Student Conference in Complexity Science

Book of Abstracts
Network Science

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Networks Science

Wednesday, 20th August 2014

11:20 - 13:00 Spatial Networks

Planar growth of spatial networks

Garvin Haslett, University of Southampton, UK (G.A.Haslett@soton.ac.uk)

Spatial scale free networks have been demonstrated to emerge from the mechanisms of space-filling, vertex fitness and link length penalisation. We add to the first class of these with a growth model that forbids new connections from crossing existing ones, i.e. planarity is conserved at each stage of network formation. Numerical results demonstrate that a power law degree distribution, the small world property, disassortativity and high clustering all obtain in the ensuing networks. The results hold for any degree of attachment, m < 3.

We investigate the extent to which planarity accounts for this outcome with a series of experiments which allow varying proportions of edge crossing. In doing so, it is observed that a small ratio maintains the properties discussed but at high values of this ratio they no longer hold.

The impact of constrained rewiring on network structure and node dynamics

Prapanporn Rattana, University of Sussex (pr87@sussex.ac.uk)

In this paper, we study an adaptive planar/geometric network. We consider a SIS (susceptible-infected-susceptible) epidemic on the network, with a link/contact rewiring process constrained by spatial proximity. In particular, we assume that susceptible nodes break links with infected nodes independently to distance, and reconnect at random to susceptible nodes available within a given radius distance. We investigate the impact of the rewiring by changing the radius of the area and consider how this impacts on the structure of the network and characteristics of the epidemic. We present a step-by-step approach to first understand the impact of the rewiring scheme on the network structure, in the absence of an epidemic, then with nodes assigned a disease status but still with no disease dynamics, before finally running the network and epidemic dynamics simultaneously. For the case of no labelling and no epidemic dynamics, we provide an analytic and semi-analytic formulas for the value of clustering achieved in the network. Our results also show that the radius of the neighborhood area and the network‘s initial structure have a pronounced effect of the final size of the epidemic; increasingly large rewiring radiuses corresponding to smaller final epidemic sizes.

The effects of social fallout on friendship circles

Elisabeth zu Erbach-Schoenberg, University of Southampton, UK (ezes1m13@soton.ac.uk)

The choices of individuals aggregate in non-linear ways to create social systems and this interaction structure can be represented as a network. These social networks are not static but vary over time as connections are made and broken or change in intensity. Generally these changes are gradual, but in some cases individuals disagree and as a result “fall out“ with each other, meaning they actively end their relationship by ceasing all contact. These “fallouts“ have been shown to be capable of fragmenting the social network into disconnected parts. Fragmentation can impair the functioning of social networks and it is thus important to better understand the social processes that have such consequences.

To answer questions about the mechanisms underlying these fragmentation processes and to understand the necessary conditions for fragmentation we need a model of social network dynamics that is stable enough such that fragmentation does not occur spontaneously, but is simultaneously dynamic enough to allow the system to react to perturbations

(i.e.\ disagreements). We present such a model and show that it is able to grow and maintain networks exhibiting the characteristic properties of social networks, and does so using local behavioural rules inspired by sociological theory.

We provide an investigation of fragmentation and identify the connections that are most important for the cohesion of the network. We are able to confirm basic intuitions of the importance of bridges for network cohesion. Furthermore, we show that this topological feature alone does not explain which points of the network are most vulnerable to fragmentation. Rather, we find that dependencies between edges are crucial for understanding subtle differences between stable and vulnerable bridges. This understanding of the vulnerability of different network components is likely to be valuable for being able to prevent fragmentation and limit the impact of social fallout.

Soft random geometric graphs: obstructions and no-convexity

Alexander Giles, Bristol University, UK (eeapkg@bristol.ac.uk)

Soft random geometric graphs are mathematical structures consisting of a set of nodes placed uniformly in some V (a subset of R^d) mutually coupled with a probability dependent on their Euclidean separation and, inter alia, are being used to model large-scale wireless networks. When considering these mathematical structures, a commonplace assumption is that V is a convex set, such that each pair of nodes is mutually visible; in the real-world, this is rarely the case, and so it is of particular interest to understand how the behaviour of these graphs changes after the convexity restriction is relaxed (such as when an obstacle is placed inside the domain, or when the graphs have to cope with an internal obstructing wall). Particularly, we focus on estimating the proportion of random graphs that connect inside an annulus.

