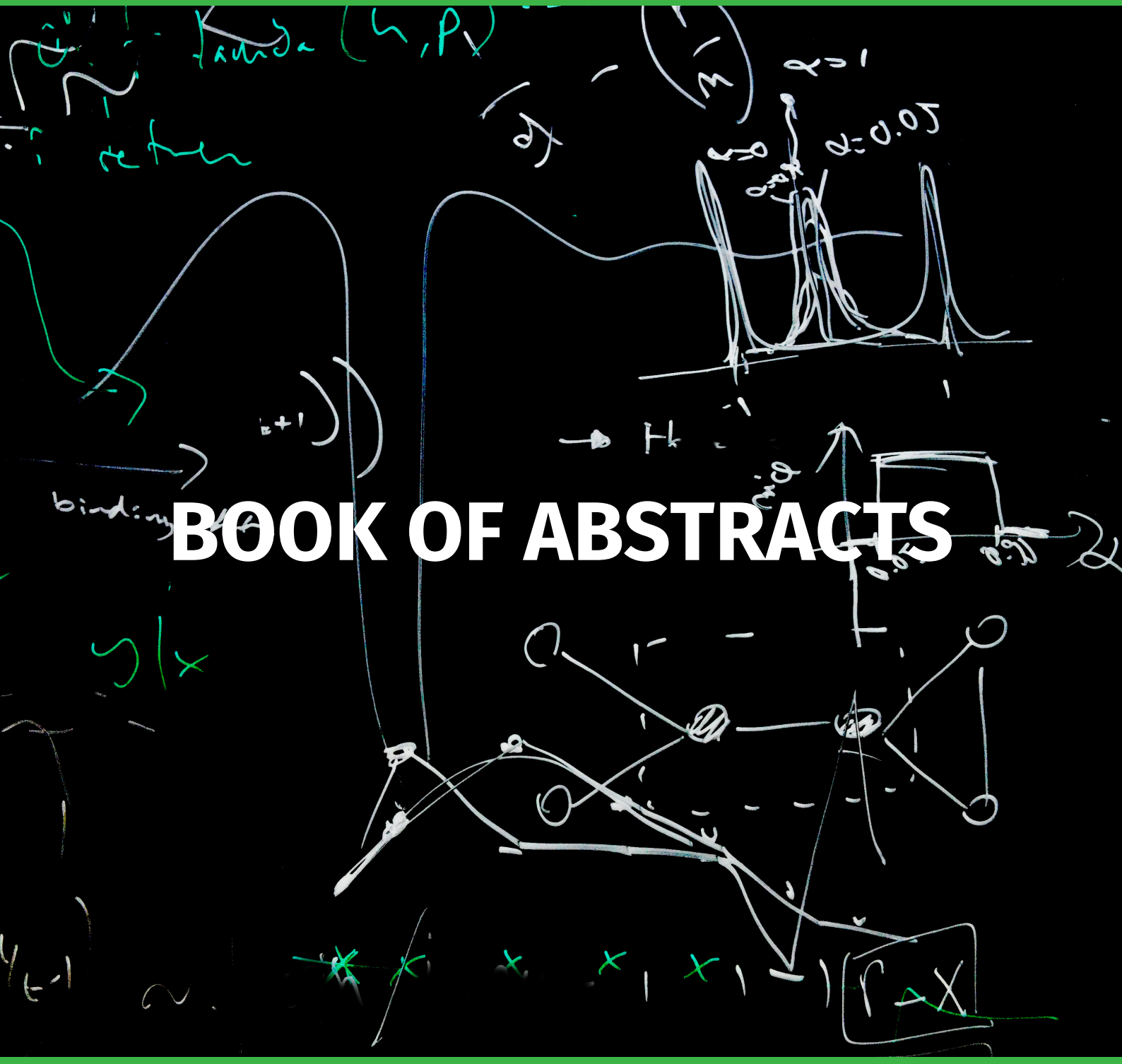
# BENET2016

Belgian Network Research Meeting



# BOOK OF ABSTRACTS

**Organizers:**
Sophie Béreau,
Jean-Charles Delvenne,
Mauro Faccin,
Yerali Gandica,
Leonardo Gutierrez,
Leto Peel,
Michael Schaub

# Contents

# Introduction

The 6th edition of the Belgian Network Research Meeting (BeNet) will be held at the Université catholique de Louvain (UCL) on December 15th, 2016.

