Complex Systems Dynamics (CoSyDy) Meeting, Leeds 25th July 2017

“Network Dynamics and Structure”

Organisers: Dr. Jonathan Ward and Dr. Mauro Mobilia (Applied Maths, Leeds)

Directions: http://www.leeds.ac.uk/info/5000/about/131/find_us and http://www.maths.leeds.ac.uk/fileadmin/user_upload/directions_2011-12.pdf

Tentative programme & abstracts of the talks

All talks will be in the Mall, level 8 of the School of Maths on Tuesday 25th July

- *12:00: Buffet lunch (School of Mathematics' foyer, level 9)*

- *13:00-13:40:* ***Prof. Mark Broom*** *(City, University of London), “Modelling evolution in structured populations using multiplayer games”*

  Abstract: Within the last ten years, models of evolution have begun to incorporate structured populations, including spatial structure, through the modelling of evolutionary processes on graphs (evolutionary graph theory). One limitation of this otherwise quite general framework is that interactions are restricted to pairwise ones, through the edges connecting pairs of individuals. Yet many animal interactions can involve many individuals, and theoretical models also describe such multi-player interactions. We shall discuss a more general modelling framework of interactions of structured populations, including the example of competition between territorial animals. Depending upon the behaviour concerned, we can embed the results of different evolutionary games within our structure, as occurs for pairwise games such as the Prisoner's Dilemma or the Hawk-Dove game on graphs. For a population to evolve we also need an evolutionary dynamics, and we demonstrate a birth-death dynamics for our framework. Finally we discuss some examples together with some important differences between this approach and evolutionary graph theory.

- *13:40-14:20:* ***Dr. Tim Rogers*** *(Bath), “Faster and stronger stochastic oscillations induced by network interference”*

  Abstract: TBA

- *14:20-15:00: Coffee, tea & cookies (School of Mathematics' foyer, level 9)*

- *15.00-15.40:* ***Dr. Cécile Mailler*** *(Bath), “Largest degree node in the Bianconi-Barabasi network”*

  Abstract: The Bianconi and Barabasi random graph was introduced as a model for scale-free networks; this model is particularly interesting because it exhibits a phase transition between a “condensation" phase and a “non-condensation" phase. Bianconi and Barabasi conjectured that in the condensation phase, the winner takes it all, meaning that the largest degree is asymptotically linear in the number of nodes of the network. I will discuss the model, and present some results obtained in collaboration with S. Dereich and P. Mörters concerning the winner-takes-all conjecture.

- *15:40-16.00:* ***Tomokatsu Onaga*** *(Limerick), "Concurrency-induced transitions in epidemic dynamics on temporal networks"*

  Abstract: *Social contact networks underlying epidemic processes in humans and animals are highly dynamic. The spreading of infections on such temporal networks can differ dramatically from spreading on static networks. Previous numerical studies have indicated that concurrency, the number of neighbours that a node has at a given time point, enhances epidemics. However, this finding lacks theoretical underpinning. In this study, we theoretically investigate the effects of concurrency, the number of neighbours that a node has at a given time point, on the epidemic threshold in the stochastic susceptible-infected-susceptible dynamics on activity-driven networks, which is a generative model of temporal networks. We show that network dynamics can suppress epidemics (i.e., yield a higher epidemic threshold) when nodes' concurrency is low, but can also enhance epidemics when the concurrency is high. We analytically determine different phases of this concurrency-induced transition, and confirm our results with numerical simulations. We obtain qualitatively similar results for another temporal network model.*

- *16:00-16:20:* ***Sadamori Koujaku*** *(Bristol), "Identifying core-periphery structure of networks across different scales using random walks"*