Null models for community detection in spatially-embedded, temporal networks

Marta Sarzynska, University of Oxford (marta.sarzynska@sjc.ox.ac.uk)

I use community detection on time-dependent correlation networks to study the geographical spread of disease. Using proprietary data on country-wide dengue fever, rubella, and H1N1 influenza occurrences for several years, I create networks with the provinces of a country as nodes and the correlation between the number of disease cases in each pair of provinces giving weights to the edges. To study these temporally evolving networks, I use the framework of "multilayer networks", which allows modelling the temporal aspect of the data with less data aggregation than with collections of ordinary (static) networks. I perform community detection, looking for groups of provinces in which disease patterns change in similar ways, and I analyse the properties of the communities (such as their relationship to climate, population, geographical location etc.) and their changes over time.

I develop a novel null model for community detection that takes into account spatial information, allowing uncovering additional structure that might be obscured by spatial proximity. The null model is based on a radiation model proposed recently for modelling human mobility, with the hope it would be better at capturing disease spread than the previous spatial null model based on gravity models for interaction between nodes. I test the behaviour of the two spatial null models against the standard Newman-Girvan null model on benchmark spatial networks with known community structures and the disease correlation networks.

I also study the performance of a temporal null model developed for correlation networks created from time series on the disease correlation networks, and observe the differences in predicted community structures and their relationship to space between the four null models. The Newman-Girvan null model finds spatial and temporal partitions of the multilayer network depending on parameters used, and the spatial null models remove majority of the network structure.

14:00 - 16:00 Network Science Applications

Analysing the structure of human language via phonological networks

Massimo Stella, University of Southampton, UK (massimo.stella@inbox.com)

This work aims to investigate the phonetic structure of English words. By using data from Wolfram Research, we build a complex network of phonological similarities, where nodes are the phonetic pronunciations of words and edges connect words differing by the addition, deletion or substitution of exactly one phoneme. The resulting network reveals interesting properties, quite uncommon in other real-world social or technological networks, such as a very high assortativity and a clustering coefficient independent of node degree. We explore whether these peculiar features are artifacts of the network construction methodology or whether they represent genuine structural patterns in the organisation of human language. We consider various null models based on repertoires of synthetic words, successively including more constraints (e.g. phoneme frequency, word length, consonant-vowel correlations). We find that some properties, such as clustering or assortativity, can partly be attributed to the underlying construction method, but others (e.g. link densities, component sizes) reveal significant additional patterns in the phonetic structure of language. Importantly, by comparing to percolation models, we argue that our findings about link densities and giant component size support the hypothesis that large parts of the (phonetic) word repertoire might have formed by gradually applying modifications to existing words in order to invent new ones. Finally, we propose a simple model that mimics such gradual process and demonstrate that it can accurately reproduce a number of important characteristics of phonetic networks. Applying tools from Statistical Physics, our results constitute a quantitative assessment of human language properties and explain how they are structurally reflected in phonetic networks.

Multiple time scales and hub structure observed in spontaneously evolved neurons on high-density CMOS electrode array

Eiko Matsuda, The University of Tokyo, Japan (eikomatsuda@gmail.com)

Spontaneous development of cultivated neural cells were recorded in vitro (DIV) with the high-density CMOS micro-electrode array, which enables the detailed study of spatio-temporal neural activity (Frey et al., 2010). We used the same system to characterize the developmental changes of neural dynamics over a few weeks. Based on the time series obtained from the neural cells, we computed transfer entropy between neuronal states, to reveal the network structure of those neurons. As the results, we found 1) those networks changed their topologies through the course of development, and 2) different network structures were distinguished by the transfer entropy measured on the different time scales. We identified the revealed network structures as "functionally connected sub-networks". In other words, the networks worked in the multiple time scales. To evaluate the network structure further, we applied the methods of network analyses (Honey et al., 2007). Especially, we focused on identifying hub nodes, i.e., nodes with very high incoming and outgoing connections, by calculating centrality of individual neurons. In general, hub nodes allow higher levels of information flow because they can connect spatially remote nodes. We therefore took the hub for an indicator of information flow in the network. As a result, at the earlier stage of the development, higher amount of hub nodes was observed, while, at the later stage, the amount of hubs was dropped. However, when we estimate the hubs with longer time scales, the amount of hubs remained high throughout the whole recoding period. The result therefore indicates that information flow at faster time scales, i.e., micro-level interaction, decreased through development, while information flow at longer ones, i.e., global interaction, maintained. As a conclusion, the result suggests the possibility that the neurons can spontaneously develop efficient structure to maintain global interaction while saving costs for micro-level interaction.