This annual meeting is a place for the Belgium-based researchers interested in the network paradigm to meet and communicate their results, regardless of the discipline: biology, communication, economics, geography, history, informatics, mathematics, medicine, physics, sociology, statistics, etc.

Previous editions were held in: Namur (UNamur 2015), Brussels (ULB 2014), Leuven (IIS/KUL 2013), Antwerpen (UA 2012) and Brussels (VUB 2011).

The scope of the meeting includes but is not restricted to:

- Social & organizational theory
- Economics & Finance
- Social media & On-line activities
- Human communication & mobility
- Information diffusion & opinion dynamics
- Political networks & collective action
- Ecology, Ethology, food webs
- Biology & Bioinformatics
- Epidemiology
- Physics, Mathematics & Statistics
- Modelling & Data Analysis
- Geography & Urban Dynamics

## Organizers

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# Invited speaker

## Econometric Models of Network Formation

Bryan S. Graham [1]

[1] University of California, Berkeley

This talk will survey some of my recent work on the econometrics of network formation. Particular attention will be given to methods which admit unobserved agent-level heterogeneity and/or allow for interdependencies in preferences for link formation. Issues of identification, as well as methods of large network inference, will be emphasized.

# Contributed Talks

# Compressing over-the-counter markets

Tarik Roukny [1]

[1] Université Libre de Bruxelles

In this paper, we show that the networked nature of decentralized markets where trading takes place over-the-counter generates excess of notional, i.e., a positive difference between the aggregate gross notional of the market and the minimum aggregate amount satisfying every participants' net position in the market. In turn, the existence of this excess makes those markets "compressible", i.e., the web of outstanding trades can be modified in order to reduce notional excess. We proceed by identifying the different classes of compression and analysing the conditions under which each approach can be applied. We show that a trade-off exists between the amount of excess that can be removed from the market and the conservation of trading relationships. Furthermore, our results highlight the fact that dealers are the prime beneficiaries of compression as their intermediary role is key to the generation of excess. We then show how different initial market structures are affected by compression under different scenarios and discuss the implications. Finally, we apply our theoretical framework to a unique and comprehensive transaction-level dataset on OTC derivatives. First, we find important levels of excess across all references. Second, we show that compression when applied at the global level can reduce a large fraction of these levels of excess. Our results are of interest for both policymakers and market participants as they highlight the mechanics of trades compression and discuss the externatilities at the systemic level.

# The impact of business location on university contract research: a two-mode ERGM analysis

André Spithoven [1]
Jef Vlegels [1]
Walter Ysebaert [1]

[1] Vrije Universiteit Brussel

Conceptually and empirically, relations between university and innovating businesses have been centre stage for some time. The research context focuses on the relationship established as a consequence of business contract research. University-industry linkages come in many shapes and forms. As indicated by the literature on distributed innovation (Coombs et al., 2003) and innovation systems (Godin and Gingras, 2000; Charles, 2006), overall businesses have various relationships with external organisations. Universities, likewise, maintain a multitude of relationships with private companies (see e.g. D'Este and Patel, 2007). There is now a large empirical body of research on university-company linkages based on large surveys, patent (citation) analyses, bibliometric research and case study material (Fontana et al., 2006). Notwithstanding the large attention in empirical studies on university-company knowledge transfer, the practice of R&D contract research to universities remains understudied as a particular source of knowledge. Hence the paper meets the call from D'Este and Patel (2007) to do further research on the variety of relationships between universities and companies. This research focussed on the market-mediated contract research by businesses in order to acquire university research. This type of knowledge transfer is considered one of the less formal linkages involving monetary flows. Within this context the research brings out the business characteristics in their location choice and at the same time account for the university quality in terms of bibliometric data from universities. Although it has become an accepted premises that location is vital for knowledge exchange; an inquiry into this issue between universities and business is currently lacking. Because existing literature posits that location is a key facilitator for knowledge transfer activities, it is considered extensively in this paper. Based on a panel of three consecutive waves of R&D surveys conducted in 2006, 2008 and 2010, the linkages of universities with R&D active businesses are empirically examined by merging two separate databases – one on university R&D investments and one on business R&D investments. We use this database to construct a two-mode network of firms and universities and we use bipartite Exponential Random Graph models to predict university industry linkages based on network characteristics, node attributes and location. The preliminary findings , because of the explorative nature of the research, highlight at present three main findings. First, the R&D intensity of a business has a positive impact on contract research. Second, the size (and quality?) of the university is important in the selection for business contract out. Third, the continuous measure of geographical

