# Book of Abstracts

## ECCS'11 Vienna

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Vienna, Sep 12-16, 2011

Editors: S. Thurner and M. Szell

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## Preface

This present volume contains the abstracts of the talks and poster presentations submitted to the *European Conference on Complex Systems*, held in Vienna from September 12 to 16, 2011. The conference has covered the main topics

- Foundations of Complex Systems
- From Molecules to Living Systems
- Policy, Planning and Infrastructure
- Collective Behavior, Society and Crisis
- Interacting Populations
- Complexity and Computer Science

ECCS'11 has further hosted a collection of 20 topical Satellite Conferences and focus meetings. Contributions to satellites who shared their abstracts with ECCS'11 are also found in this volume.

Vienna, August 2011
S. Thurner and M. Szell

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# Keynote Lectures

### Structure, evolution and dynamics of gene regulatory networks

M. M. Babu*

*MRC Laboratory of Molecular Biology, Cambridge, United Kingdom*

The availability of complete genome sequences and the wealth of literature on gene regulation have enabled us to model an organism's transcriptional regulation system in the form of a network. In such a network, transcription factors or target genes are represented as nodes and regulatory interactions are represented as directed edges. In this talk, I will address the following aspects of transcriptional regulatory networks: (i) Structure and organization: I will first introduce the concept of networks and discuss our understanding of the structure and organization of transcriptional networks. (ii) Evolution: I will then describe the different mechanisms and forces that influence network evolution and shape network structure. (iii) Dynamics: Here, I will discuss studies that have integrated information on dynamics such as mRNA abundance, half-life, etc with data on transcriptional network in order to elucidate general principles of regulatory network dynamics. In particular, I will discuss how cell to cell variability in the levels of transcription factors could permit differential utilization of the same underlying network by distinct members of a genetically identical cell population. Finally, the implications for evolution, development, disease and specific applications such as genetic engineering will also be discussed.

### The Fractal Geometry of the Mandelbrot Set

R. L. Devaney*

*Boston University, Boston, USA*

In this lecture we describe several folk theorems concerning the Mandelbrot set. While this set is extremely complicated from a geometric point of view, we will show that, as long as you know how to add and how to count, you can understand this complexity (almost) completely. We will encounter many famous mathematical objects in the Mandelbrot set, like the Farey tree and the Fibonacci sequence. And we will find many soon-to-be-famous objects as well, like the "Devaney" sequence. There might even be a joke or two in the talk.

### Generalized entropies

M. Gell-Mann*

*Santa Fe Institute, Santa Fe, USA*

### The Structure and Dynamics of The Network of Export Similarity

R. Hausmann*

*Harvard University, Cambridge, USA*

As countries develop, they acquire the capacity to make and export products that they were until then unable to do. What factors affect this process? In this paper we show that beyond changes in domestic factors, countries are positively affected by the productive capacity of their neighbors. Having a neighbor that already exports a particular good increases the probability that a country will add that product to its export basket in the future by 44%. This result controls for all static sources of similarity between countries and for time-varying changes in income, relative factor endowments and product characteristics, showing that the diffusion observed here is not driven by similarity in language, geology, colonial past, or other attributes that neighbors may share. This productive diffusion process overwhelms the differentiating effects that come from competition through trade, which would make countries move away from, rather than towards the products that are exported by their trading partners. We show that the countries that are now in the European Union have become more similar, in spite of more intense trade, shedding new light on how economic integration

affects economic outcomes. In collaboration with D. Bahar and C.A. Hidalgo.

### Evolution of masting – synchronized and intermittent reproduction of trees

Y. Iwasa*

*Kyushu University, Japan*

Trees in mature forests often show intermittent reproduction (masting), synchronized over a long distance. According to the dynamics of the resource reserve of individuals, trees can show a large between-year fluctuation in the seed crop even in a constant environment. Reproduction of different trees may be synchronized if fruit production is limited by the availability of outcross pollen. We study conditions for masting to evolve. Based on the analysis of invasibility of mutants, we confirm that for the evolution of masting, the seedlings (young plants) need to survive for multiple years. In addition, specialist seed predators promote the evolution of masting.

### Tracing the source of complexity in evolution

P. Schuster*

*Universität Wien, Vienna, Austria and Santa Fe Institute, Santa Fe, USA*

Every biologist will - I think - agree with two statements: (i) Evolution is an enormously complex process and (ii) biological evolution on Earth proceeds from lower towards higher complexity. Each of the two assertions contains a paradox that needs to be resolved. Despite the apparent complexity of evolutionary processes, the dynamics of natural selection is exceedingly simple, and despite the undeniable increase in complexity from unicellular bacteria to man, prokaryotes were not replaced by more complex organisms as bacteria are still with us and even within us. The lecture will mainly address the first paradox and make a suggestion how to resolve it: Not the dynamics of evolutionary processes is complex, but complexity is an attribute of the relation between genotypes and phenotypes commonly addressed as fitness landscape, be it the mapping of polynucleotide sequences onto structures or the relation between the human genome and the entire spectrum properties and functions, which constitute the human phenotype. Fitness is an environment dependent, highly elaborate property projecting the phenotype onto the evolution relevant axis measuring reproductive success. In case of the exceedingly simple system of in vitro evolution of RNA molecules the genotype-phenotype map can be accessed through RNA folding of sequences into structures. The conventional simple case of one sequence forming one structure will be reviewed together with the more elaborate situation considering long-lived metastable conformations together with the minimum free energy structure. A suggestion is made for the introduction of complexity into simple model landscapes. Natural molecules, in particular single conformational RNA molecules like the tRNAs or RNA switches with two or more conformations, are designed by evolution for their specific function and their properties differ significantly from those of RNAs with random sequences.

