DY 3: Statistical physics of complex networks I

Time: Monday 10:30–12:30 Location: A 053

DY 3.1 Mon 10:30 A 053

Global Ownership: Unveiling the Structures of Real-World Complex Networks — •James Glattfelder, Stefano Battiston, and Frank Schweitzer — Chair of Systems Design, ETH Zurich, Switzerland

The empirical analysis of complex networks is often limited to the case of undirected graphs. However, there is a richer structure to be discovered by incorporating additional knowledge of the network under study, namely the orientation and weights of edges next to state variables associated with the vertices, serving as proxies for real-world quantities. The networks of shareholding relationships of quoted companies in selected countries serve as an example of how topological and weighted observables show different statistical properties. In addition to the generalization of standard network measures, new statistical quantities are introduced which heavily rely on the aforementioned hallmarks. The empirical analysis presented here yields fine-grained insights into real-world networks, where edges and vertices carry auxiliary information.

DY 3.2 Mon 10:45 A 053

The Phase Diagram of Random Threshold Networks — •Agnes Szejka, Tamara Mihaljev, and Barbara Drossel — Institut für Festkörperphysik, TU Darmstadt, Hochschulstrasse 6, 64289 Darmstadt, Germany

Threshold networks are used as models for neural or gene regulatory networks. They show a rich dynamical behavior with a transition between a frozen and a chaotic phase. We investigate the phase diagram of randomly connected threshold networks with real-valued thresholds h and a fixed number of input nodes per node. The nodes are updated according to the same rules as in a model of the cell-cycle network of *Saccharomyces cereviseae* [PNAS **101**, 4781 (2004)], which successfully reproduces the overall dynamical properties of the real network. Using the annealed approximation, we derive expressions for the time evolution of the proportion of active nodes in the network and for the average sensitivity of nodes to changes of the states of their input nodes. The results are compared with simulations of quenched networks. We find that the fact that with this update schema nodes do not change their state when the sum of their inputs is equal to the threshold value, leads to deviations of the dynamical behavior of quenched systems from the one predicted by the annealed approximation.

DY 3.3 Mon 11:00 A 053

The Critical Line in Random Threshold Networks with Inhomogeneous Thresholds — •Thimo Rohlf — Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501, USA — Max-Planck Institute for Mathematics in the Sciences, Inselstrasse 22, D-04103 Leipzig

We calculate analytically the critical connectivity K_c of Random Threshold Networks (RTN) for homogeneous and inhomogeneous thresholds, and confirm the results by numerical simulations. We find a super-linear increase of K_c with the (average) absolute threshold $|h|$, which approaches $K_c(|h|) \sim h^2/(2\ln|h|)$ for large $|h|$, and show that this asymptotic scaling is universal for RTN with Poissonian distributed connectivity and threshold distributions with a variance that grows slower than h^2. Interestingly, we find that inhomogeneous distribution of thresholds leads to increased propagation of perturbations for sparsely connected networks, while for densely connected networks damage is reduced; the cross-over point yields a novel, characteristic connectivity K_d. Further, damage propagation in RTN with in-degree distributions that exhibit a scale-free tail k_{in}^{γ} is studied; we find that a decrease of γ can lead to a transition from supercritical (chaotic) to subcritical (ordered) dynamics. Last, local correlations between node thresholds and in-degree are introduced. Here, numerical simulations show that even weak (anti-)correlations can lead to a transition from ordered to chaotic dynamics, and vice versa. Interestingly, in this case the annealed approximation fails to predict the dynamical behavior for sparse connectivities $\bar{K}$, even for large networks with $N > 10^4$ nodes.

DY 3.4 Mon 11:15 A 053

Asynchronous Random Boolean Networks — •Florian Greil and Barbara Drossel — Institut für Festkörperphysik, Technische Universität Darmstadt

Random Boolean networks (RBNs) were introduced by Stuart Kauffman nearly 40 years ago as a simple model for gene regulation. The dynamics of such systems is characterized by attractors, the properties of which can be best understood when the nodes are classified into frozen, nonfrozen and relevant nodes. The latter are arranged in relevant components which determine the dynamics. This talk shows that the properties of the attractors depend on the way how the nodes are updated. We discuss deterministic asynchronous and stochastic updating schemes for critical RBNs. Compared to synchronous parallel update, asynchronous updating schemes generally reduce the attractor numbers, while the number of states belonging to an attractor usually increases.