distance showed a nonlinear U-shaped relation to the value of contract research: on the one hand universities located nearby can be seen to be part of the technology cluster of the company, on the other hand when the desired knowledge is located at far away universities these are also eligible partners for contract research. The results in this paper will provide some insights on how science policy may reinforce regional innovation systems by acknowledging the role played by universities without enforcing universities to sell out the family silver and become 'entrepreneurial' organisations.

# Causal Inference Using Multi-Channel Regime Switching Information Transfer Estimation

Carl-Henrik Dahlqvist [1,2]

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[2] Université Catholique de Louvain

The past decade has seen the development of new methods to infer causal relationships in biological and socio-economic complex systems, following the expansion of network theory. Nevertheless, the standard estimation of causality still involves a single pair of time dependent variables which could be conditioned, in some instance, on its close environment. However, interactions may appear at a higher level between parts of the considered systems represented by more than one variable. We propose to study these types of relationships and develop a multi-channel framework, in the vein of Barrett and Barnett (Phys. Rev. E, 81 (2010)), allowing the inference of causal relationships between two sets of variables. Each channel represents the possible interaction between a variable of each sub-system. Based on this new framework, we develop two different multi-channel causality measures derived from the usual Granger causality to account for linear interactions and from the concept of transfer entropy for nonlinear contribution. Our measures provide different information about the inferred causal links: the strength of the global interaction between the two sub-systems, the average frequency of the channel switches and the channel contributing the most to the information transfer process for each time step. After having demonstrated the ability of our measures to infer linear as well as nonlinear interactions, we propose an application looking at the U.S. financial sector in order to better understand the interactions between individual financial institutions, as well as parts of the financial system. At the individual level, the considered channels between financial institutions are expressed both in terms of spectral representation using wavelet transform and probability distribution using quantile regressions. Beyond the application presented in the paper, this new multi-channel framework should be easy to implement in other fields of complex system science such as neuroscience, biology or physics.

# Assessing dynamic changes of the US financial market: insights from network science

Yerali Gandica [1,2,3]
Marco Geraci [1,3,4,5]
Sophie Béreau [1,2,6,7]
Jean-Yves Gnabo [1,2,3]

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Drawing on the recent and buoyant literature inferring financial interconnectedness from market data by means of various time series techniques [Billio et al. (2012), Diebold and Yilmaz(2015) and Geraci and Gnabo (2016)], we propose in this communication an in-depth analysis of the US financial market and its dynamic, using tools coming from network science. The financial system analyzed consists in a large set of 154 banks, brokers/dealers, insurance and real estate companies listed in the Standard & Poor's 500 index for the period 1993 - 2014. Looking at the individual, sectoral, community and system wide levels, we show that network science's tools are able to support well-known features of financial markets such as the dramatic fall of connectivity amid Lehmann Brother collapse. In addition, we also unveil several important new patterns within US financial institutions interconnectedness. Overall, our results improve our understanding of the US financial landscape and may have important implications for risk monitoring as well as macroprudential policy design.