Brain signal complexity correlates with conscious level

Michael Schartner, University of Sussex, UK (m.schartner@sussex.ac.uk)

What is the key feature of brain activity that determines that we are conscious when we are awake and that we are unconscious when we are in deep sleep? Tononi's integrated information theory (IIT) of consciousness suggests that for the awake brain, causal interactions between brain regions are both integrated, i.e. all regions are to a certain extent connected, and differentiated, i.e. there is inhomogeneity and variety in the interactions. IIT has inspired the development of several measures of dynamical complexity, each designed to capture in different ways the co-existence of these two features of network dynamics. Casali et al recently successfully applied a measure based on Lempel-Ziv complexity to robustly predict presence or absence of consciousness from EEG responses to pulses of magnetic stimulation applied transcranially (TMS), recorded during deep sleep, anaesthesia and wakeful rest. We explored several different complexity measures on spontaneous EEG from subjects undergoing propofol induced anaesthesia, and through them could reliably distinguish wakeful rest from anaesthesia.

Community structure of a phone calls network

Federico Botta, University of Warwick (f.botta@warwick.ac.uk)

Real-world networks often present a community structure which has important consequences on the topology and the properties of the network itself. There are several methods to try and detect such structures, the most prominent one given by the modularity function introduced by Newman. Recently, other methods have been shown to give good results by using non-backtracking operators on the networks. In the talk, I will present my work to try and extend this method to directed and/or weighted networks.

Exploring the vulnerability of spatially complex infrastructure networks

Craig Robson, Newcastle University, UK (c.a.robson1@ncl.ac.uk)

The resilience of critical infrastructure networks, such as such as transport, energy and telecommunications, to perturbations is of significant interest given their increasing importance to our quality of living and economic prosperity. Such systems have been shown in several notable cases to be vulnerable to unforeseen events leading to their catastrophic failure for significant time periods. However, different types of infrastructure system seem to respond in different ways to a range of failure types, due to their particular individual characteristics such as their spatial and topological configuration. Thus, in order to understand how infrastructure systems can be adapted and their resilience improved, one needs to understand their initial vulnerability to different types of perturbations.

In our work, we have compiled a comprehensive suite of critical spatial infrastructure networks for the UK covering energy, water, transport and telecommunication sectors. Using a range of graph metrics that characterise their basic and higher-order topology, along with a suite of failure models these networks have been statistically analysed and compared to synthetic graph models that range from random through to hierarchical and include scale-free and small-world examples. In total, 25 infrastructure networks were investigated. Most networks (16) were found to exhibit statistically a scale-free or small world structure. However, a notable number (5) were found to exhibit a hierarchical or hierarchical communities structure. Critically, such hierarchical networks when subjected to failure modelling were found to be much more vulnerable than scale-free models. This suggests that real infrastructure systems that exhibit a hierarchical structure will require in the future greater adaptive capacity via increased redundancy in terms of their topological structure. Authors: Craig Robson, Stuart Barr, Phil James and Alistair Ford.

Modelling the formation and hierarchical network structures of covert illegal organisations assembled within law abiding social populations.

Dominic Kerr, University of Warwick, UK (d.g.kerr@warwick.ac.uk)

My talk will present research obtained from the simultaneous agent-based modelling of civilian and illegal human interaction networks, whose motives for social interactions and communication of personally held ideologies are fundamentally different. I will also introduce results from a social experiments I have conducted in order to investigate the handshaking mechanisms used in the formation of illegal organisations within student populations, and the accuracy with which individuals perceive the personal opinions held my the members of their social neighbourhoods.