  Abstract: Many networks often have core-periphery structure consisting of at least one pair of a core and a periphery. A core is a group of densely interconnected nodes and a periphery is a different group of nodes that are adjacent to most of the core nodes but not to other peripheral nodes (other definitions also exist). The core and periphery often correspond to, for instance, the leaders and followers in social networks and hubs and regional airports in airport networks. Networks can have core-periphery structure in different scales simultaneously, as is the case of community structure. For example, in worldwide airport networks, international hub airports and regional airports may constitute a single global core-periphery pair. There may be local core periphery pairs within each country composed of domestic hubs and domestic airports. Here, we uncover the multi-scale organisation of core-periphery structure of networks using the property of random walks. In a core-periphery pair, discrete-time random walkers tend to move to the core either from the core nodes or the peripheral nodes in one time step because every node in the core-periphery pair is adjacent to the core nodes but not to the peripheral nodes. The random walkers in a small core-periphery pair would reach the core in a small number of steps, whereas they would need a large number of steps to reach the core in a large core-periphery pair. By regarding the number of steps as a resolution parameter, we identify core periphery structure across different scales. We argue that core-periphery structure is present on a local scale but not on a global scale.

- *16:20-16:40:* ***Dr. Mirco Musolesi*** *(UCL), "Spatio-temporal Networks: Reachability, Centrality, and Robustness"*

  Abstract: While recent advances in spatial and temporal networks have enabled researchers to more-accurately describe many real-world systems, existing models do not capture the combined constraint that space and time impose on the relationships and interactions present in a spatio-temporal complex network. This has important consequences, often resulting in an over-simplification of the resilience of a system and obscuring the network's true structure. In this paper, we study the response of spatio-temporal complex networks to random error and systematic attack. Firstly, we propose a model of spatio-temporal paths in time-varying spatially embedded networks. This model captures the property that, in many real-world systems, interaction between nodes is non-instantaneous and governed by the space in which they are embedded. Secondly, using numerical experiments on four empirical examples of such systems, we study the effect of node failure on a network's topological, temporal, and spatial structure. We find that networks exhibit divergent behaviour with respect to random error and systematic attack. Finally, to identify weaknesses specific to the behaviour of a spatio-temporal

system, we introduce centrality measures that evaluate the importance of a node as a structural bridge and its role in supporting temporally efficient flow through the network. We explore the disruption to each system caused by attack strategies based on each of these centrality measures. This exposes the complex nature of fragility in a spatio-temporal system, showing that there is a variety of failure modes when a network is subject to systematic attack.

- *16:40-17:00:* ***Prof. Richard Wilson*** *(York), "Loop-centrality in complex networks"*

  Abstract: Cycles (loops) on networks represent feedback processes which play a central role in dynamical self-regulation and resiliency against perturbations in complex systems. In spite of a flurry of research from biology to economy into such phenomenon, there is no established measure of importance for individual loops. We introduce a centrality measure to this effect, which quantifies the fraction of the total dynamical flow of the network passing through a loop. This measure is computationally cheap, numerically well-conditioned, induces a centrality measure on arbitrary subgraphs and reduces to the eigenvector centrality on vertices. As an illustration, we study the centrality of strategic ensembles of sectors in the input-output macro-economical model of four countries over the 2000-2014 period. We find the results to accurately reflect the structures of these countries' economies. In particular, the evolution of the centrality of the finance-real estate-insurance clique in the US economy clearly shows the effects of deregulation, crashes, bail-outs, and even novel legislations. These insights are not replicated by vertex-centralities. Finally, we study the protein-protein interaction network of the plant *Arabidopsis thaliana* and two pathogens. We show that 69% of the plant proteins targeted by the pathogens are among triads of proteins in the top 2% of centrality values, suggesting that pathogens primarily aim at maximising the fraction of disrupted chains of protein reactions in the host. These results contrast with the 42% target classification accuracy in state-of-the-art models. Co-author: Pierre-Louis Giscard (York).

- *17:00: Wine and nibbles (School of Mathematics' foyer, level 9)*

- *17:45: Close*

We are grateful to the ***London Mathematical Society*** *for their kind financial support*.

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