# Shareholding network of financial institutions: a dynamic analysis

Cyrille Dossougoin [1]
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Over the last decade interconnectedness has become key to characterize the financial system and to analyze phenomena that can jeopardize its stability. Financial institutions are involved in many transactions like lending and borrowing contracts, syndicated loans, international capital flows and cross-holdings to list a few. All these transactions create complex linkages among them which, in case of downfall of an institution, can result in bad outcomes for the real economy as materialized in the recent financial crisis. Therefore to strengthen policy interventions, tools from the network literature are used to study the architecture of financial systems. We contribute to this ongoing debate by analyzing the topology of cross-shareholding network of financial institutions (banks, insurance companies, broker-dealers etc.). For this we exploit portfolio holdings data of 82 large financial institutions located in United States and Europe over the period 2006-2012. We are able to study the changes in the network structure through time and thus complement common works on static interbank networks. Furthermore we use network based measures to quantify the level of integration and diversification of each financial institutions. Integration refer to the level of exposure of financial institutions to each other and the diversification captures how the cross-shareholding is spread out. Our results show that as time passes the cross-shareholding network becomes dense and exhibit a scale free property. In addition some financial institutions tend to keep their levels of integration and diversification stable while for others those factors decrease mainly after the financial crisis in 2008. These findings offer new insights on the systemical importance of financial institutions.

# Sovereign Wealth Funds' cross-border investments: assessing the role of country-level drivers and spatial competition

Malik Kerkour [1]
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[1] University of Namur
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The aim of this paper is to identify the driving forces of cross-border investments emanating from Sovereign wealth funds and to test the existence of spatial competition among recipient countries. For this, we develop an original econometric framework that quantifies the role of spatial dependence in the location of investments, and that uses a modified version of the standard estimation procedure of spatial panel model, which accommodates the Inverse Hyperbolic Sine transformation of the dependent variable. This transformation copes with two critical features of net capital flows, namely an highly skewed distribution and the presence of zero and negative values. Using a large-scale database, we provide evidence of negative spatial dependence, investments in one country being on average at the expense of its neighbors.

# Stochastic Model for Information Propagation in Complex Networks

Dimitri Papadimitriou [1]

[1] Nokia Bell Labs

Most information propagation models in complex networks are probabilistic as they rely on the probability that vertices interact only locally with their neighbors. In this paper, we propose a stochastic propagation model that takes into account uncertainty in drift and diffusion. For this purpose, we consider the motion of information as being driven by an uncontrolled state process X(t): t > 0. The probability density function u(x,t) associated to this state process represented by the random variable X(t) satisfies the so-called Fokker-Planck (a.k.a. Kolmogorov forward) equation. The equation governing the information propagation model by combining drift and diffusion collectively defines thus a convective propagation phenomena. Our computational method makes use of polynomial chaos expansions (PCE) that enable to compactly represent the variable of interest as a linear combination of orthogonal polynomials which depend on another continuous random variable z (with known distribution). The latter characterizes uncertainty in model parameters (the drift and diffusion coefficients), input and output variables. The solution u(x,t,z) can thus be represented as a truncated series of orthogonal polynomials multiplied by deterministic coefficients. The dimension of the resulting system of coupled non-linear partial differential equations grows with the order of the polynomial chaos expansion and the dimension of the stochastic input. The resolution of this system of partial differential equations, realized using Matlab produces a propagation pattern that accounts for the convective effects induced by medium- and long-distance interactions (thus, beyond local interactions). Moreover, since various interactions between information yield delays which may alter the propagation dynamics due to the so-called memory effect (future behavior of the state process depends not only on the present but also on former states), we further explore propagation models where the governing equation is formulated by the nonlinear stochastic delay-differential equation (SDDE) also referred to as Stochastic Differential Equations with Memory.

# Learning graph-structured dictionaries for sparse representation of diffusive signals on graphs

Shuyu Dong [1]

[1] Université Catholique de Louvain

Dictionary learning provides an efficient and flexible way for sparse representation of signals such as natural images. However for signals residing on the vertices of a graph instead of a regular domain, the graph structure of the input space carries important information that an unstructured dictionary may not be able to capture. In order to achieve better adaptability to input signals, it is also desirable to optimise the graph-structured information, which is otherwise predefined in heuristic manners. We address the problem of learning a graph-structured dictionary jointly with the graph for sparse representation of graph signals and propose to design the dictionary using a characteristic diffusion model. Experiments on synthetic and real datasets show that the proposed dictionaries not only have comparable representation performance than unstructured dictionaries but also significantly reduce overfitting of data.

