1. Presentation by: Sergio Faci-Lázaro

Poster title: **Synchronization and robustness in neuronal networks**

Authors: Sergio Faci-Lázaro and Jesús Gómez-Gardeñes from U. Zaragoza and GOTHAM lab, BIFI; and Jordi Soriano from U. Barcelona

Abstract
According to Graph Theory, complex networks can be defined as a set of nodes, V, and a set of edges (or links), L[1]. In our case, neurons will be the nodes; whereas the links will be their synaptic connections. These networks are represented with an adjacency matrix, A. This networks are created following a generalization of the method put forward by Orlandi et al. [2], which that emulates the growth of a biological culture of neurons over a surface; and to simulate their dynamics, we will use the Izhikevich model [3], which describes de behavior of a neuron through its membrane potential, inhibitory currents and the external stimulation that gets as an input from the synaptic pulses of its neighboring neurons and background noise. To describe the transition to synchronization, we will mainly study the avalanches of coherent activity (as defined in [4]). The results we got from these measurements show that there exists a microscopic synchronization regime in absence of macroscopic synchronization. Finally, to test the robustness of our cultures, we put them through failures (removing a random neuron from the culture) and directed attacks (removing a neuron from the culture following a specific criteria) and measured their activity in each experiment. This results showed that there is only a small fraction of our cultures that is fundamental to see coherent activity even though some activity can be observed after this neurons are removed.
[1] M. Newman, Networks: An Introduction (Oxford University Press, Oxford, 2010).
[2] J. Orlandi, J. Soriano, E. Alvarez-Lacalle, S. Teller, and J. Casademunt, Noise focusing and the emergence of coherent activity in neuronal cultures, Nat. Phys. 9, 582 (2013).
[3] E. M. Izhikevich, Simple model of spiking neurons, IEEE Trans. Neural Netw. 14, 1569 (2003).
[4] J. M. Beggs and D. Plenz, Neuronal avalanches in neocortical circuits, J. Neurosci. 23, 11167 (2003).

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2. Presentation by: Konstantin Anokhin

Poster title: **Cognitome: the theory of neural hypernetwork**

Authors: Konstantin Anokhin NRC "Kurchatov Institute", Lomonosov Moscow State University, Anokhin Institute of Normal Physiology, Moscow

Abstract
Despite a great progress of neuroscience, we still lack a satisfactory theory of higher brain functions. I will suggest a framework for such a theory based on the previous ideas in the Russian neuroscience. Its central notion is a cognitive neural hypernetwork – cognitome. Cognitome is a complete set of all cognitive elements, a memory of a cognitive agent. Despite its enormous complexity, the entire cognitome can be viewed as a cognitive network consisting of vertices – COGs, and edges – LOCs. However, the network theory is restricted only to pairwise interactions and cannot address multilateral relationships between n-objects that associate n-neurons into an emerging cognitive group. Also, it has no formal tools to represent the emergence of new qualitative levels in complex systems, which is necessary to link neuroscience to the cognitive domain. To overcome these limitations, I will propose a hypernetwork theory of cognition. Hypernetwork is a network of hypersimplices. Hypersimplex is an ordered set of vertices with an explicit n-ary relation defined as its apex, which exists at a higher level of representation than its vertices. In multilevel systems, hypersimplices are given names and treated as atomic objects at a higher level of the system. COG is a hypersimplex. At macrolevel it stands for a COGnizance – a unit of knowledge. At microlevel cog stans for COG - Co-Operative Group of neurons which collectively encode a particular element of knowledge. Two cogs can establish connection by being co-allocated into the overlapping neural elements. Such conjoint group of neurons forms LOC – Link of Cogs. LOC is also represented at two levels – as a link between units of knowledge and as a group of neurons with a double cognitive affiliation. I will discuss some

consequences of the proposed theory including the combinatorial cognitive explosion and an emergence of consciousness. Supported by RFBR 17-00-00215 and RSF 19-75-30019.