### Molecular networks to elucidate and perturb biological systems

G. Superti-Furga*

*CeMM, Austrian Academy of Sciences, Vienna, Austria*

Physiology relies on the concerted action of a number of molecular interactions of gene products and metabolites operationally organized in so-called pathways and in yet larger molecular networks. Through integrated approaches using systematic protein identification by mass spectrometry - bioinformatics (proteomics) as central "glue" it is possible to obtain physical, functional and "knowledge" maps of human pathways. We use affinity proteomics to chart protein complexes around cellular or viral "pertubers" as well as larger molecular networks. We also use drugs to establish the profiles of the proteins interacting with the drug. The combination of these approaches allows not only to map drug/ligand- target relationships but also to position these elements onto molecular pathways and to estimate their impact on the system. We mapped pathways involved in innate immunity and in chronic myelogenous leukemia (CML). We also compared drugs against CML, investigated the Bcr-Abl protein network and progressed in our effort to map innate immunity pathways. The data suggest: 1. It is possible to map entire human signalling pathways using mass spectrometry-based

proteomics, 2. Proteomics helps to identify the "sensors" of pathogen-associated-molecular patterns. 3. Even "modern" targeted drugs are promiscuous, 4. Drug targets may generally be part of larger protein complexes, 5. Drugs are likely to be understood as systems perturbers and not "erasers" of protein activity (with some gain-of-function effects matching loss-of-function). 6. Viral proteins "re-wire" the cellular circuitry for their maximal benefit- to escape cellular defence mechanism and promote viral programs. A better understanding of these drug and virus perturbations should form the basis for an informed combination-type of therapy. In collaboration with A. Pichlmair, K. Kandasamy, F. Grebien, O. Hantschel, Ch. Baumann, K. Bennett and J. Colinge.

### Towards increasing complexity in the hominin lineage: Confrontational scavenging as a possible source for language and cooperation

E. Szathmáry*

*Parmenides Centre for the Study of Thinking, Munich, Germany and Collegium Budapest, Hungary*

The emergence of language and the high degree of cooperation found among humans seems to require more than a straightforward enhancement of primate traits. Some triggering episode unique to human ancestors was likely necessary. Here it is argued that confrontational scavenging was such an episode. Arguments for and against an established confrontational scavenging niche are discussed, as well as the probable effects of such a niche on language and co-operation. Finally, several possible directions for future research are suggested.

Bickerton, D., Szathmary E. (2011) Confrontational scavenging as a possible source for language and cooperation. BMC Evol Biol, to appear.

### Evolution of eusociality and limitations of inclusive fitness theory

C. Tarnita*

*Harvard University, Cambridge, USA*

Eusociality, in which some individuals reduce their lifetime reproductive potential to raise the offspring of others, underlies the most advanced forms of social organization and the ecologically dominant role of social insects. For the past four decades, kin selection theory, based on the concept of inclusive fitness, has been the major theoretical attempt to explain the evolution of altruism and social behavior, and in particular the evolution of eusociality. In this talk I will propose a standard natural selection model that attempts to explain the evolution of eusociality without needing to invoke the concept of inclusive fitness. Furthermore, I will discuss the applicability and the limitations of inclusive fitness as a framework and show that it requires assumptions that are restrictive and unlikely to hold for any realistic situation. I will argue that standard natural selection theory in the context of precise models of population structure represents a simpler, more solid and more general approach.

### Statistical mechanics for nonergodic systems - An overview

C. Tsallis*

*Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil*

The celebrated Boltzmann-Gibbs entropy and statistical mechanics are based on hypothesis such as ergodicity and probabilistic (quasi)independence. What can be done when these simplifying hypothesis are not satisfied, which is indeed the case of many natural, artificial and social systems? The nonadditive entropy Sq and its associated nonextensive statistical mechanics attempt to provide a theoretical frame for approaching a wide class of such complex systems. Some basic concepts and some recent applications will be presented.

[1] C. Tsallis, Introduction to Nonextensive Statistical Mechanics - Approaching a Complex World (Springer, New York, 2009); [2] C. Tsallis, Entropy, in Encyclopedia of Complexity and Systems Science, ed. R.A. Meyers (Springer, Berlin, 2009); [3] J.S. Andrade Jr., G.F.T. da Silva, A.A. Moreira, F.D. Nobre and E.M.F. Curado, Phys. Rev. Lett. 105 , 260601 (2010); [4] F.D. Nobre, M.A.R. Monteiro and C. Tsallis, Phys. Rev. Lett 106,

140601 (2011); [5] http://tsallis.cat.cbpf.br/biblio.htm

**Searching for Simplicity and Unity from Cells and Ecosystems to Cities and Companies**

G. B. West*

*Santa Fe Institute, Santa Fe, USA*

Despite its extraordinary complexity and diversity, many of Life's most fundamental and complex phenomena, whether cells or cities, scale with size in a surprisingly simple and universal fashion. For example, metabolic rate scales approximately as the 3/4-power of mass over 27 orders of magnitude from complex molecules to multicellular organisms. Time-scales (such as lifespans and growth-rates) and sizes (such as genome lengths, RNA densities, and tree heights) scale with exponents which are typically simple multiples of 1/4. These "universal" 1/4 power scaling laws follow from underlying constraints embedded in the dynamics and geometry of space-filling, fractal-like, branching networks leading to a general quantitative, mechanistic, predictive framework that captures many essential features of diverse biological systems, including vasculature, growth, cancer, aging and death, sleep, cell size, and evolutionary rates. Similarly, most characteristics of cities and companies, from wages to AIDs cases, scale systematically with size in an approximately universal fashion suggesting that generic principles, presumably reflecting underlying social network dynamics, are at play. Are cities and companies "just" very large organisms? Why then do almost all cities persist, yet all companies die? Why does the pace of life continue to accelerate and how is this related to innovation and wealth creation that fuel socio-economic systems? Answers to such questions have potentially dramatic implications for growth, development and global sustainability.

# I. Foundations of Complex Systems

### Superstatistics in high energy physics

C. Beck*

*Queen Mary, University of London*

Superstatistical techniques are very useful to analyse the behaviour of complex systems with time scale separation and to develop a generalized statistical mechanics formalism of the underlying complex system [1,2]. In this talk, after briefly reviewing this concept, I will concentrate on recent applications of superstatistics in high energy physics. Scattering data of high energy processes are well fitted by superstatistical models [3]. However, generalized statistical mechanics can also enter at a much more fundamental level, when discussing structure and dynamics of the vacuum [4,5]. I will discuss a model in which the vacuum is regarded as a kind of selfsimilar network of spontaneous momentum fluctuations that are coupled with running standard model coupling constants. This network model of the vacuum exhibits strongly chaotic behaviour and appears to distinguish observed standard model parameters as states of minimum vacuum energy.