# Network Effect on Stock Market Participation

Olga Balakina [1]
Anastasia Parakhonyak [2]

[1] Bocconi University, Italy
[2] Toulouse School of Economics, France

This paper investigates the effect of social networks on stock market participation in the economy. We study how stock market participation depends on number of informed agents and the intensity of social interactions, while controlling for the wealth distribution. We proceed to compare the performance of different models to estimate the significance of these effects. The impact of social networks on stock market participation is prominent in the empirical evidence of peer effects in the financial literature. We therefore introduce a model of social interaction of agents embedded in a social network and study diffusion of information about an entrance and operating on the stock market. In the model each agent faces fixed participation costs depending on agent type, professional and non-professional. We assume that non-professional agent has high participation cost due to lack of information about the stock market. The cost for non-professional agent is decreasing in the number of informed neighbors who provide information to their friends. We provide an algorithm for finding an equilibrium stock market participation for a particular network structure and use Danish registry data for the period 2010–2013 to test our hypothesis of the connectivity affecting the stock market participation.

# Emergent features of triadic relations in political networks

Jan Ryckebusch [1]
Andres M. Belaza [1]
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Koen Schoors [1]

[1] University of Ghent

We propose a model with five energy levels that encodes the dynamics of triadic relationships in a political network. The model builds on insights gleaned from structural balance theory to which we add elements from Boltzmann-Gibbs statistical physics and go beyond the restrictions of signed networks. We start from the idea that two agents that maintain ties in a political network can be either enemies, or friends, or neutrals to each other. The generic Hamiltonian associated with the five energy levels contains three parameters. One is connected with a three-body interaction inspired on social balance theory. The other two parameters take into account the costs of symmetry breaking and of changing a link. We stress the role of the degeneracy of the different energy levels and how it affects the degree of frustration in the political network. The validity of our model is tested on an extended data set for the time series of triadic relationships for the standings between alliances in a massive multiplayer online role-playing game. We also analyze real-world data for the different factions that play a role in the current war in Syria. We find emerging properties in the triadic relationships between the nodes in a political network, for example reflecting itself in a persistent hierarchy between the different energy levels.

# SIS Epidemics and the Direction of Information Flow in Brain Networks

Jil Meier [1]

[1] Delft University, The Netherlands

The interplay between structural connections and emerging information flow in the human brain remains an open research problem. A recent study observed global patterns of directional information flow in empirical data using the measure of transfer entropy. For higher frequency bands, the overall direction of information flow was from posterior to anterior regions whereas an anterior-to-posterior pattern was observed in lower frequency bands. In this study, we applied a simple SIS epidemic spreading model on the human connectome with the aim to reveal the topological properties of the structural network that give rise to these global patterns. In order to quantify the information flow between regions, we computed the transfer entropy values for all node pairs evaluating different time windows. We found that direct structural connections induced higher transfer entropy between two brain regions and that transfer entropy decreased with increasing distance between nodes (in terms of hops in the structural network). Applying the SIS model, we were able to confirm the empirically observed opposite information flow patterns, which seem to be linked to different time scales of the spreading process. Posterior hubs in the structural network appear to play a dominant role in the network dynamics since the global pattern of information flow is in the posterior-to-anterior direction when these hubs are strong senders, and in the opposite direction when they are strong receivers. Our analysis suggests that these global patterns of directional information flow are the result of an unequal spatial distribution of the structural degree between posterior and anterior regions.

# The Belgian Production Network

Glenn Magerman [1,2]
Emmanuel Dhyne [2,3]

[1] Université Libre de Bruxelles
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This presentation covers the overview of a large economic research agenda on firms and production networks in Belgium. Using data on enterprise-to-enterprise transactions for the universe of Belgian enterprises between 2002 and 2014, combined with a myriad of enterprise-level databases, we present several ongoing projects in this agenda. We start with the description of the production network and its characteristics in both cross-sections and dynamics. Then, we turn to the impact of idiosyncratic productivity shocks to individual firms on the aggregate of an economy. We show that idiosyncratic shocks can propagate through the network and generate volatility in GDP in the same order of magnitude as observed GDP. Moreover, only a handful of firms (0.15top 100 firms) contributes to over 90model. In a related project, we analyse the impact of productivity shocks channeled through imports. In another project centered on international trade, we show that the distance to exports correlates with firm-level productivity. One project looks at the supplier-buyer network from a bilateral perspective and revisits the old question why firms are big. Using a model-based decomposition, we show that 80firm sizes is generated by inter-firm demand. Moreover, the extensive margin (number of suppliers/customers) contributes most to the variation on both the supply side and the demand side. Finally, a last project looks at the geographical constellation of production clusters. We show that there are 6 large clusters in Belgium that are both geographically and sectorally concentrated.