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3. Presentation by: Ksenia Toropova

Poster title: **Cellular brain resting state networks: global properties and sensitivity to past experience**

Authors: Toropova K., Ivashkina O., Gruzdeva A., Konovalova E., Ivanova A., Ivanitsky A., Anokhin K. – CNCS MSU; NRC KI; IHNA&NPh RAS

Abstract
Resting state network (RSN) is a correlated activity of many neural structures in absence of external stimulation or functional tasks, and it is a fundamental endogenous feature of human and animal brain. The nature of this spontaneous activity remains poorly understood. According to our hypothesis it reflects hidden replay of neural networks of prior experience. We started a project on mouse cellular brain imaging that relates RSNs activity to animal's past experiences. We characterized activity of 104 mouse brain areas and showed that RSNs identified by c-Fos protein were stable and reproducible. c-Fos activity of 42 selected brain areas was further investigated in naive and stressed mice that received post-traumatic stress disorder (PTSD) induction. Using Pearson correlation we reconstructed 7 networks with CCorr varying from 0.6 to 0.9 (inclusive, step=0.05) for naive and PTSD mice and compared experimentally identified networks with model networks (random, scale free and small world) of the same size using clustering, global efficiency and degree distribution. In both groups of mice, clustering was at the level of a random network. These clusters had weak interactions with each other: global efficiency of experimental networks was extremely low. PTSD induction strongly affected RSN activity all over the brain: PTSD RSN network was less clustered and clusters were separated by longer routes than in naive mice. PTSD induction caused global changes in the RSN structure: while in control animals cortical connectivity was high, in PTSD mice subcortical thalamus, striatum and amygdala were most connected. While cingulate and retrosplenial cortices were the main hubs in naive mice, functional connectivity between those areas was lost in PTSD mice, and paraventricular thalamus became a hub. Thus, we showed that experience of stressful event can change resting state network functional connectivity patterns long after the traumatic episode. Supported by RSF 16-15-00300.

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4. Presentation by: David Soriano Paños

Poster title: **Epidemic-risk indicator for the spread of vector-borne diseases**

Authors: David Soriano-Paños and Jesús Gómez-Gardeñes, Department of Condensed Matter Physics, Zaragoza, Spain.

Abstract
Here we propose a new formalism to account for the effects of human mobility on the spread of vector-borne diseases. Relying on metapopulations, we propose a set of Markovian equations which allows us to quantify the density of infected agents with residence in a specific area. To validate our formalism, we perform extensive mechanistic simulations, showing an almost perfect agreement both theoretical and numerical results. Based on this agreement, we derive an analytical expression for the epidemic threshold which enables to capture the critical values of the epidemiological parameters which triggers the onset of epidemics. In this sense, we also obtain an epidemic risk indicator to rank the different patches as a function of their exposure to vector-borne diseases. Finally, we use this indicator to reproduce the spatial distribution of Dengue cases from 2015 to 2016 across the city of Santiago de Cali.

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5. Presentation by: Xavier Ouvrard

Poster title: **Hb-graphs and their applications**

Authors: Xavier Ouvrard (Univ. Geneva / CERN), Jean-Marie le Goff (CERN), Stéphane Marchand-Maillet (Univ. Geneva)

Abstract
Hyperbag-graphs (hb-graphs for short) are families of multisets on a common universe. They extend hypergraphs allowing indivual weighting of the vertices in hyperedge. When coming to natural hb-graphs, this individual weighting is interpretable in term of redundancy of vertices, previously introduced by K. Pearson. Hb-graphs fit for modeling many real datasets. When diffusing by exchange on them, they allow not only the retrieval of main vertices but also of the main hb-edges. We are also using them for modeling adjacency in general hypergraphs. For more information: http://www.infos-informatique.net

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6. Presentation by: Mariia Frolkina

Poster title: **Dynamic probing of cluster structure in complex networks**

Authors: V. Avetisov (1), M. Frolkina (1); 1 - Semenov Institute of Chemical Physics RAS, 119991, Moscow, Russian Federation