[1] C. Beck, Phil. Trans. Royal Soc. 369, 453 (2011) [2] E. Van der Straeten, C. Beck, Physica A 390, 951 (2011) [3] C. Beck, Eur. Phys. J. A 40, 267 (2009) [4] C. Beck, Spatio-temporal Chaos and Vacuum Fluctuations of Quantized Fields, World Scientific (2002) [5] M. Schaefer, C. Beck, Dyn. Syst. 25, 253 (2010)

### Beyond space for community detection in spatially embedded networks

P. Expert*, T. S. Evans, V. D. Blondel, R. Lambiotte

*Imperial College, London, UK*

Many complex systems are organized in the form of a network embedded in space. Important examples include the physical Internet infrastucture, road networks, flight connections, brain functional networks and social networks. The effect of space on network topology has recently come under the spotlight because of the emergence of pervasive technologies based on geo-localization, which constantly fill databases with peoples movements and thus reveal their trajectories and spatial behaviour. Extracting patterns and regularities from the resulting massive amount of human mobility data requires the development of appropriate tools for uncovering information in spatially-embedded networks. In contrast with most works that tend to apply standard network metrics to any type of network, we argue for a careful treatment of the constraints imposed by space on network topology. In particular, we focus on the problem of community detection and propose a modularity function adapted to spatial networks. We show that it is possible to factor out the effect of space in order to reveal more clearly hidden structural similarities between the nodes. The method presented is tested on a large mobile phone network.

### Multiple Equilibria, Binges, and Chaos in Rational Addiction Models

G. Feichtinger*, D. A. Seidl

*TU Wien, Vienna, Austria*

Addictions play a role of increasing importance in our time. People become addicted to alcohol, nicotine, drugs, eating, television, work and many other activities. At a first look addictive behaviour seems to be the result of irrationality. A rational decision maker maximizes the discounted utility stream over an infinite time horizon subject to a budget which can be replenished by habit-dependent earnings. Addiction to the good requires that past consumption increases the marginal utility of current consumption. Becker and Murphy (1988) have established the existence of unstable steady states leading to tipping behavior for optimal consumption rates. In the first part of this talk a simple linear-quadratic optimal control model is used to illustrate how their approach fits into the framework of multiple equilibria and Skiba points. By changing the degree of addicition and the level of harmfulness we obtain a variety of behavioral patterns including 'cold turkey'. In the second part it is shown that strong complementarity might imply persistent oscillations in the optimal consumption pattern. Using Hopf bifurcation theory, we prove the existence of stable limit cycles. Finally, we will show how chaotic consumption patterns may evolve in a discrete, two-state behavioral addiction model. The occurence

of chaos is proven by locating a horseshoe in the phase space.

### Multiplex Modeling of Cascade Dynamics on Complex Networked Systems

K. I. Goh*, K. Lee, I. M. Kim

*Korea University, Seoul, Korea*

Most studies on complex networks thus far have focused on the properties of networks with a singular or aggregated link-type. Recently, it is increasingly appreciated that many real-world systems are better represented by a network of multiplex structure with coupled, interacting, or interdependent connection types. In such systems, the collective dynamics may exhibit behaviors unanticipated from a simplex network perspective. Here we take cascade dynamics on the global economic system [1] as specific example and apply a multiplex modeling to dynamics of multiplex complex systems. By comparing its simplex counterpart, we study how the collective dynamics of cascading failures is affected, finding that multiplex modeling reveals much richer and consequential dynamics than a simplex modeling considering only aggregate connectivity [2]. In particular, we show that a simplex modeling severely underestimates the degree of potential systemic risks as probed by the avalanche sizes obtained from the cascade model. Therefore, we suggest that the multiplexity should be considered an essential concept for a better understanding of real-world complex system dynamics.

[1] K.-M. Lee, J.-S. Yang, G. Kim, J. Lee, K.-I. Goh, and I.-M. Kim. PLoS ONE 6, e18443 (2011). [2] K.-M. Lee, K.-I. Goh, and I.-M. Kim. in preparation (2011).

### How to classify entropies?

R. Hanel*, S. Thurner

*Medical University of Vienna, Austria*

Shannon and Khinchin have used four information theoretic axioms to uniquely determine entropy to be of Boltzmann-Gibbs type. For many systems with non-trivial scaling properties - where the larger system is not just more of the smaller system - one of these axioms may be violated. The so called separation axiom (Shannon-Khinchin axiom 4) will in general not be valid and entropy takes a more general form which is determined by two scaling laws. Two scaling exponents, c and d, associated with the scaling laws, unambiguously determine the equivalence class of a statistical systems entropy in its thermodynamic limit. Given this two parameter class of generalized entropies the question of when do such entropies apply can be tackled. The extensive entropy of a statistical system is determined by the way the number of accessible states in a system grows with its size. As a consequence systems with extensive non Boltzmann-Gibbs entropies have to be strongly non ergodic. We illustrate the situation for binomial processes and argue that generalized entropies could be relevant for self organized critical systems such as sand piles, for certain types of spin systems and problems associated with anomalous diffusion.

### Collective behaviour in complex networks: scaling and beyond

C. Von Ferber, R. Folk, Y. Holovatch*, R. Kenna, V. Palchykov

*Coventry University, UK*

Phase transitions and critical behavior in complex networks currently attract much attention because of their unusual features and broad array of applications, ranging from socio- to nanophysics. The questions we address in this report concern two fundamental principles of critical phenomena: universality and scaling. Both of these questions have to be reconsidered when a system resides on a network. To this end, we consider several simple models on scale-free networks and analyze their critical behavior in terms of scaling functions which are of fundamental interest in the theory of critical phenomena. We obtain general scaling functions for the equations of state and thermodynamical functions extending the principle of universality to systems on scale-free networks and quantifying an impact of fluctuations in the network structure on critical behavior. Moreover, we address the logarithmic corrections to the leading power laws governing thermodynamic quantities that appear as the second order phase transition point is approached. We show the validity of scaling relations for the new set of the logarithmic correction-to-scaling exponents and derive new scaling relations for the exponents of logarithmic corrections, for which these relations were unknown.

1. C. von Ferber, R. Folk, Yu. Holovatch, R. Kenna, V. Palchykov. Phys. Rev. E (2011), (to appear) [arXiv:1101.3680v1]. 2. V. Palchykov, C. von Ferber, R. Folk, Yu. Holovatch, R. Kenna. Phys. Rev. E, vol. 82 (2010) 011145.