DY 3.5 Mon 11:30 A 053

Long-term Evolution of Boolean Network Populations — •Tamara Mihaljev and Barbara Drossel — Institut für Festkörperphysik, Technische Universität Darmstadt, Hochschulstraße 6, 64289 Darmstadt

We investigate the evolution of populations of Random Boolean Networks under the influence of a selection pressure for higher robustness (i.e., a higher probability to return to the same attractor after perturbing one node), and of random mutations (addition and deletion of links, change of update functions). We find that already after a short time the populations reach a state of high fitness. When the population is evolved for much longer times, the mean fitness decreases slowly, and so does the proportion of networks with highest fitness, although the selection pressure remains the same. We ascribe such long-term changes to the fact that even after reaching a state of high fitness evolution slowly drives the populations into regions of network space that are far away from those reached first.

DY 3.6 Mon 11:45 A 053

Modelling Paradigms for Random Movements on complex networks: How "anti-hubs"control dispersa — •Vasily Yu. Zaburdaev[1,2], Marc Timme[2,3], and Dirk Brockmann[2,4] — [1]Technische Universit"at, Berlin — [2]Max-Planck-Institute for Dynamics and Self-Organization, Göttingen — [3]Bernstein Center for Computational Neuroscience, Göttingen — [4]Northwestern University, Evanston IL, USA

Recently a huge number of studies focused on dynamical properties of stochastic processes evolving on networks of complex topology. Very often, researchers strive to understand whether, how and why highly connected nodes (hubs) in scale free networks accelerate relaxation and change the dynamics qualitatively. In all models of physical dispersal phenomena, the topology of the network as defined by a weight matrix w_{ij} is translated into transition probability rates $p_{ij} = w_{ij}/\sum_i w_{ij}$ that define the random process such that waiting times are independent of node degree (system A).

This relationship between topology and dynamics, appealing as it may seem, is by no means unique. In fact for a number of physical systems it is appropriate to interpret weights directly as probability rates, i.e. $p_{ij} = w_{ij}$ (system B). Here we show that both systems exhibit drastically different dynamical properties: Contrary to the common notion that hubs are the key players in dispersal facilitation, nodes with few connections determine the relaxation properties more strongly, an effect that generically arises in type B systems.

DY 3.7 Mon 12:00 A 053

A Monte Carlo method for generation of random graphs — •Bartlomiej Waclaw[1], Leszek Bogacz[2], Zdzislaw Burda[2], and Wolfhard Janke[1] — [1]Institut für Theoretische Physik, Universität Leipzig, Vor dem Hospitaltore 1, 04103 Leipzig, Germany — [2]Faculty of Physics, Astronomy and Applied Informatics, Jagellonian University, Reymonta 4, 30-059 Krakow, Poland

Random graphs are widely used for modeling the Internet, transportation, biological or social networks. Many models, based on some simple rules for growth and rewiring of links, have been proposed to explain their specific structural features as for instance power-law degree distribution and small diameter. However, to study dynamical phenomena taking place on networks with a given structure, it is desirable to have a general algorithm which produces a variety of random graphs. The method presented here is based on a random walk in the space of graphs. By ascribing to each graph a certain statistical weight we can set up a sort of Markovian process that generates networks with the desired probability. One can change their typical properties by tuning the weight function and thus to generate networks of different types. The method works for both growing and maximal-entropy graphs, that is graphs which are maximally random for a given constraint. Various properties, like power-law degree distribution, degree-degree correlations or higher clustering can be easily obtained. The method is very flexible and allows for further improvement, e.g. multicanonical simulations.

DY 3.8 Mon 12:15 A 053

(Un)detectable cluster structure in sparse networks — •Jörg Reichardt[1] and Michele Leone[2] — [1]Universität Würzburg, Institut f. Theoretische Physik — [2]ISI Foundation, Torino, Italy

We study the problem of recovering a known cluster structure in a sparse network, also known as the planted partitioning problem, by means of statistical mechanics. We find a sharp transition from unrecoverable to recoverable structure as a function of the *separation* of the clusters. For multivariate data, such transitions have been observed frequently, but always as a function of the *number of data points* provided, i.e. given a large enough data set, two point clouds can always be recognized as different clusters, as long as their separation is non-zero. In contrast, for the sparse networks studied here, a cluster structure remains undetectable even in an infinitely large network if a critical separation is not exceeded. We give analytic formulas for this critical separation as a function of the degree distribution of the network and calculate the shape of the recoverability-transition. Our findings have implications for unsupervised learning and data-mining in relational data bases and provide bounds on the achievable performance of graph clustering algorithms.
Ref.: pre-print: http://arxiv.org/abs/0711.1452