Abstract
Propagation of excitation in complex networks, along with its wide applications, is a timely issue. Questions rise like, “Could the propagation be sensitive to topological heterogeneity of complex networks? Could the network topology be specified by the propagation of excitations?” Having these in mind, we propose a dynamic algorithm for highlighting the clustering structure in complex networks. The algorithm is based on the method of the slowing the activity transfer when the activity propagates from the initial core to the network periphery. In clustered networks, the area of contact between clusters typically obstructs the passage of the activity front from one cluster to another. Our algorithm amplifies such limitation and transforms that area into a bottleneck for the propagation, even when the area is saturated with the network links. As a result, the algorithm gives more contrasted picture of limitations caused by the clustered structure. The algorithm can also be used for identifying topologically associating domains in complex networks. This work was partially supported within frameworks of the state task for ICP RAS 0082-2014-0001 (state registration #AAAA-A17-117040610310-6).

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7. Presentation by: Jinha Park

Poster title: **Traveling wave synchronization transitions through metastable state on structured networks**

Authors: Jinha Park and B. Kahng (Seoul National University)

Abstract
Inspired by inhibitory and excitatory neurons in brain, we consider a competing Kuramoto model (c-KM) which assigns two opposite-sign coupling constants $K1 < 0$ and $K2 > 0$ to $1 - p$ and p fractions of nodes, respectively. In our previous paper [J. Park and B. Kahng, Phys. Rev. E 97, 020203(R) (2018)], we obtained a rich phase diagram of this model with uniform intrinsic frequency distribution, including incoherent (IC), π, and traveling wave (TW) phases. We reported a hybrid phase transition occurring through an intermediate metastable π state. This metastable state is characterized by a dynamic flow which remains for a long time within a limited region of phase space bounded by saddles and stable fixed points. Interestingly, intermediate activity states are also noticed from human brain during the consciousness recovery from anesthesia. We extend our study to the case where oscillators locate on structured random networks. Using the heterogeneous mean-field theory, we obtain phase diagrams and transition types which are overall similar to those on the fully connected network. However, numerical simulations on the structured networks produce different results. When the mean degree of the structured networks is small, TW state does not

appear and transition types are different from the predictions of the mean field calculations and simulations. Mean degree can have an additional impact on the emergence of traveling wave and coherence in the competing system on a structured network. Our results suggest that the emergence of TW state from the c-Kuramoto model is sensitive to network structure and connection profile.

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8. Presentation by: Christy Kelly

Poster title: **Self-Assembly of Geometric Space from Random Regular Graphs**

Authors: Christy Kelly(1), Carlo A Trugenberger(2) and Fabio Biancalana(1). 1 Heriot-Watt University. 2 SwissScientific Technologies SA

Abstract
We present a Euclidean quantum gravity model in which random graphs dynamically self-assemble into discrete manifold structures. Concretely, we consider a statistical model driven by a discretisation of the Euclidean Einstein-Hilbert action; contrary to previous approaches based on simplicial complexes and Regge calculus our discretisation is based on the Ollivier curvature, a coarse analogue of the manifold Ricci curvature defined for generic graphs augmented with a canonical metric measure structure. The Ollivier curvature is generally difficult to evaluate due to its definition in terms of optimal transport theory, but we present a new exact expression for the Ollivier curvature in a wide class of relevant graphs purely in terms of the numbers of short cycles at an edge. This result should be of independent intrinsic interest to network theorists. Action minimising configurations prove to be cubic complexes up to defects; there are indications that such defects are dynamically suppressed in the macroscopic limit. Closer examination of a defect free model shows that certain classical configurations have a geometric interpretation and discretely approximate vacuum solutions to the Euclidean Einstein-Hilbert action. Working in a configuration space where the geometric configurations are stable vacua of the theory, we obtain direct numerical evidence for the existence of a continuous phase transition; this makes the model a UV completion of Euclidean Einstein gravity. Notably, this phase transition implies an area-law for the entropy of emerging geometric space. Certain vacua of the theory can be interpreted as baby universes; we find that these configurations appear as stable vacua in a mean field approximation of our model, but are excluded dynamically whenever the action is exact indicating the dynamical stability of geometric space.