### Representation of Dirac delta in q-plane waves and q-generalization of the inverse Fourier transform

M. J. Jáuregui*, C. Tsallis

*Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, Brazil*

We shall introduce a q-generalization of the plane waves, namely the q-plane waves, from the definition of the q-exponential function, which is well-known and widely studied in the literature on nonextensive statistical mechanics. We shall prove that the q-plane waves can be normalized, and also that Dirac delta can be represented by a linear combination of q-plane waves. On the other hand it will be shown that it is possible to determine the inverse of the q-Fourier transform, which is relevant in the proof of the q-generalized central limit theorem, in the space of probability densities by considering some extra information related to the concept of the q-moments. Moreover, a method that makes this possible will be presented.

### Extension of Computational Mechanics to Continuous Clustered Data

D. Kelly*, K. Wiesner, M. Dillingham, A. Hudson

*University of Bristol, UK*

The definition and quantification of complexity has long been a source of debate. One of the most promising answers has been provided by Crutchfield, Shalizi and co-workers. They identify complexity as the amount of information required to optimally predict the future of a process. A methodology, named computational mechanics, was developed to compute this quantity for discrete time series. Here we present a scheme for extending computational mechanics to continuous data which clusters around discrete values. This adapted methodology is applicable to the analysis of single molecule experimental data, giving advantages over current analysis methods (see http://arxiv.org/abs/1011.2969). Additionally we examine certain aspects of the Causal State Splitting Reconstruction (CSSR) algorithm of Shalizi and Klinkner which has been re-implemented to include the adaptation to continuous, clustered data and will be made publicly available. Finally we discuss this method in the context of quantification of the information processing capacity of natural systems (natural computation).

### Optimization with landscape encodings: the case of number partitioning

K. Klemm*, A. Mehta, P. F. Stadler

*Leipzig University, Germany*

Many stochastic heuristics for combinatorial optimization operate by iterating mostly improving (downhill) steps on an energy (cost) landscape. These local search strategies include gradient descent, adaptive walk and simulated annealing. The difficulty of an optimization problem manifests itself in the abundance of local optima where local search may “get trapped” before finding a globally optimal solution (ground state). A so-called encoding of a landscape establishes a surjective mapping from a different set Y into the set of original solutions X. Even though Y is typically chosen much larger than X, searches in the landscape on Y (with a suitable adjacency relation) may outperform searches in the original landscape. This effect of faster search in a larger landscape for the same problem instance has been demonstrated for the number partitioning problem with a so-called prepartition encoding [Ruml et al 1986, J Optimiz Theory Appl, 1986] feeding into the differencing algorithm [Karmakar and Karp, 1982]. Here we analyze this encoded landscape in detail with the following results. (1) Enrichment: compared to the original landscape, the density of states of the encoded landscape is concentrated at energies close to the ground state. (2) Non-ruggedness: we do not find strict local minima, at least not in random instances of numerically tractable size. (3) Neutrality: on average, most neighbours of a configuration x have the same energy as x itself. (4) Optimization dynamics: adaptive walks are outperformed by a simple ”Randomly Generate and Test“ (RGT). Although the ”smoothness” of the encoded landscape means that the search dynamics are not interrupted by local minima, this is counteracted

by neutrality: the latter generates energy plateaux, where time is wasted in random walks before a lower energy configuration is found by the search algorithm. In conclusion, the encoding supports optimization by the enrichment of low energy solutions.

### On Synchronization of Pulse Coupled Oscillators

J. Klinglmayr*

*Klagenfurt University, Austria*

Pulse coupled oscillators are an example of complex systems with non linear effects. The interaction between these oscillators relies on the oscillator's update function. In our work we consider a new kind of coupling strategy. We introduce self-coupling - a pulse emitted by an oscillator now also causes the emitting oscillator to adjust- and additionally demand that an oscillator reduces its internal phase upon pulse reception. This presents a new approach for pulse coupling used in wireless technical systems. This strategy is now investigated on its effects in fully connected networks in systems without delay or with random delays. In our work, we can analytically show that the system reaches synchronization in delay-free environments. If delays are present we can ensure that a certain precision is reached, a close to synchrony state, since synchronization in this case is not possible. We further adapt our statement to also hold for slightly inhomogeneous oscillators. For a generalization to random networks we notice that the positive dynamics induced by our update function break down if links are missing. To overcome this defect, we introduce intentional heterogeneities on the behavior of the individual oscillator. This slight modification on the oscillator's behavior has a dramatic effect. It equals out network deficiencies and distributes the pulses, that are sent within the system, to all oscillators. By this modification we can show that synchronization is now achieved even in sparsely connected networks. To demonstrate the dynamics of our presented algorithm we consider line topologies. Within this kind of network we observe that certain patterns can form. These patterns turn out to structure the dynamics and are of vital importance to understand the formation of synchronization.

### Time-varying Networks

V. Latora*

*University of Catania and INFN Catania, Italy*

Interacting agents moving over geographic space, functional relationships between the cortical areas of a brain during the performance of a task, messages and contacts over online social systems, are all examples of networks in which the links are frequently changing over time. All such systems have to be described in terms of time-varying networks, i.e. time-ordered sequences of graphs defined over a fixed set of nodes. Concepts, metrics and models for static networks do not straightforwardly apply to time-varying networks. In this talk we will discuss new metrics and models which allow to capture crucial information on the time ordering, correlations and eventual concurrency of links in real time-varying complex networks. We will also investigate how the additional dimension of time influences collective processes. Finally, as an application, we will show how to exploit temporal centrality measures to contain mobile phone viruses that spread via Bluetooth contacts.

