Dynamics On and Of Complex Networks IV

A Satellite Workshop of European Conference on Complex Systems, 2010

16 September, 2010, Lisbon University Institute, Lisbon, Portugal

Technical Schedule
and
Abstracts

Organizers

Fernando Peruani
Max Planck Institute for the Physics of Complex Systems, Germany

Niloy Ganguly
Indian Institute of Technology Kharagpur, India

Monojit Choudhury
Microsoft Research, India

Animesh Mukherjee
ISI Foundation, Italy

Contacts

peruani@pks.mpg.de
niloy@cse.iitkgp.ernet.in
monojitc@microsoft.com
animesh.mukherjee@isi.it

Website:
http://users.isi.it/~doocn/

Technical Schedule

Session 1: Internet

09:00 – 09:30 José J. Ramasco, Web traffic: analysis of navigation data and modeling at single user level

09:30 – 10:00 Marian Boguñá, The metric properties of the Internet

10:00 – 10:30 Coffee Break

Session 2: Social/ Communication Network

10:30 – 11:00 Pablo Jensen, Complex systems science: dreams of universality, reality of interdisciplinarity

11:00 – 11:30 Victor Eguiluz, The voter model: from complex networks to co-evolution

11:30 – 12:00 Jari Saramäki, Temporal correlations and spreading dynamics in communication networks

12:00 – 12:30 Fernando Peruani, Information cascades in mobile-phone data

12:30 – 14:00 Lunch Break

Session 3: Internet/ Social Networks

14:00 – 14:30 Subrata Nandi, Coverage-maximization in networks under resource constraints

14:30 – 15:00 Fabien Tarissan, Relying on statistical properties for measuring evolving complex networks: case studies

15:00 – 15:30 Ciro Cattuto, Analysis of social behavioral networks from wearable sensors

15:30 – 16:00 Marc Barthélemy, Mobility networks and statistics of human movements

16:00 – 16:30 Coffee Break

Session 4: Agent

16:30 – 17:00 Petter Holme, Collective dynamics of memory webs

17:00 – 17:30 Nicolas Perony, An agent-based approach to sociality in wild house mice

17:30 – 18:00 Anne-Ly Do, Patterns of cooperation: fairness and coordination in networks of interacting agents

Abstracts

Web traffic: analysis of navigation data and modeling at single user level

José J. Ramasco
ISI Foundation, Italy

Abstract

Our era has started to be known as the Information Age. This name reflects the importance that fast communication means and information retrieval tools as Internet and the WWW are gaining in our everyday life. Since the opening of Internet to the general public, an important question is whether it is possible to predict the traffic that users generate in Web sites. The answer to this question, and most importantly a reliable method to do such prediction, could have immediate practical consequences. Examples are PageRank and the search engine that it inspired (Google), but also guiding automatic search processes (crawlers) or predicting advertising revenues for the sites. In this talk, I will describe our efforts to bridge the gap between real data and models in this area. We have performed several data collection campaigns with the aim of tracking navigation patters of users. Each individual user has his/her own particular characteristics, but we have found some common statistical features underlying their behavior in the Web. This allows us to propose realistic models able to reproduce individual Web surfing and by the aggregation of the different users to study site traffic.

The metric properties of the Internet

Marian Boguñá
University of Barcelona, Spain

Abstract

In the age of Information Technology, the Internet has become our primary communication system. It is estimated that more than a billion users surf every day the web looking for information, sharing files, or developing new applications. The physical Internet is like a new world where all kind of new social and technological structures are constantly emerging. The Internet has thus become a common good, such as roads, railways, or airline connections and, as such, should be considered. The most surprising fact about the Internet is that, despite some preconceived ideas, its complex architecture is the result of a self-organized process where individual agents (Internet Service Providers or ISPs) interact locally without any central authority controlling its evolution. This turns the Internet into subject of truly scientific research.