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9. Presentation by: Oliver Smith

Poster title: **Cascades on networks with variable node properties**

Authors: Oliver Smith, Reuben O'Dea, Keith Hopcraft, Ettiene Farcot, John Crowe (all University of Nottingham)

Abstract
Cascading failures on flow networks, such as a blackouts in electrical grids, can be catastrophic to their operation. Recent work has shown how various topological properties of networks influence the extent and damage done by a cascade. In this work we focus instead on how node properties influence the cascade dynamics, to ascertain how, for a given network topology, the node properties should be controlled to promote resilience. We consider flow networks whose nodes have the property of being sources, sinks or passive conduits of flow, and assess network resilience as a function of the configuration of these node types. This is motivated by energy micro-grids, whose nodes may variably be net consumers or producers of electricity. We investigate the case where flows are computed using steady state DC power flow equations, and also and an ODE based flow model that incorporates transients. In both flow regimes, the resilience against cascades is shown to have a predictable dependence upon the proportions of sources to sinks, with highest resiliences occurring where the proportions of nodes are equal. These results are interpreted for the operation of micro-grids.

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10. Presentation by: Pitambar Khanra

Poster title: **Explosive synchronization in phase-frustrated multiplex networks**

Authors: Pitambar Khanra, Department of Mathematics, National Institute of Technology, Durgapur 713209, India.

Abstract
We investigate the emergence of first order transition called as explosive synchronization (ES) in phase-frustrated multiplex network. We use an adaptive coupling generated from local order parameter. The key question, we have raised here whether ES can be established in all layers of a multiplex network where as one of the layers may not reveal ES in the absence of inter-layer connection. We study the transition point in adaptive Sakaguchi-Kuramoto model on Erdös-Rényi (ER) and uncorrelated scale-free (SF) networks. We investigate the backward transition point of synchronization by analytically deriving the self-consistent equations for group angular velocity and the order parameter for both the cases of single layer and multilayer network and also investigate the forward point of transition by adding a small perturbation to check the stability of the incoherent state.

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11. Presentation by: Verena Schamboeck

Poster title: **Towards Euclidean-space-embeddable networks using directed n-colored random graphs**

Authors: V. Schamboeck, I. Kryven, P. D. Iedema, University of Amsterdam, Van't Hoff Institute for Molecular Sciences

Abstract
Many networks in the real world are embedded in Euclidean space. Especially in material sciences we find vast examples as polymer networks, macromolecular gels, hydrogen bond networks, and other phenomena. Apart from their nodes having explicit coordinates, they often underlie strong conditions: (1) the nodes are distributed in space with constant density; (2) the edges length is limited to short metrical distances. Due these constraints, metrical distance between two arbitrary nodes of the same connected component is to some extend linked to the distance in the network. Thus, as the volume of a ball in Euclidean space exhibits algebraic growth with its radius, also the network has to show algebraic growth in terms of the increase of number of neighbors of an arbitrary root node with increasing distance. Most long-established models in the field of material sciences that are used to predict network topologies do not address the aspect of algebraic growth. Thus, we developed a theory based on directed n-colored random graphs that specifically targets the issue of algebraic growth behavior. Surprisingly, we proof that networks with algebraic growth behavior exhibit the same percolation threshold as networks without this constraint.

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12. Presentation by: Prosenjit Kundu

Poster title: **Perfect synchronization in networks of Sakaguchi-Kuramoto oscillators**