### Statistically validated networks in bipartite complex systems

F. Lillo*

*Scuola Normale Superiore Pisa, Palermo University and Santa Fe Institute*

Many complex systems present an intrinsic bipartite structure where elements of one set link to elements of the second set. In these complex systems, such as for instance the system of actors and movies, elements of one set are qualitatively different than elements of the other set. The properties of these complex systems are typically investigated by constructing and analyzing a projected network on one of the two sets (for example the actor network and the movie network). Complex systems are often very heterogeneous in the number of relationships that the elements of one set establish with the elements of the other set, and this heterogeneity makes it very difficult to discriminate projected network links that are just reflecting systems heterogeneity from links relevant to unveil the properties of the system. Here we introduce an unsupervised method to statistically validate each link of a projected network against a null hypothesis that takes into

account system heterogeneity. We apply the method to a biological, an economic and a social complex system. The method we propose is able to detect network structures which are very informative about the organization and specialization of the investigated systems, and identifies those relationships between elements of the projected network that cannot be explained simply by system heterogeneity. We also show that our method applies to bipartite systems in which different relationships might have different qualitative nature, generating statistically validated networks in which such difference is preserved. (PlosOne, in press)

### Self-organization of Peirce's semiosis in complex systems

A. Loula*, J. Queiroz

*State University of Feira de Santana, Brazil*

A number of investigators maintain that C.S.Peirces pragmatic notion of meaning process (semiosis), and its ontological counterpart, must be considered in terms of complex emergent, self-organizing adaptive systems. As Kelso (1995: 1) argues, symbols, like the whirlpools in a river, may evince relatively stable patterns or structures that persist for a certain lapse of time, but actually they are neither static nor atemporal. In this light, we have theoretically and empirically explored diverse consequences of simulation and modeling in terms of Peirces semiosis as a complex system (e.g., Loula et al 2010a,b; Queiroz & Merrell 2009; Ribeiro et al, 2007; Queiroz & Merrell 2006; Queiroz & El-Hani 2006a,b). Semiosis is described as an emergent self-organizing process in a complex system of distributed sign users interacting locally and mutually affecting each other. Contextually grounded, semiosis is characterized as a pattern that emerges through the cooperation between agents in a communication act, which concerns an utterer, a sign, and an interpreter. To model semiosis as a self-organized process, we developed a Artificial Life experimental protocol to investigate a potentially self-organizing dynamics of communication, via local interactions. Results show that semiosis can be viewed as a self-organizing process that can conduct to an ordered state of sign usage by means of self-correcting dynamics. We also explore the adequacy and philosophical implications of self-organization to Peirces pragmatism and theory of signs, especially with his communication model accompanied by habit change processes.

Kelso, S. (1995) Dynamic Patterns: The Self-organization of Brain and Behavior. The MIT Press. Loula, A. , Gudwin, R., El-Hani, C. Queiroz, J. (2010a) Emergence of self-organized symbol-based communication in artificial creatures. Cognitive Systems Research 11:131-147. Loula, A. Gudwin, R.; Ribeiro, S. & Queiroz, J. (2010b). On Building Meaning: A Biologically-Inspired Experiment on Symbol-Based Communication. Brain Inspired Cognitive Systems. Amir Hussain, Igor Aleksander, Leslie S. Smith, Allan Kardec Barros, Ron Chrisley and Vassilis Cutsuridis (Eds.). Springer New York. pp.77-94. Queiroz, J. & El-Hani, C. N. (2006a). Semiosis as an emergent process. Transactions of C.S.Peirce Society: A Quarterly Journal in American Philosophy 42 (1): 78-116. (2006b). Towards a multi-level approach to the emergence of meaning processes in living systems. Acta Biotheoretica 54 (3): 174-206. Queiroz, J. & Merrell, F. (2009). On Peirce s pragmatic notion of semiosis –a contribution for the design of meaning machines. Minds & Machines 19: 129-143. Ribeiro, S., Loula, A., Araújo,I., Gudwin, R. & Queiroz, J. (2007). Symbols are not uniquely human. Biosystems 90: 263-272.

### Multi-stage complex contagions

S. Melnik*, J. Ward, J. P. Gleeson, M. A. Porter

*University of Oxford, UK*

Studying models of cascades allows one to gain insights into a variety of processes ranging from the spread of fads and ideas in social networks to the appearance of cascading failures in infrastructure networks. To date researchers have mostly considered single-stage cascade models wherein the propagation of a cascade is characterized by a single subpopulation of active agents [1-4]. Thus, it is usually assumed that all active agents exhibit the same amount of influence on their peers. In reality however, regular users of, say, a certain product are often more enthusiastic in recommending it to their friends than just casual users. We present a model of multi-stage cascading dynamics in which agents can exert different amounts of influence on their peers depending on the stage of their adoption (i.e., the level of their commitment to a certain product or idea) [5]. We investigate the dynamics of this model on networks and provide an analytical method for solving it. This method, for example, gives excellent prediction for the expected sizes of cascades on configuration model networks.

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### A multifractal hierarchical scale-free network and Ising model on the network

J. Moon*, M. Park, S. Kim

*POSTECH, Pohang, Korea*

With rapid advance of information technology gathering and analyzing data of large-scale complex networks such as the World Wide Web (WWW), social and biological networks became possible in recent years. It has been found that complex networks often exhibit small-world and scale-free properties, and some even have fractal scaling behavior if they are measured by the box-counting method. Several models explaining and depicting the fractal property of complex networks appeared recently. In this work, we present a hierarchical scale-free network model which is multifractal in the sense of box-counting dimension. We also study the behavior of Ising model on the network. First, we generalize Migdal-Kadanoff(M-K) type hierarchical scale-free lattices(1),(2) with monofractal dimension to have spatially inhomogeneous fractal dimensions. The multifractal dimension spectrum Dq of the generalized network is exactly solvable by constructing a generator in the fashion of Halsey et al.(3) Second, we run Monte-Carlo simulations of zero field Ising model on these networks using Wolff algorithm. We examine the effects of the underlying network being multifractal, and show that the Ising model can have different phase transitions depending upon the construction of the underlying network.