The Internet is now facing a serious scalability problem with its routing architecture. To route information packets to a given destination, Internet routers must communicate to maintain a coherent view of the global Internet topology. The constantly increasing size and dynamics of the Internet thus leads to immense and quickly growing communication and information processing overhead, a major bottleneck in routing scalability causing concerns among Internet experts that the existing Internet routing architecture may not sustain even another decade. In our approach, we assume that the Internet (and other complex networks) lives in a hidden metric space that shapes its topology. Discovery of this hidden metric space can then be used to greedily route information without detailed global knowledge of the network structure or organization.

Following these ideas, we have introduced a network model that combines the small-world effect, scale-free degree distributions, and high clustering coefficient with metric properties. This model nicely reproduces the main topological properties of the Internet graph and other complex networks. By using it, we have shown that the metric and topologic requirements for a network to be (efficiently) navigable are met by the majority of real networks. We have also provided empirical evidence that the Internet and some social networks can be embedded in metric spaces, which justify our pursuit of metric properties in complex networks. We have also shown that if we are to associate a metric space to real networks like the Internet, this

space must be negatively curved (hyperbolic) and that in this geometry, greedy routing strategies achieves the optimal performance.

Complex systems science: dreams of universality, reality of interdisciplinarity

Pablo Jensen
CNRS, France

Abstract

Fundamental science has striven to reduce the diversity of the world to some stable building blocks such as atoms and genes. To be fruitful, this reductionist approach must be complemented by the reverse step of obtaining the properties of the whole (materials, organisms) by combining the microscopic entities, a notoriously difficult task. The science of complex systems tackles this challenge, adding the unifying idea that "universal principles" could exist. Ludwig Von Bertalanffy wrote already in 1968: "It seems legitimate to ask for a theory, not of systems of a more or less special kind, but of universal principles applying to systems in general.". This dream of universality is still active: [Complex networks science] suggests that nature has some universal organizational principles that might finally allow us to formulate a general theory of complex systems. Are universal principles effectively linking disciplines as sociology, biology, physics and computer science, which are very different in both methodology and objects of inquiry. Or is the whole "complexity" field buzz?

In this paper, we study empirically the "complex systems" field and its claims to universality. We have developed original tools to analyze a large database (more than 200 000 records) of "complex systems" articles published since the beginning of the 20th century. This gives us a *global* point of view on this highly interdisciplinary field, which is generally analyzed from a disciplinary point of view. Our empirical test of the idea of universality shows that it remains a dream, which has lead to interesting albeit more modest realities. The whole domain is linked by one scientific idea (self-organization) and the use of computer-based methods for analyzing the massive amount of digital data recently available (fMRI, genomics, phone data ...). Instead of connection through universality, we find specific "trading zones" built around fertile connections between theoretical and experimental disciplines.

The voter model: from complex networks to co-evolution

Victor Eguiluz
IFISC, Spain

Abstract

The voter model is one of the simplest models that can be implemented in a network. Each agent is located in the nodes of a complex networks; the state of a node can only take two values. At each time step one random agent changes its state to the state of a random neighbor. The simplicity of the model allows us to extract analytical results of its time evolution of the system and to explore the effect on the ordering of the system of different settings. In this talk we will present the effect of network topology in finite size systems as well as in the limit of infinite system sizes, in both directed and undirected networks. We will show conservation laws associated to the dynamics of the voter model, and how to identify the influence of a node in the dynamics. Motivated by recent findings in human dynamics, we will also explore the effect of changing the timing of the update rule in the ordering of the system. Finally we will explore the consequences of the co-evolution of nodeâ€™s state with the topology.

References

[1] Serrano et al, Journal of Statistical Mechanics: Theory and Experiment P10024 (2009).
[2] Vazquez, EguÃluz, New Journal of Physics 10, 063011 (2008).
[3] Vazquez et al, Physical Review Letters 100, 108702 (2008).

