinetic Cucker-Smale models

Domènec Ruiz
Universitat de Barcelona

Abstract: The Cucker-Smale model is an apparently simple model in which flocking can be observed. Agents arrange their velocities according to others velocities ending up, under specific conditions, to a consensus. Here it will be showed different results of these specific conditions for different variations of this model.

Y.Choi and J.Haskovec. Cucker-Smale model with normalized communication weights and time delay.
F.Cucker and S.Smale. Emergent behavior in flocks
F.Cucker and S.Smale On mathematics of emergence
S-Y Ha E.Tadmor. From particle to kinetic and hydrodynamic descriptions of flocking
B.Piccoli, F.Rossi, E.Trélat. Control to flocking of the kinetic Cucker-Smale model
J.A.Cañizo, J.A. Carrillo, J.Rosado, A well-posedness theory in measures for some kinetic models of collective motion

Meghdad Saeedian

Co-evolution of Hieder's Balance dynamics and the Susceptible-Infected model

M. Saeedian[1] 1 , N. Azimi-Tafreshi[2], G. R. Jafari[3], and J. Kertesz[4,5]

[1] IFISC (UIB-CSIC), Palma de Mallorca, Spain

[2] Physics Department, Institute for Advanced Studies in Basic Sciences, Zanjan, Iran

[3] Department of Physics, Shahid Beheshti University, G.C., Evin, Tehran, Iran

[4] Center for Network Science, Central European University, Budapest, Hungary

[5] Institute of Physics, Budapest University of Technology and Economics, Budapest, Hungary

Abstract: Most studies of disease spreading consider the underlying social network as obtained without the contagion, though epidemic influences people's willingness to contact others: A "friendly" contact may be turned to "unfriendly" to avoid infection. We study the susceptible-infected (SI) disease spreading model on signed networks, in which each edge is associated with a positive or negative sign representing the friendly or unfriendly relation between its end nodes. In a signed network, according to Heider's theory, edge signs evolve such that finally a state of structural balance is achieved, corresponding to no frustration in physics terms. However, the danger of infection affects the evolution of its edge signs. To describe the coupled problem of the sign evolution and disease spreading, we generalize the notion of structural balance by taking into account the state of the nodes. We introduce an energy function and carry out Monte-Carlo simulations on complete networks to test the energy landscape, where we find local minima corresponding to the so-called jammed states. We study the effect of the ratio of initial friendly to unfriendly connections on the propagation of disease. The steady state can be balanced or a jammed state such that a coexistence occurs between susceptible and infected nodes in the system.

Giacomo Scettri

NetWars- A Board Game on Network Theory

Giacomo Scettri

[1]IFISC (UIB-CSIC), Palma de Mallorca, Spain

Abstract: Can we teach network theory through a board game? To explore this opportunity, we designed a board game where the basic concepts of network theory, from nodes and links to degree distribution and centrality measures are implemented. These abstract ideas are here rendered more accessible through a physical medium. In particular, players will have to design commercial routes in the Mediterranean Sea, spreading their economy across all the nodes of a trading network, which will be created as the interaction among the sea lanes of all the players develops. Here are illustrated the main rules and concepts implemented in the game and the first results obtained in elementary schools.

Laura Sidhom

Thompson Sampling as a Game Learning Algorithm

Laura Sidhom

Complex Systems and Statistical Physics group, The University of Manchester

Abstract: Thompson sampling was developed for the multi-armed bandit problem, I have explored the use of Thompson sampling as a Game learning algorithm for 2-player 2-strategy games. I have found that players converge to playing a Nash equilibrium for games with pure-strategy Nah equilibria only. The algorithm can be modified by using memory loss and batch-learning. This results in the convergence to mixed-strategy Nash equilibria.