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### Competitive Diffusions in Nonlinear Fokker-Planck Equations and Related Entropies

M. S. Ribeiro, F. D. Nobre*, E. M. F. Curado

*Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, Brazil*

Nonlinear Fokker-Planck equations are appropriate to describe many real phenomena, although their main motivation concerns anomalous diffusion. One important result associated with nonlinear Fokker-Planck equations is the H-theorem, and its generalizations, which leads to relations involving terms of these equations and entropic forms. In the present work we study a Fokker-Planck equation with two nonlinear diffusion terms, characterized respectively, by the pairs of parameters, $(D_1, q_1)$ and $(D_2, q_2)$ , where $D_i$ represent the diffusion constants and $q_i$ the exponents of the probability of each term. Recently, the particular case $(D, 2)$ and $(k_{\mathrm{BT},1})$ was shown to be relevant for a system of interacting vortices performing an overdamped motion in a random pining landscape, which is known to be an appropriate model to describe flux front penetration in disordered type-II superconductors [1]. Particularly, at zero temperature, the interactions among vortices leads to a strongly-correlated state, and such a system is well described in terms of the nonextensive statistical mechanics formalism. For finite temperatures one has an interesting competition between the temperature and the strength of interactions among vortices, leading to an stationary solution that is expressed in terms of a $W$-Lambert function; only in the high-temperature limit this solution approaches the Gaussian distribution, associated with the Boltzmann-Gibbs entropy. We show that the more general case $(D_1, q_1)$ and $(D_2, q_2)$ exhibits other interesting particular cases, where stationary solutions may be calculated exactly, leading to possible physical applications. Particularly, the ratio $\eta = (D_1/D_2)$ plays an important role, leading to a crossover between the two anomalous regimes.

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### Correlations between tag statistics and network topology

P. Pollner*, G. Palla, K. Orosz, T. Vicsek

*Statistical and Biological Physics Research Group of HAS, Budapest, Hungary*

We investigate the fundamental statistical features of tagged (or annotated) networks having a rich variety of attributes associated with their nodes. Tags (attributes, annotations, properties, features, etc) provide

essential information about the entity represented by a given node, thus, taking them into account represents a significant step towards a more complete description of the structure of large complex systems. Our main goal here is to uncover the relations between the statistical properties of the node tags and those of the graph topology. We study the behavior of the clustering coefficient and the community structure of the network, and how these topological properties correlate with the distribution of the node tags. We show some examples where missing labels can be predicted from the graph topology and where unclassified nodes can be classified to communities.

### A dynamical model for hierarchy and modular organization: The trajectories en route to the attractor at the transition to chaos

A. Robledo*

*Universidad Nacional Autonoma de Mexico, Mexico*

We show that the recently determined [1] features of the dynamics towards the Feigenbaum attractor, present in all low-dimensional maps with an unimodal feature, form a hierarchical construction with modular organization that leads to a clear-cut emergent property. This well-defined nonlinear model system combines a simple and precise definition, an intricate nested hierarchical dynamical structure, and the emergence of a power-law property absent in the exponential-law modules. It is put forward as a working example for complex collective behavior. Elements in our analysis are the following: i) The pre-images of the attractor of each of the related supercycles appear entrenched in a fractal hierarchical structure of increasing complexity as period doubling develops. ii) The limiting form of this rank structure results in an infinite number of families of well-defined phase-space gaps in the positions of the Feigenbaum attractor. iii) The gaps in each of these families can be ordered with decreasing width in accordance with power laws and are seen to appear sequentially in the dynamics generated by uniform distributions of initial conditions. iv) The power law with log-periodic modulation associated with the rate of approach of trajectories towards the attractor is explained in terms of the progression of gap formation. v) The relationship between the law of rate of convergence to the attractor and the inexhaustible hierarchy feature of the pre-image structure is elucidated.

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### Noise-induced phenomena in one-dimensional maps

Y. Sato*

*Hokkaido University, Japan*

Problems of complex behavior of random dynamical systems is investigated based on numerically observed noise-induced phenomena in Belousov-Zhabotinsky map (BZ map) and modified Lasota-Mackey map with presence of noise. We found that (i) both noise-induced chaos and noise-induced order robustly coexist, and that (ii) asymptotical periodicity of density is varied according to noise amplitude. Applications to time series analysis are also discussed.

### Three-body degree correlations in networks

R. Sinatra*, S. Meloni, J. Gomez-Gardenes, V. Nicosia, V. Latora

*Università di Catania, Italy*

The structure of real-world networks is far from being random. To understand to which extent this is the case, networks are compared to null models, usually random graphs with the same degree distribution as the original networks. When doing this, it emerges that real networks display non-trivial features, absent in their randomized version, such as degree-degree correlations, clustering coefficients scaling with the node degree, or the so-called "rich club effect". In this work, we show how to measure three-body degree correlations, and we give empirical evidence that non-trivial three-body correlations do occur in a number of networks, if compared to null models which exhibit not only the same degree distribution, but also the same (two-body) degree-degree correlations as the original networks. We write an analytical expression for the clustering coefficient in terms of three-body degree distribution, showing that in many cases it perfectly approximates the real clustering coefficient, and we extend the concept of rich-club. Finally, we prove that three-body correlations play an

important role in many processes on networks, such as in biased random walks or in the evolution of strategies in some evolutionary games.

### Chimera order in spin systems

R. Singh*, S. Sinha, S. Dasgupta

*The Institute of Mathematical Sciences, Chennai, India*

It has recently been shown that a population of oscillators having identical environments can exhibit a heterogeneous phase topology termed as *chimera state*. We extend this phenomenon to the broader perspective of order-disorder transitions in physical systems with discrete states. By exact analytic treatment we show that chimera states can occur in a system of Ising spins in thermal equilibrium. We also numerically establish the existence of chimera ordering in 3-dimensional models of layered magnetic materials (such as manganites) suggesting possible means of experimentally observing it.

### Dramatic Effects of Coupling Between Isolated Networks

H. E. Stanley*

*Boston University, Boston, USA*

We will introduce the "modern theory of coupled networks" in terms understandable to the nonspecialist. Then we will describe specific examples that support the idea that there are universal features that characterize coupled networks that are completely different than those which characterize isolated networks. As an example, we will discuss very recent work on the dramatic effects of coupling between isolated networks [1-3], emphasizing its direct applicability to specific problems of preventing network breakdown. The key concept is that systems comprised of more than one network are vastly more susceptible to failure cascades than isolated networks. We also discuss potential applications to understanding financial breakdowns. This work was carried out in collaboration with a number of colleagues, chief among whom are S. Havlin & R. Parshani (Bar-Ilan), S. V. Buldyrev (Yeshiva U), X. Huang, J. Gao, V. Plerou, G. Paul.