Authors: Prosenjit Kundu, National Institute of Technology Durgapur, India

Abstract
From the power grid to neuronal networks, synchronization phenomena have found diverse and pertinent applications capturing the emergence of collective behavior in complex systems. The classic framework, proposed by Kuramoto, portrays synchronization as a balance between the diversity of the system's components, i.e. their eigen-frequency distribution, and the strength of the coupling between the oscillators, driving them towards synchrony. This trade-off cannot capture, however, the common scenario where the coupling between the system's components induces phase-lags. Indeed, such phase-frustrated coupled oscillators avoid global synchronization even under extremely strong coupling or with a homogeneous

eigen-frequency distribution. Here we show that such systems can still exhibit collective synchronous dynamics with the appropriate analytically derived choice of the nodes' eigen-frequencies. As opposed to the classic synchronization framework, for phase-frustrated oscillators, we find that collective behavior is often the result of a diverse eigen-frequency set, rather than a homogeneous one. We also show that beyond a certain point, increasing the coupling strength does not contribute to the global synchronization and may, in fact, harm the collective behavior. Demonstrating our results on first- and second-order phase-frustrated Kuramoto dynamics, we implement them on both model and real power grid networks, showing how to achieve synchronization in a phase-frustrated environment.

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13. Presentation by: Benjamin Steinegger

Poster title:

Authors: Benjamin Steinegger, URV; Alex Arenas, URV; Jesús Gómez-Gardeñes, University of Zaragoza; Clara Granell, URV

Abstract
Infectious diseases often display oscillations in the number of infected cases through time. Sometimes the ups and downs are caused by seasonal, exogenous events, such as the increase of influenza cases in winter. Other times, infection displays non-seasonal periodic oscillations, like syphilis, which oscillates with a period of 8-11 years. Several mathematical models aim to capture these oscillations, either by considering a periodic transmission rate, by allowing rink rewiring, or by including temporary immunization. Here we present a stochastic, yet analytically tractable, epidemic spreading model consisting in a SIS process coupled with a two-strategy evolutionary game, where the individuals of the population decide whether to take preventive measures depending on the global extent of the disease. The combined feedback between the human decision on prophylaxis, and the perceived epidemic risk, are sufficient conditions for the emergence of self-sustained oscillations in diseases well-described by the SIS compartmental model, as it is the case for many sexually transmitted diseases. Finally, we propose plausible mechanisms to damp the oscillations. Our study prompts to the design of persistent prevention campaigns, substantiated on not only perceived but real risks, to improve human prophylactic behavior.

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14. Presentation by: Ivan Bonamassa

Poster title: **Critical stretching of mean-field regimes in spatial networks**

Authors: I. Bonamassa, B. Gross, M. Danziger, S. Havlin

Abstract
We study a spatial network model with exponentially distributed link-lengths on an underlying grid of points, undergoing a structural crossover from a random, Erdos-Renyi graph to a 2D lattice at the characteristic interaction range ζ. We find that, whilst far from the percolation threshold the random part of the incipient cluster scales linearly with ζ, close to criticality it extends in space until the universal length scale ζ^(3/2) before crossing over to the spatial one. We demonstrate this {\em critical stretching} phenomenon in percolation and in dynamical (epidemic) processes, and we discuss its implications to real-world phenomena, such as neural activation, traffic flows or epidemic spreading. Finally, we report on the occurrence of extreme non-monotonic variations in the effective exponents measuring the crossover from one universality class to another, which we justify by means of corrections to scaling arguments.

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15. Presentation by: Felix Kramer

Poster title: **Use it or lose: Remodelling complex flow networks**

Authors: Felix Kramer, Carl Modes

Abstract
Recent work on self-organized remodelling of vasculature in slime-molds, leave venation systems or vessel systemsin vertebrates has provided a plethora of potential adaptation mechanisms. All these have in common the underlying hypothesis of a flow driven machinery, meant to prune primary plexi in order to optimize the system's dissipation, robustness or more, with different versions of constraints.
Nevertheless the long-term dynamics of adapting networks whose architecture and function is particularly dependent of their respectove enviroment have not been properly understood. Therefore, intertwinded capillary systems such as found in the liver, kidney and pancreas, present a novel challenge regarding the field of coupled distribution networks. Currently we study an advanced version of the discrete Hu-Cai model, coupling two spatial networks in 3D and analysing its final structure by calculating the nullity. It seems that spatial coupling of two flow adapting networkscan controlthe onset of topological complexity given the system is exposed to short-term flow fluctuations.