Michele Tizzani

Epidemics Spreading on temporal networks with memory effects

M. Tizzani, S.Lenti, E.Ubaldi, A.Vezzani, C.Castellano, R.Burioni

Università degli Sudi di Parma, INFN, Università degli studi di Roma La Sapienza, ISI

Abstract: Activity Driven models are an interesting class of temporal networks. They are characterized by assigning to each node an activity, easily measured from extensive datasets, that represents the number of activations per time of a node. Strong ties and rules for links formations in activity driven networks can be encoded in a memory function that represent the probability, to establish a new link. The memory function has been extensively measured from real datasets and it has been shown to reproduce well the asymptotic evolution of several real temporal networks. In activity driven networks without memory effects, epidemic models can be analytically studied due to the fully mean field nature of the model. Here, we perform a detailed analysis of the SIS and SIR models on activity driven networks with memory. We show that, in general, memory effects lower the epidemic threshold, promoting the infection spreading. Interestingly, we also show that memory induces non ergodic effects in the dynamics: the value of the epidemic threshold

strongly depends on the starting time of the epidemic spreading, in particular it depends on the average value of the initial degree. Despite this complex dynamical behavior, we are able to provide an analytic description of the epidemic thresholds in the case of large initial time, i.e. when the epidemics starts at a very large value of the average initial degree. In this case, the creation of new connections becomes very unlikely so that the epidemics evolve on an effective static network. Moreover this static network is characterized by a large connectivity so that a suitable site dependent mean field approach can be applied as well. A surprising effect is that strong memory, the value of the threshold tends to the memoryless system. This is due to the fact that, in the effective static networks, large activity nodes are also the most connected and this amplifies the effects of the activity fluctuations. In this framework, degree fluctuations vanishes when increasing the memory parameter.

Joanna Toruniewska

New constant of motion for coevolving voter model

Joanna Toruniewska[1], Krzysztof Kułakowski[2], Krzystof Suchecki[1], and Janusz A. Hołyst[1]
[1] Warsaw University of Technology,
[2] AGH University of Science and Technology

Abstract: In the coevolving voter model [1] a topology of the network changes in response to the voter dynamics on the network. In detail, nodes can change their state and links can rewire in order to connect nodes of the same state. We consider the process of reaching the final state in this model. We treat mean degree of nodes in different states as separate variables, which do not have to be equal. This allows to discuss the magnetization of nodes and the magnetization of links as potentially independent variables. Our studies shows that in the active phase mean value of magnetization of nodes and links tend to the same value. Mean field calculation indicate that these two magnetizations are coupled if their linear combination is a statistical constant of motion. Obtained results were confirmed by numerical simulations.

The work was partially supported as RENOIR Project by the European Union Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 691152.

Reference: [1] F. Vazquez, V. M. Eguíluz, M. San Miguel, Phys. Rev. Lett. **100**, 108702 (2008).

Pietro Verzelli

Edge of Chaos in binary Echo State Networks

Pietro Verzelli[1], Lorenzo Livi[2], and Cesare Alippi[1,3]
[1]Università della Svizzera Italiana, Lugano, Switzerland
[2] University of Exeter, Exeter, UK.
[3] Dipartimento di Elettronica, Politecnico di Milano, Milano, Italy.

Abstract: It is a widely accepted fact that the computational capability of recurrent neural networks (RNNs) is maximized on the so-called “Edge of Chaos (EoC)”. Once the network operates in this configuration, it performs efficiently on a specific application both in terms of low prediction error and high memory capacity. Since the behavior of recurrent networks is strongly influenced by the particular input signal driving the dynamics, a universal method for determining the EoC is still missing. In this work, we propose a simplified RNN in which both the weights and the the states can only assume binary values. Such networks show a very sharp transition from a frozen regime to the chaotic one and their EoC can be derived theoretically in the autonomous case. We then discuss how noise can change the shape of the EoC region and discuss how these networks can be used to elaborate a (continuous) signal.

Maximilian Voit

A hierarchy of heteroclinic cycles

Maximilian Voit and Hildegard Meyer-Ortmanns
Jacobs University Bremen gGmbH, Campus Ring 1, 28759 Bremen, Germany

Abstract: Heteroclinic cycles are structures in phase space consisting of saddle equilibria whose stable and unstable manifolds connect them to a topological circle. The saddles need not necessarily be ordinary saddle fixed points but may also take other forms, e.g. limit cycles with saddle-type stability or unstable attractors. However, also heteroclinic cycles themselves can possess stability properties of the saddle type. Here we present a hierarchical heteroclinic network, i.e. a "large" heteroclinic cycle whose vertices are "small" heteroclinic cycles.We demonstrate its construction originating from the required topology and analyze the two emerging time scales, associated with the large and small heteroclinic cycles. Furthermore, we study the influence of additive noise and show how changing the noise strength acts similarly to the tuning of another bifurcation parameter, both causing the collapse of the lower hierarchy levels.