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### Determination of the scale of coarse graining in complex network of earthquake

N. Suzuki*

*Nihon University, Japan*

The seismic data are mapped to growing random networks [1,2]. Vertices and edges of such networks correspond to coarse-grained events and event-event correlations, respectively. Yet unknown microscopic dynamics governing event-event correlations and fault-fault interactions is replaced by these edges. Global physical properties of seismicity can then be explored by examining its geometric (e.g., topological etc.), statistical and dynamical properties. Firstly, we show that the earthquake network is scale free, being characterized by the power-law connectivity distribution [3,4]. We give a physical interpretation to this result based on network growth with the preferential attachment rule together with the Gutenberg-Richter law. Secondly, we study the small-world structure of the earthquake network reduced to an undirected simple network [4]. The value of the clustering coefficient is found to be much larger than that of the classical random network. In addition, the average path length is very small. Thirdly, we show that the earthquake network possesses hierarchical organization [5]. We interpret this fact in terms of vertex fitness and vertex deactivation by the process of stress release at faults. Fourthly, We find that the earthquake network has the property of assortative mixing. This point is an essential difference of the earthquake network from the Internet that has disassortative mixing. Combined with other dynamical properties [6], the present results imply that yet unknown mechanism governing seismicity may be so-called glassy dynamics on a growing complex network. These observations have

obvious importance for constructing and improving physical models of seismicity such as the ones exhibiting self-organized criticality. In the discussions above, the cell size, which is the scale of coarse graining needed for constructing an earthquake network, has remained as a free parameter. We finally report a method for determining it based on the scaling behavior of the network [7,8]. Quite remarkably, both the exponent of the power-law connectivity distribution and the clustering coefficient are found to approach the respective universal values and remain invariant as the cell size becomes larger than a certain value, $l_*$, which depends on the number of events contained in the analysis, in general. This $l_*$ fixes the scale of coarse graining. Universality of the result is demonstrated for all of the networks constructed from the data independently taken from California, Japan and Iran.

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### Linking probabilistic and algorithmic measures of complexity

K. Wiesner*

*University of Bristol, UK*

Measures of complexity are plentiful and not always possible to compare. In particular, there are two fundamentally different approaches. One is based on the Shannon entropy which is defined over probability distributions and the other is based on algorithmic complexity which is defined for single objects. We discuss two prominent such measures, the statistical complexity defined by Crutchfield, Shalizi et al. [J. P. Crutchfield and K. Young, "Inferring statistical complexity,"Phys. Rev. Lett. 63, (1989) 105; C. R. Shalizi and J. P. Crutchfield, "Computational Mechanics: Pattern and Prediction, Structure and Simplicity,"J. Stat. Phys. 104, (2001) 817-879] and the effective complexity defined by Gell-Mann and Lloyd [M. Gell-Mann and S. Lloyd, "Information measures, effective complexity, and total information,"Complexity 2, (1996) 44-52]. Where the former is based on the Shannon entropy the latter is based on algorithmic complexity. We show that there is a unique mapping from the statistical complexity to the effective complexity. Hence, the two measures are identical in the sense that they are linearly dependent. Although the effective complexity is uncomputable in the Turing sense our result yields a way to compute it approximately for a large class of complex systems, those with ergodic-type behaviour or translation-invariant structure. The result illustrates that the fractured landscape of complexity measures is not as disconnected as it seems. This might be a first step in finding a unified set of complexity measures; which is not to indicate that there necessarily is a *unique* set of complexity measures. These new results are based on recent developments in the physics of information and quantum information [K. Wiesner et al., "Information erasure lurking behind measures of complexity", Preprint, 2010, http://arxiv.org/abs/0905.2918; M. Gu et al., "Sharpening Occams Razor with Quantum Mechanics,"Preprint, 2011, http://arxiv.org/abs/1102.1994]. The results will also be discussed in relation to a classification framework of complexity measures [J. Ladyman et al, "What is a complex system?,"Preprint, 2011, http://philsci-archive.pitt.edu/8496/].

### Van Kampen Expansion: Its exploitation in some social and economical problems

H. S. Wio*, J. R. Iglesias, J. A. Revelli

*Universidad de Cantabria, Italy*

In this talk we will analyze a simple opinion formation model consisting of two parties, A and B, and a group I, of undecided agents. We will assume that the supporters of parties A and B do not interact among them, but only interact through the group I, and that there is a nonzero probability of a spontaneous change of opinion (A $\rightarrow$ I, B $\rightarrow$ I). After writing the master equation, and via the Van Kampen's $\Omega$-expansion approach, we obtain the so called "macroscopic" evolution equation, as well as the Fokker-Planck equation governing the fluctuations around the macroscopic deterministic behavior. Within the same approach, we could also obtain information about the typical relaxation behavior for small perturbations. We will also consider the effect of the presence of 'fanatics' , that is supporters that do not change their opinion. In addition, herding models approaches (see, e.g., Kirman, 1991, 1993; Lux and Marchesi, 1999; Alfarano et al., 2005, Gordon, 2006) emphasize social and economic processes where because of the social interactions the agents display a

tendency to follow the crowd. Those models consider generally binary choices, i.e. to buy or not to buy a product or to buy or sell an asset. In some cases the behavior of the agents is characterized as bullish or bearish. But in normal situations we can be in the presence of a choice among three or more possibilities: bearish-bullish-undecided, or more general: to buy to sell or to keep an asset. Hence, we discuss the adaptation of the initial model to such a situation for markets.

# II. From Molecules to Living Systems

### Simulation of prokaryotic gene evolution under coding signal as selection pressure

P. Blazej*, P. Mackiewicz, S. Cebrat

*University of Wroclaw, Poland*

We have elaborated a new model of prokaryotic gene evolution which takes into account two different mutational pressures associated with various replication mechanism of two DNA strands (i.e. leading and lagging). As a selection pressure we used a gene coding signal which was calculated by a modified algorithm for gene finding. To check how the proposed model of gene evolution works, we have considered population of 200 individuals. Each individual consisted of 475 protein coding sequences from Borrelia burgdorferi genome showing striking DNA asymmetry resulting from the replication-associated mutational pressure. We simulated evolution of these genes under stable, opposite, and changing in time the mutational pressure.