Temporal correlations and spreading dynamics in communication networks

Jari Saramäki
Aalto University, Finland

Abstract

Communication networks show the small-world property of short paths, but spreading dynamics in them is slow due to network topology, variability of link intensities, and burstiness of human activities. We follow the time evolution of information propagation through communication networks by using the SI model with empirical data on contact sequences. We introduce null models where the sequences are randomly shuffled in different ways, enabling us to distinguish between the contributions of different impeding effects. The slowing down of spreading is caused by weight-topology correlations and the bursty activity patterns of individuals.

Information cascades in mobile-phone data

Fernando Peruani
MPI Physics of Complex Systems, Germany

Abstract

We study the statistical properties of information cascades in mobile-phone data. We observe that users tend to phone short after receiving a phone call. This suggests that users may forward the information they receive, which opens the possibility of observing causality trees in the database. We investigate the properties of such trees and compare them with the outcome of null models. We find that the distribution of cascade sizes follows a power-law whose exponent depends on the time-scale of the observation. Random and real cascades can be distinguished at time-scales that go from 30 min to ~12 hs, at which point cascades can be arbitrarily large – i.e., they exhibit a diverging second moment.

Coverage-maximization in networks under resource constraints

Subrata Nandi
IIT Kharagpur, India

Abstract

Efficient coverage algorithms are essential for information search or dispersal in all kinds of networks. We define an extended coverage problem which accounts for constrained resources of consumed bandwidth B and time T. Our solution to the network challenge is here studied for regular grids only. Using methods from statistical mechanics, we develop a coverage algorithm with proliferating message packets and temporally modulated proliferation rate. The algorithm performs as efficiently as a single random walker but $O(B^{(d-2)/d})$ times faster, resulting in significant service speed-up on a regular grid of dimension d. The algorithm is numerically compared to a class of generalized proliferating random walk strategies and on regular grids shown to perform best in terms of the product metric of speed and efficiency.

Relying on statistical properties for measuring evolving complex networks: case studies

Fabien Tarisssan
Université Pierre et Marie Curie, France

Abstract

The term dynamics used in networks studies involves two very different phenomena which are both of interest. One sense refers to the dynamics of the structural aspect of a network – related to its topological properties – like the addition and the removing of nodes and links during its evolution. The second sense involves the transmission of information using the structure of the network (like rumours spreading on social networks or diseases diffusion in a

population). Both are strongly related to non trivial statistical properties that have shown to be shared by networks stemming from very different contexts. In this talk, I will focus on the first aspect and present different problematics that arise when trying to collect data on evolving networks.

The first problem I will address concerns the measurement of the Internet degree distribution. While many contributions rely on the Internet topology, the knowledge of this property is still partial and based on biased and erroneous measurements. Recently, in [1], a new approach was proposed to avoid issues raised by classical measurements. It aims at measuring the neighbourhood of Internet core routers by sending traceroute probes from many monitors distributed in the Internet towards a given target router. I will present briefly the method, the simulation results [2] we obtained and some very recent real measurements performed by the ComplexNetworks team.

In a second part, I will present another data collection issue which arises in social networks. In the context of analysing large scale networks of interaction, the question of being able to extract rapidly a representative view of a given network in order to enable pertinent and valid analysis of such a sample becomes more and more important. Based on the remark that complex networks share common statistical properties (relatively high local density, heterogeneous degree distribution), we proposed in [4] a procedure in two steps. We first perform a short random phase in which the existence of a link between random pairs of nodes is tested. This gives a partial knowledge of the network topology which, related to the expected statistical properties, helps in a second step to predict what are the links that are the most likely to exist. Beyond the quantitative aspect of the problem, expressed as how fast we are able to retrieve a certain amount of existing links in the network, the qualitative perspective appears to be of paramount importance: how to characterise the bias induced by the techniques used to extract the samples. I will present briefly our contributions in this context and show how this link prediction point of view might be used from the perspective of an event detection tool.