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16. Presentation by: Shogo Mizutaka

Poster title: **Degree correlations of percolating clusters in random networks**

Authors: Shogo Mizutaka and Takehisa Hasegawa, Department of Mathematics and Infomatics, Ibaraki University, Mito 310-8512, Japan

Abstract
In a network consisting of several components, the degree correlation of each component is not the same as that of the whole network. Recent works have investigated the average degree $k_{\rm nn}(k)$ of nearest neighbor nodes of degree-k nodes [Tishby et al., Phys. Rev. E 97, 042318 (2018)] and the assortativity r defined by Pearson's coefficient for nearest degrees [Bialas and Oles, Phys. Rev. E, 77, 036124 (2008)] on the GC from the joint probability of degrees in the giant component (GC) formalized by the generating function method. As shown in these works, the GCs in uncorrelated random networks can display the negative degree correlation (disassortativity).

In this study, we consider the site percolation process on networks. Analyzing the GC formed by site percolation process on random networks with arbitrary degree distribution $P(k)$, we discuss the generality of the disassortativity observed in GCs [Mizutaka and Hasegawa, Phys. Rev. E 98, 062314 (2018)]. We analytically show that the assortativity is negative, $r<0$, above (at) the percolation threshold if the third (forth) moment of $P(k)$ is finite. In addition, it is shown that $k_{\rm nn}(k)$ on GCs at the percolation threshold is proportional to k^{-1} if the third moment of $P(k)$ is finite. To summarize, the GC formed by the site percolation process on uncorrelated networks possesses disassortativity at and above the percolation threshold. Our result supports the previous report [Yook et al., Phys. Rev. E 72, 045105 (2005)] suggesting the relation between fractality and disassortativity of real-world networks. The validity of our analytical calculations is confirmed by extensive Monte-Carlo simulations.

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17. Presentation by: Lluís Arola Fernández

Poster title: **Critical uncertainty in complex networks**

Authors: Lluís Arola-Fernández, Alex Arenas (Universitat Rovira i Virgili, Tarragona, Spain)

Abstract
The combination of dynamical processes and networks has become the paradigmatic framework to model a wide variety of phenomena in complex systems and many significant advances have been achieved in

the last decades towards a complete understanding on the interplay between structure and function. Furthermore, we have an increasing amount of empirical data that can be used to validate the theoretical models and build more sophisticated ones. However, the data is usually incomplete and show errors that can produce inaccurate theoretical predictions which may lead to dramatic consequences in real systems (as e.g. the underestimation of the epidemic threshold in the spreading of a disease or the abrupt synchronization threshold of neurones in epilepsy attacks). Motivated by the unavoidable presence of errors in the measurements of real complex networks, in this work we tackle the problem of quantifying the uncertainty of the critical threshold when induced by microscopic noise in the weights of the network interactions. The obtained expressions, based on applying error propagation methods, are valid for a wide variety of dynamical processes and depend non-linearly on the explicit binary network structure and the features of the noise considered in the microscopic weights. We validate the theoretical predictions in synthetic and empirical networks with very different structural properties, obtaining good agreement against numerical simulations in most of the cases. Furthermore, we show that the heterogeneity in the degree distribution and other non-trivial connectivity patterns tend to amplify the fluctuations of the critical point, enhancing the macroscopic critical range of the system.

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18. Presentation by: Jose Ricardo G. Mendonça

Poster title: **Restricted permutations for the symmetric simple exclusion process in discrete time over graphs**

Authors: J. Ricardo G. Mendonça (EACH/USP), Fábio Tosetto Reale (EACH/USP)

Abstract
Exclusion processes are usually defined as continuous-time stochastic processes, but in many situations it would be desirable to have a discrete-time version of them. We define the symmetric simple exclusion process in discrete time over graphs by means of restricted permutations over the labels of the vertices of the graphs and describe a straightforward sequential importance sampling algorithm to simulate the process. As an example, we investigate the approach to stationarity of the process over loop-augmented Bollobás-Chung "cycle-with-matches" graphs that interpolate between the loop-augmented cycle graph (no matches) and a highly connected graph akin to two fully joined loop-augmented path graphs.