## Deformed Laplacians on graphs and networks with applications to ranking, visualization and community detection

Michael Fanuel [1]

[1] Katholieke Universiteit Leuven

Many problems related to graphs and networks, like for instance multiscale community detection or visualization, can be solved by using the so-called combinatorial Laplacian. Various diffusion processes on networks are generated by a series of normalized combinatorial Laplacians, providing efficient tools in many applications. Recently, several deformations of this discrete Laplacian have been used for solving a variety of problems in applied mathematics; some important examples are the signed Laplacian and the connection Laplacian. Within this context, we propose a class of deformed Laplacians and discuss their properties in view of applications. Among all the options, a possible deformation is the dilation Laplacian whose least eigenvector (i.e., the one of the smallest eigenvalue) can be used to rank objects from ”noisy” pairwise comparisons; in this problem, the objects are the nodes of a graph and the comparisons are the directed edges. The nodes may for instance represent currencies and the edges may be associated to exchange rates. While still using the dilation Laplacian, we can compute a ranking of players in sport tournaments, where cyclic inconsistencies in the comparisons may arise. Another type of deformed Laplacian is the magnetic Laplacian, which is complex valued and Hermitian. The least eigenvectors of the magnetic Laplacian, called the magnetic eigenmaps, can be used in order to visualize directed networks and to uncover certain types of community structures in directed graphs. In this talk, an overview of the construction of such deformed Laplacians will be given in the light of certain analogies with physical systems. Several illustrations of potential applications will be outlined.

# Contributed posters

## The Evolution of Networks during the Development Process: Evidence from Rural Gambia

Simon Heß [1]
Dany Jaimovich [1]
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[1] Goethe University, Frankfurt

This paper sheds light on the question of how the process of economic development affects interactions in economic and social networks. We study networks of exchanges in rural villages of The Gambia, West Africa, in the context of a randomized program that directly allocates resources of an economically significant magnitude to villages. We find significantly fewer exchanges in treatment villages, but no evidence for heterogeneous program effects. We investigate several possible mechanisms, and our findings are most consistent with a village-level transformation process from a gift economy to a more formal economy (Kranton, 1996). Regarding development interventions, our findings suggest the networks-channel as an avenue through which programs may have unintended consequences that should be considered when costs and benefits are evaluated.

# The ground truth about metadata and community detection in networks

Leto Peel [1]
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Across many scientific domains, there is common need to automatically extract a simplified view or a coarse-graining of how a complex system's components interact. This general task is called community detection in networks and is analogous to searching for clusters in independent vector data. It is common to evaluate the performance of community detection algorithms by their ability to find so-called ground truth communities. This works well in synthetic networks with planted communities because such networks' links are formed explicitly based on the planted communities. However, there are no planted communities in real world networks. Instead, it is standard practice to treat some observed discrete-valued node attributes, or metadata, as ground truth. Here, we show that metadata are not the same as ground truth, and that treating them as such induces severe theoretical and practical problems. We prove that no algorithm can uniquely solve community detection, and we prove a general No Free Lunch theorem for community detection, which implies that no algorithm can perform better than any other across all inputs. However, node metadata still have value and a careful exploration of their relationship with network structure can yield insights of genuine worth. We illustrate this point by introducing two statistical techniques that can quantify the relationship between metadata and community structure for a broad class models. We demonstrate these techniques using both synthetic and real-world networks, and for multiple types of metadata and community structure.

## Power Networks — A network approach to voting theory

Ádám Telek [1]

[1] University of Alicante

In this paper I study elections where the preferences of the voters are derived from their position in the social network. I argue that in some cases studying the ideology of the electorate is not the right way to understand the result of an election. In small electorates or in committees the personal connections can be much more important than political ideology. I develop a voting model where these personal connections add up to a social network and I study what network properties and the social structures lead to a voting equilibrium. I show that single peaked preferences on chain and tree networks are inherent in my model, then I define a set of networks where the equilibrium is robust to changes in the intensity of a connection. Finally I provide a method to locate potential Condorcet winners in the network. In the discussion I relate my approach to the practice of using centrality measures (betweenness or eigenvector centrality) in the analysis and in an illustrative example I calibrate my model to predict the victory of the Medici family in a medieval power struggle.