Thursday, 21th August 2014

9:00 - 10:20 Dynamics on Complex Networks

Robustness and self-organization in complex networks

Xueke Lu, Queen Mary University of London, UK (xueke.lu@qmul.ac.uk)

Networked ecosystems originated from complex interactions are highly dynamic and often subject to a wide range of perturbations that may lead to rippling effects in networks. For instance, telecommunications networks are susceptible to random failures and malicious attacks which affect reachability of nodes; and ecological networks (e.g. food webs, mutualistic networks) are exposed to numerous environmental (e.g. climate change, acidification, pollution) and biotic (e.g. invasive species) stressors, whose impacts on biodiversity have been the subject of considerable research activity. Robustness refers to a system's ability to sustain its behaviour when it is disturbed and it is often used to assess the effect of perturbations. Here, we examine the evaluation of robustness and methodologies in identifying vulnerabilities in various disciplines of complex networks, with a particular emphasis on ecological networks. Self-organization property in food webs is said to be one of the underlying reasons why food webs are stable. For example, link rewiring forces predators to switch diet when their original prey goes extinct, preventing them from dying out. Top-down/bottom-up control directly and indirectly enables population of each species to flow within range when disturbance takes place. Weak interactions between species can effectively disperse the dependence of one predator fed on a certain prey, which strengthens the robustness. This provides means to better understand how robust network is organized and pertained in natural systems, and enable us to gain an insight into designing better and more stable networks.

Dynamical systems coupled in heterogeneous networks, reduction and synchronisation

Matteo Tanzi, Imperial College London, UK (m.tanzi13@imperial.ac.uk)

It is nowadays widely agreed that graphs are an invaluable tool for modelling a large class of real world systems in all kinds of scientifical and societal investigation fields. In these network models, each fundamental element (neurons, servers, power plant,…) occupies a node of the network, and interacts with the elements to which it is connected by an edge. The state of the elements can be described by internal variables that undergo time-evolution prescribed by some law plus the effect of the coupling with other elements. It then seems necessary to develop a mathematical theory able to describe the time evolution of these variables in the light of their internal laws, the type of coupling, and the structure of the network.

In my work I have considered the case of piecewise C^1 expansive maps coupled in a highly heterogeneous network, i.e., a network characterised by highly connected nodes (hubs) and poorly connected nodes. For certain types of couplings, it is possible to describe the influence of nodes on the hubs with a mean field approach. To do this I have used ergodic properties of the dynamics of the poorly connected nodes treating the coupling as a perturbation and analysing the spectrum of the perturbed transfer operator. The analysis leads to the conclusion that one can substitute the non-autonomous coupling with its averaged value with respect to the unique invariant density of the internal dynamics. This introduces a time-dependent error term whose norm is controlled by the size of the network.

TITLE TBC

Ed Barter, University of Bristol, UK (edmund.barter@gmail.com)

A major challenge in networks research is to understand how information spreads through society. Given a message that enters a social network at a certain point, and is then retransmitted along social contacts with given probability, we want to know the extent to which the message spreads. This question is closely related to invasion percolation on networks. Here we revisit this problem and derive an expression for the number of people who receive a message with a particular probability of transmission. Further we present derivations for the number of people who receive a message from any number of distinct paths. We compare the analytical solutions to simulations on networks representing real communities in rural India. We also consider data giving the variation of participation rates in a Microfinance scheme between these communities. The analytical solutions are shown to give a good correlation with simulations for the reach of the message. The variation in Mircofinance participation is shown to potentially be explained by the existence of a critical point in the relationship between the probability of message transmission and its final reach. Many of the derivations are such that more complicated models of message transmission may be easily considered within the same framework.

Exploring altruism in social networks

Abeer El-Bahrawy, Cairo University, Egypt (a.yehia@fci-cu.edu.eg)

The objective of this presentation is to show the effect of social pressure and social networks properties on the diffusion of altruistic behaviour. The analysis is conducted by simulating the ultimatum game on different network topologies. While many studies focused on the evolution of the number of altruistic agents given different game rules such as the nature of agents and the strategic update rules, our work focuses on the relationship between network structure and the community pressure on the diffusion. The model starts with a selfish population with a limited number of altruistic agents to show how altruistic behaviour spread around the network forming a clique given different social pressure. Agents in the model are empathic and memoryless and the strategic update rule is natural selection.