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19. Presentation by: Evgeniy Yudin

Poster title: **Growing graph with the nonlinear rule of preferential attachment**

Authors: Yudin E.B. (Sobolev Institute of Mathematics, RAS), Zadorozhnyi V.N. (Omsk State Technical University)

Abstract
A random growing graph with the nonlinear rule of preferential attachment (NPA) is considered. When generating NPA graphs an arbitrary function f(k) of vertex degree k can be used as a measure of preference. This research presents a method [1] to select the function f(k) to get required 1) vertex degree distribution 2) two-dimensional arc/edge degree distribution and 3) clustering coefficient. The possibilities of the developed method are also shown while modeling some social networks and the Internet at the level of autonomous systems. Finally, we discuss the extension of the NPA graphs taking into account a random loss of nodes or connections as well as a random addition of communities [2].
[1] Zadorozhnyi V. N., Yudin E. B. Growing Networks: Models following Nonlinear Preferential Attachment Rule. Physica A: Statistical Mechanics and its Applications 428, 2015, Pp. 111–132.
[2] Yudin E. B. 2018 Growing graphs with addition of communities. Journal of Physics: Conference Series, V. 1050, P. 012099.

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20. Presentation by: Sofia Tolstouhkova

Poster title: **Stability of network characteristics with respect to experimental noise and partial data removal**

Authors: S. Tolstoukhova (1), E. Patrusheva (1), M. Zvereva (2), O. Valba (1), M. Tamm (1,2)
(1) Department of Applied Mathematics, MIEM, Higher School of Economics, 123458, Moscow, Russia
(2) Faculty of Physics, Lomonosov Moscow State University, 119992, Moscow, Russia

Abstract
Experimental networks are routinely characterized by a variety of structural parameters, from local ones, like degree distributions, to collective, such as, e.g., spectra of the networks. The resulting network characteristics are then used in order to explain various phenomena related to the material object represented by the network in question.
However, in most cases the experimental data used to construct a network is noisy or some relevant data is missing. Also, in many cases the construction of network implies throwing away some of the information obtained in the experiment by, for example, putting arbitrary thresholds separating bond from no-bond, replacing weighted networks with unweighted ones or removing some of vertices, which for one reason or another are deemed irrelevant. All this factors, generally speaking, influence the network characteristics mentioned above. Therefore, one faces a question: how stable and robust are various local and global characteristics of the network with respect to experimental noise and human interference on the stage of representation of the experimental dataset with a network.
In this work we consider two different datasets on free associations between words of English language. The first of them is a directed weighted network, which includes only nodes with out-degree more than zero. The second dataset includes nodes with zero out-degree but it is unweighted, and all of the bidirectional edges are replaced by unidirectional ones apparently at random. We compare various structural characteristics of these two networks, as well as several other obtained from these datasets by partial deletion of the data. We show that while some of the structural properties are very robust (e.g., the in-degree distribution), some other differ quite radically (e.g., the structure of the eigenvalue spectrum). We discuss the reasons and possible implications of these instabilities. This work is supported by RFBR grant 18-29-03167.

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21. Presentation by: Ilya Kasyanov

Poster title: **Does the English network of free associations have an underlying hyperbolic geometry?**

Authors: Kasyanov (1), M. Tamm (1,2), O. Valba (1)
(1) Department of Applied Mathematics, MIEM, Higher School of Economics, 123458, Moscow, Russia
(2) Faculty of Physics, Moscow State University, 119992, Moscow, Russia