# Empirical household contact networks and their implication for infectious disease spread

Pietro Coletti [1]
Niel Hens [1]

[1] University of Hasselt

Airborne infectious diseases such as influenza are primarily transmitted from human to human by means of social contacts and thus easily spread within households. Epidemic models, used to gain insight in infectious disease spread and control, typically rely on the assumption of random mixing within households. Until now there was no direct empirical evidence to support this assumption. In this work, we present the first social contact survey designed to study contact networks within households. The survey was conducted in Flanders in 2010-2011 focusing on households with young children. We analysed data from 318 households totaling 1266 individuals with household sizes ranging from 2 to 7 members. Exponential-family random graph models (ERGMs) were fitted to the within-household physical contact networks to reveal the processes driving close contact between household members, both on weekdays and weekends. The fitted ERGMs showed a high degree of clustering, with individuals tightly connected within a household and, specifically on weekdays, decreasing connectedness with increasing household size. Furthermore, we found that the odds of a physical contact between father and child is smaller than for any other pair except for older siblings. This supports the findings of te Beest et al. (2014) i.e. pertussis infection of a child by the father or a sibling takes longer than through other pathways. Epidemic simulations from a discrete-time chain binomial model assuming random mixing within households and using realistic contact networks simulated from the fitted ERGMs, showed only small differences between the two mixing assumptions. Finally, we discuss how the implementation of contact duration may affect the aforementioned picture and we present preliminary results on simulations that take into account the different duration of each contact.

## Stationarity of the inter-event power-law distributions

Yerali Gandica [1]
Joao Carvalho [2]
Fernando Sampaio Dos Aidos [2]
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A number of human activities exhibit a bursty pattern, namely periods of very high activity that are followed by rest periods. Records of these processes generate time series of events whose inter--event times follow a probability distribution that displays a fat tail. The grounds for such phenomenon are not yet clearly understood. In this communication we will present some results concerning the use the freely available Wikipedia's editing records to unravel some features of this phenomenon. We will show that even though the probability to start editing is conditioned by the circadian 24 hour cycle, the conditional probability for the time interval between successive edits at a given time of the day is independent from the latter. We confirm our findings with the activity of posting on the social network Twitter. Our result suggests there is an intrinsic humankind scheduling pattern: after overcoming the encumbrance to start an activity, there is a robust distribution of new related actions, which does not depend on the time of day.

# Do you believe what you know? Stereotype learning in the context of social networks

Julia Eberlen [1]
Olivier Klein [1]
Matteo Gagliolo [1]

[1] Université Libre de Bruxelles

"Belgians like to drink beer" is a common stereotype in- and outside of Belgium. However, we would be hard-pressed to indicate when we learned about it, as clearly, nobody is born with that knowledge. In addition, knowing about the stereotype is not the equivalent of believing it. We propose that stereotypes are the product of social learning that depends on an individual's position in a network. We created an agent-based model in order to investigate how people might come to know about stereotypes and are currently implementing the difference between knowledge and endorsement. In the model, agents are connected in a scale-free network generated by the powerlaw cluster graph algorithm (Holme & Kim, 2002) with a clustering coefficient of 0.14. Each node represents one individual who has the ability to learn and remember. The model contains one single stereotype and learning is formalized as purely social. This means that each agent takes into account what it already knows about the stereotype in addition to the stereotype-relevant information presented by its network neighbors. While what the agent "knows" is a nuanced, continuous stereotype, what its neighbors see is different: from their point of view, the agent will show dichotomous stereotype information, namely whether or not it believes in the stereotype. This reflects people's shortcomings in presenting their knowledge in a differentiated, nuanced manner, as well as our tendency to simplify and categorize the information surrounding us. The model is currently being tested in a number of configurations, differing in network structure, allocation of initial biases towards one or another stereotype to the nodes, and parameters of the learning rule. Ultimately, this work will give us further evidence on the impact of network structure on the formation and transmission of stereotypes.

# Participants

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