This last point will allow me to draw the principle of an event detection method which proceeds in several steps. It consists in monitoring the evolution of a chosen statistical property of the network during time. This monitoring leads to the detection of any statistically relevant variation (outliers), which in turn allows to determine the region of the network which has triggered the variation and then to zoom in this region in order to interpret the identified event. The crucial point here relies in choosing carefully the relevant properties to monitor. This will directly depend on the kind of event one is looking for detection. I will present in this talk some results we obtained recently [3].

Finally, I will draw some perspectives for upcoming studies focusing on the dynamics of the networks. Among them, the study of the influence of the dynamics on the measurements are particularly important if one wants to escape from natural biases in this context. We might also wonder how to integrate the different aspects of the dynamics presented here. How would it be possible to raise reasonable questions on diffusion phenomena occuring while netwoks are evolving? I will quickly address this question at the end of the talk.

References:

[1] Christophe Crespelle, Matthieu Latapy, and Elie Rotenberg. Rigorous measurement of ip-level neighborhood of internet core routers. In 2nd IEEE International Workshop on Network Science and Communication Networks (NetSciCom'10), 2010. To appear.

[2] Christophe Crespelle and Fabien Tarissan. Evaluation of a new method for measuring the internet degree distribution: Simulation results. In Computer Communication. Elsevier, to appear.

[3] Assia Hamzaoui, Matthieu Latapy, and Clmence Magnien. Detecting events in the dynamics of ego-centered measurements of the internet topology. In Proceedings of International Workshop on Dynamic Networks (WDN'10), 2010.

[4] Fabien Tarissan, Matthieu Latapy, and Christophe Prieur. Effcient measurement of complex networks using link queries. In Proceedings of the IEEE International Workshop on Network Science For Communication Networks (NetSciCom'09), 2009.

Analysis of social behavioral networks from wearable sensors

Ciro Cattuto
ISI Foundation, Italy

Abstract

Wearable devices, wireless networks, and the possibility of mining the ever-increasing amount of digital traces that we leave behind in our daily activities are changing the way we can approach the study of human mobility and interactions. High-resolution data on behavioral social networks in physical space, however, are generally limited to relatively small groups of individuals. We describe a scalable experimental framework designed to sense proximity and face-to-face interactions between individuals, and report on the deployment of this sensing platform in a variety of real-world contexts that include conferences, museums, company offices and hospitals. We build and analyze dynamical networks of co-presence and face-to-face proximity, uncovering similarities in the way individuals interact in different contexts, and investigating the impact of network dynamics on simple spreading processes.

Mobility networks and statistics of human movements

Marc Barthélemy
CEA, Paris, France

Abstract

How individuals move in a city and between cities is a crucial ingredient in many models. For example in epidemiology, human movements govern the spread of infectious diseases and in urban planning, congestion in a city depends on the commuters movements, etc. More generally, the structure of a city is in strong interaction with the transportation network and the pattern of movements. The mobility network can be described by the origin-destination (OD) matrix which contains all the information about these movements. This matrix is however very difficult to obtain and to measure and I will discuss some recent studies which focused on the trip length distribution. I will then discuss the so-called gravity law which enters many models and which allows to give quantitative estimates of some elements of the OD matrix. In particular, I will discuss the limitation of the usual entropy maximization approach and how simple statistical arguments could help in understanding the dominant mechanisms governing the movements of individuals.

Collective dynamics of memory webs

Petter Holme
Umeå University, Umeå

Abstract

We understand the dynamics of the world around us as by associating pairs of events, where one event has some influence on the other. These pairs of events can be aggregated into a web of memories representing our understanding of an episode of history. The events and the associations between them need not be directly experienced—they can also be acquired by communication. In this paper we take a network approach to study the dynamics of memories of history. First we investigate the network structure of a data set consisting of reported events by several individuals and how associations connect them. We focus our measurement on degree distributions, degree correlations, cycles (which represent inconsistencies as they would break the time ordering) and community structure. We proceed to model effects of communication using an agent-based model. We investigate the conditions for the memory webs of different individuals to converge to collective memories, how groups where the individuals have similar memories (but different from other groups) can form. Our work outlines how the cognitive representation of memories and social structure can co-evolve as a contagious process. We generate some testable hypotheses including that the number of groups is limited as a function of the total population size.