Abstract
The power-law or approximately power-law degree distributions are often observed in experimental networks. There exist a variety of stochastic network models, which reproduce this behavior (see, e.g., [1,2]). However, most of these models have been invented and studied for the case of undirected and unweighted networks, and it is interesting to adapt existing models for the case of directed networks.
Here we consider a dataset [3] of the Florida University network of free associations in English language. This is a weighted directed dataset. The out-degree distribution of this network (in terms of the number of edges) is approximately normally distributed, while the in-degree distribution has a power law tail with exponent close to three.
We generalize the embedding procedure described in [4] in order to embed this directed network into the hyperbolic space. Also, we construct random networks with similar characteristics (number of nodes and edges, in- and out-degree) using the preferential attachment model [5] and the popularity vs similarity model [4], and compare their structural characteristics to the characteristics of the original dataset. This work is supported by RFBR grant 18-29-03167.
[1] Barabási, A.-L. & Albert, R. Emergence of scaling in random networks. Science 286, 509–512 (1999).

[2] Krioukov, D., Papadopoulos, F., Kitsak, M., Vahdat, A. & Boguñá, M. Hyperbolic geometry of complex networks. Phys. Rev. E 82, 036106 (2010).
[3] Nelson, D.L., McEvoy, C.L. & Schreiber, T.A. Behavior Research Methods, Instruments, & Computers (2004) 36: 402.
[4] Papadopoulos, F., Kitsak, M., Serrano M. Á., Boguñá, M. & Krioukov, D. Popularity versus similarity in growing networks. Nature 489, 537–540 (2012).
[5] Barabási, A.-L. The Barabási-Albert Model. Network Science. (2016).

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22. Presentation by: Priodyuti Pradhan

Poster title: **Principal Eigenvector Localization in Multilayer Networks**

Authors: Priodyuti Pradhan and Sarika Jalan, Complex Systems Lab, Physics, Indian Institute of Technology Indore, India

Abstract
Networks furnish a mathematical framework to model and decipher the collective behavior of the complex real-world systems. Scrutiny of principal eigenvector (PEV) and the corresponding eigenvalue of the networks are known to provide an understanding of various structures as well as the dynamical evolution of the networks. Recently, scrutiny of eigenvector localization has received tremendous attention in network science due to its versatile applicability in many different areas which includes analyzing centrality measure, spectral partitioning, development of approximation algorithms and disease spreading phenomenon. One key factor of our interest is to understand the properties of networks which may help in spreading or restricting perturbation in networks. For a network, PEV is said to be localized when most of its components are near to zero, with few taking very high values. The traditional monolayer network framework offers only a limited representation of complex systems having different layers of interactions. Recent years have witnessed the emergence of the multilayer network (MN) framework, which provides more accurate insights into the behaviors of complex systems possessing multiple types of relations among the same units. Starting with a multilayer network corresponding to a delocalized PEV, we rewire the network edges using an optimization technique such that the PEV of the rewired MN becomes more localized. The framework allows us to scrutinize the structural and spectral properties of the networks at various localization points during the rewiring process. For a two layers MN, the optimization process can be implemented in two different edge rewiring protocols; (1) by rewiring edges in both-layers or (2) by rewiring edges in only one layer. We reveal that for both the rewiring protocols, though there is an emergence of various specific structural features, the different rewiring protocols lead to a noticeable difference in the spectral properties of the optimized MN. For the both-layers rewiring protocol, PEV is sensitive to a single edge rewiring in the optimized MN, and however, interestingly, we get rid of this sensitivity of PEV for the single-layer rewiring protocol. This sensitivity in the localization behavior of PEV is accompanied by the second largest eigenvalue lying very close to the largest one. Furthermore, analysis of MNs constructed using real-world social and biological data show a good agreement with the simulation results for model MN.

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23. Presentation by: Yury Maximov

Poster title: **Exact and Approximate Inference in k-Planar Graphs**

Authors: Yury Maximov, Los Alamos Nationa Laboratory

Abstract
In this talk I present novel tractable methods for exact and approximate statistical inference for zero-field Ising model on planar, k-planar and several minor-free graphs. To derive the algorithms, an equivalent linear transition to perfect matching counting and sampling on an expanded dual graph. At the end of the talk I discuss methods scalability and complexity/accuracy trade-offs. The talk is based on joint works with Misha Chertkov (U Arizona) and Valerii Likhoshertov (Skoltech).