11:20 - 12:40 Structural Properties of Complex Networks

The useage of nestedness for the analysis of bipartite networks

Stephen Beckett, University of Exeter, UK (S.J.Beckett@exeter.ac.uk)

Many different metrics have been devised to assess the structure and behaviour of bipartite (two part) networks. Nestedness is a network structural concept that has gathered much attention, particularly within the field of ecology where they can be used to describe and explain abundance patterns in species-site data and the patterns of interactions between members of mutualist (e.g. plant-pollinator) or antagonistic (e.g. phage-bacteria) networks. These methods are increasingly being applied to other types of bipartite networks (which need not be ecological!).

Many measures of nestedness have been proposed, but which of the many tools should be chosen for a particular network is still an open question. I will discuss the implications of having such a wide selection of tools at our disposal and show results from a recent effort to compare nestedness indicators in bipartite networks - and explore some of the networks I have been investigating (phage-bacteria, genes-genomes, users-hashtags).

Random weighted networks with fixed strengths

Francesc Font-Clos, Centre de Recerca Matemàtica, Spain (fontclos@crm.cat)

Complex networks grow subject to structural constraints which affect their measurable properties. Assessing the effect that such constraints impose on their observables is thus a crucial aspect to be taken into account in their analysis. To this end, we examine the effect of fixing the strength sequence in multi-edge networks on several network observables such as degrees, disparity, average neighbor properties and weight distribution using an ensemble approach. We provide a general method to calculate any desired weighted network metric and we show that several features detected in real data could be explained solely by structural constraints. We thus justify the need of analytical null models to be used as basis to assess the relevance of features found in real data represented in weighted network form.

TITLE TBC

Martin Ritchie, Univeristy of Sussex, UK (mr284@sussex.ac.uk)

Motifs, connected subgraphs that appear with greater frequency than one would expect in random networks, destroy a network's tree-like property by introducing loops. Conceptually this has been addressed by viewing the network at a higher level and considering motifs as meta-nodes to recover the tree-like structure. As yet this approach has only been applied in specific cases or to specific classes of motifs. We introduce the notion of hyperstubs - a structured grouping of classic stubs - and use it to generalise the configuration model to account for networks composed of an arbitrary set of motifs. Given a set of motifs, we first identify the set of hyperstubs and then impose a hyperstub degree distribution (HDD) on nodes, a multivariate distribution describing the probability of a node having a certain combination of hyperstubs. Following a configuration model approach we use the HDD to generate sequences of hyperstubs that are combined to form motifs. Using the HDD's probability generating function, and taking the SIR epidemic model as an example, we derive the set of ODEs giving the average system behaviour. A highly modular approach is taken where each motif has a corresponding system of ODEs akin to the exact Kolomogorov equations, which are embedded in a framework that describes the interaction between motifs. Finally we provide a computational framework to automate this process for arbitrary sets of motifs. This framework has the potential to facilitate the next generation of models on highly structured networks.

The entropy of conditional Markov trajectories. Application to mobility predictability

Mohamed Kafsi, EPFL, Switzerland (mohamed.kafsi@epfl.ch)

Quantifying the randomness of Markov trajectories has applications in graph theory and in statistical physics, as well as in the study of random walks on graphs. The need to quantify the randomness of Markov trajectories first arose when Lloyd and Pagels defined a measure of complexity for the macroscopic states of physical systems. They examine some intuitive properties that a measure of complexity should have and propose a universal measure called depth. They suggest that the depth of a state should depend on the complexity of the process by which that state arose, and prove that it must be proportional to the Shannon entropy of the set of trajectories leading to that state. Subsequently, Ekroot and Cover studied the computational aspect of the depth measure. In order to quantify the number of bits of randomness in a Markov trajectory, they propose a closed-form expression for the entropy of trajectories of an irreducible finite state Markov chain. Their expression does not allow, however, for computing the entropy of Markov trajectories conditional on the realisation of a set of intermediate states. Computing the conditional entropy of Markov trajectories turns out to be very challenging yet useful in numerous domains, including the study of mobility predictability and its dependence on location side information. In our work, we propose a method to compute the entropy of conditional Markov trajectories through a transformation of the original Markov chain into a Markov chain that exhibits the desired conditional distribution of trajectories. Moreover, we express the entropy of Markov trajectories—a global quantity—as a linear combination of local entropies associated with the Markov chain states.