An agent-based approach to sociality in wild house mice

Nicolas Perony
ETH, Switzerland

Abstract

The study of the structure and dynamics of inter-individual interactions is one of the major topics of social networks science, because of their importance as the basis of complex societies. These interactions give rise to an intricate network structure, subject to constant evolution due to the dynamic nature of the individual activity patterns. Of particular interest in the network are emergent community structures, capturing tightly bound circles of individuals sharing the same set of interests or attributes. Although the benefits of group formation are now widely recognised, little is known of the processes that make these communities form and dissolve, and the influence that their dynamics have on individual fitness.

In this article, we address this question by studying the association network of a population of wild house mice and proposing a network model for their association patterns. Each individual within the population is individually marked with an RFID tag, to allow for their position to be recorded whenever they enter or exit one of the 40 nestboxes present in the barn hosting the population. Our 2-year long dataset contains about 11 million location records for over 500 mice, accounting for more than 1.3 million stays in all nestboxes, and leading to over 1 million one-to-one encounters. The frequency, context and duration of these encounters were used as a proxy for the characterisation of social interactions.

In a first part, we concentrate on the description of the network structure. We find that the social network of associations consistently exhibits a highly modular pattern, which would not arise if the associations were passive. The decomposition of the network into communities is found to yield a number of distinct social groups. The number and size of those groups remain remarkably consistent over the study period, even though the average generation time (around 4 months) is much shorter than the time range covered by our data. We study the stability of the communities and their robustness to the arrival and removal of individuals, as births and deaths occur continuously in the system. We investigate whether these communities form around some central individuals or if they depend on more institutional factors, such as territorial behaviours or food-sharing constraints. The typical life cycle of a community is computed and compared to results from previous research on the evolution of network communities in real-world data.

We then proceed to relate these empirical findings to an agent-based model of social interaction in a weighted, fully-connected network. In this network, the dynamics of the edge weights result from the expected outcome of interaction between agents. The agents are characterised by a payoff function that depends on internal (such as sex, age, or reproductive status) as well as external (such as information perceived from neighbouring individuals) factors. We assume that the strength of interactions between agents is subject to time changes. Based on their current associations and the computation of their respective payoff matrix, each agent decides of their interaction behaviour, both in terms of time (meeting duration) and quality (from cooperative to antagonistic). Based on the study of the intra- and inter-community mixing patterns both in the data and the model, we speculate on the influence of genetic relatedness as the driving force behind the formation of social groups, as predicted by principles of evolutionary biology. We compute the necessary conditions for the emergence of such communities within a social network and hint at an explanation of why such clustered structures are not systematically observed in other species and other social structures. Finally, we comment on the relevance of our results with regard to real-world applications.

This work attempts to bridge the existing gap between the physics of complex systems and long-established principles of behavioural science by using a modeling approach that draws techniques and ideas from both of these fields. Our results should be of relevance for the respective communities.

Patterns of cooperation: fairness and coordination in networks of interacting agents

Anne-Ly Do
MPI Physics of Complex Systems, Germany

Abstract

We study the self-assembly of a complex network of cooperative interactions among self-interested agents. The agents can maintain different levels of cooperation with different partners. Further, they continuously, selectively, and independently adapt the amount of resources allocated to each of their interactions in order to maximize the obtained payoff. We show analytically that the system approaches a state in which the agents make identical investments, and links produce identical benefits. Despite this high degree of social coordination some agents manage to secure privileged topological positions in the network enabling them to extract high payoffs. Our analytical investigations provide a rationale for the emergence of unidirectional non-reciprocal interactions and different responses to the withdrawal of a partner from an interaction that have been reported in the psychological literature.