### Unveiling structural reorganization of functional brain networks in mild cognitive impairment

J. M. Buldu*, R. Bajo, F. Maestu, N. Castellanos, I. Leyva, I. Sendiña-Nadal, J. A. Almendral, A. Nevado, F. Del Pozo, S. Boccaletti

*Universidad Rey Juan Carlos, Spain*

A key issue in neuroscience is the understanding of the coexistence of local specialization and long distance integration in the complex structure of the brain. Graph theory provides valuable tools to describe the topological organization supporting cognitive processes [1]. In particular, the approach led to a characterization of structural and functional networks in the brain, typically endowed with high clustering and short non-Euclidean distance between nodes, the fingerprint of a Small World (SW) architecture. In addition, graph analysis helps to identify network signatures of impairment in pathological conditions, such as the network organization in Alzheimers Disease (AD) [2]. A crucial point is whether the pathophysiology of AD would be detected long before the actual diagnosis of the disease. Indeed, the identification of preclinical AD could significantly enhance the benefit of new drugs and vaccines, at the time when the severe brain damage, such as widespread brain atrophy, associated with AD, has not taken place yet. On the other side, Mild Cognitive Impairment (MCI) is an intermediate state between healthy aging and dementia. In fact, 12% to 15% of MCI subjects develop some form of dementia per year. This makes MCI patients an ideal population to search for neurophysiological profiles of prediction of who will develop dementia. In the work presented here we characterize the topological properties of functional brain networks in MCI subjects. We apply methods from complex networks theory to compute macroscopic and mesoscopic parameters of the functional networks in a group of nineteen MCI patients and a group of control participants of the same size. Brain activity was measured by means of MEG during a Sternbergs letter-probe memory task and functional connectivity was calculated using the Synchronization Likelihood (SL), a measure to evaluate the generalized synchronization based on the theory of nonlinear dynamical systems. We show that an increase in global network synchronization in MCI patients occurs, as compared to healthy controls, and that an evolution of the MCI functional network towards a more random structure takes place [3]. Interestingly, MCI patients feature an increased synchronization between brain areas, and AD patients a corresponding decrease in connectivity. Finally, based on the experimental observations, we develop a computational evolutionary network model that simulates the transition from healthy to MCI topology, and satisfactorily reproduces the changes in the network metrics observed in MCI subjects.

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### Complexity of human brain networks

E. Bullmore*

*University of Cambridge, United Kingdom*

I will describe recent studies that have explored the non-random topology of human brain networks using neuroimaging techniques such as functional MRI and MEG. Human brain networks are typically small-world,

modular, with fat-tailed degree distributions. High efficiency has been associated with superior cognitive performance, as predicted by workspace theory, but at a premium on connection distance or wiring cost. The interplay between spatial and topological aspects of human brain networks is likely to be important in understanding their normal and abnormal development in disorders like schizophrenia.

### Global properties of commonly expressed human proteins

J. Colinge*, T. R. Burkard, K. L. Bennett, G. Superti-Furga

*CeMM, Austrian Academy of Sciences, Vienna, Austria*

We define the central human proteome (CHP) as the common protein repertoire expressed by all the human cells. Through proteomics experiments we have obtained a first unbiased approximation of the CHP. Bioinformatics analysis shows that the CHP is comprised of evolutionary conserved proteins involved basic metabolic pathways and proteostasis (maintenance of appropriate protein concentration). Integration of the CHP with known human protein-protein interactions (PPIs) reveals a central human interactome (CHI) that, beyond its primary tasks, has a topology optimized to synchronize protein synthesis with the other biological processes. In general, the CHI is also broadly distributed among human PPIs and therefore gains in robustness. The CHP and the CHI have characteristics that confer them additional flexibility to operate in multiple environments. In particular, their proteins have more transcriptional flexibility due to exon-rich gene structures and an augmented ability to bind other proteins. In fact, this flexibility is further supported by the participation of CHP members, in a context specific manner, in specialized protein complexes (Bossi and Lehner, 2009). We further explore a new facet of this capability to analyze the participation in diseases. Finally, we show that several features of the CHP are protein abundance dependent, e.g. their ability to bind and positions in pathways, thereby suggesting that evolution has optimized energy consumption by making the most common and the most abundant building blocks as flexible as possible. Such trends are not experimental biases from available human datasets.

### Structure of the "hyper-brain"network during social interactions

F. De Vico Fallani*, V. Nicosia, R. Sinatra, L. Astolfi, F. Cincotti, D. Mattia, C. Wilke, A. Doud, V. Latora, B. He, F. Babiloni

*University of Rome La Sapienza, Italy*

The comprehension of the mechanisms subserving the social interactions in groups of individuals can be addressed through mathematical frameworks belonging to the so-called game theory. In a game, the players adopt one among a set of possible actions (strategies), and the reward or penalty for each player crucially depends on the actions taken by all players [1]. Game theory has proven useful in the investigation of the neural basis of social interactions and social decision-making. In particular, researchers have investigated what happens in the brain of subjects involved in games where each player can choose between cooperative and non-cooperative behaviors, or between altruistic and selfish behaviors, with the aim of understanding the modification of brain activity related to the selected strategy [2]. Most of the approaches used so far to characterize brain responses during social interaction have the major limitation of measuring signals from just one player at a time. The functional connectivity between the brain activities of two interacting individuals is thus not measured directly, but inferred from independent observations subsequently aggregated by statistical models, which associate observed behaviors and neural activation. In the present study, we used i) simultaneous neuroelectric recordings from two subjects, i.e. EEG hyper-scanning ii) localization of cortical activity, i.e. high-resolution EEG iii) and spectral Granger causality indexes, i.e. Partial Directed Coherence (PDC) [3] to estimate, in the frequency domain, the information propagation among different cortical regions within- and between-brains. We considered one of the most common cooperation games, the Iterated Prisoners Dilemma (IPD) [4], where each player can either defect or cooperate with the other player and might punish the opponent for previous non-cooperative behavior. The EEG period of interest (POI) is the time interval during which both players are formulating the strategies to adopt in the next round of the game i.e. the initial decision-making phase. The resulting networks of functional connectivity estimated from the cortical activity of the two players were described by a directed weighted graph [5]. Each node corresponds to a specific cortical region - also called region of interest (ROI) - of one of the two subjects brain. A weighted link between two ROIs indicates the degree of their interaction as estimated by the PDC. In practice, we represented the functional connectivity of the two brains altogether in the same graph: a link in the graph can be either an intra-brain or an inter-brain connection, according to the fact that it expresses the relationship between two ROIs belonging

to the same brain, or between a region of one brain and a region of the other brain. We named such a graph a hyper-brain network. The obtained hyper-brain networks were analyzed using tools and measures coming from complex networks theory, such as efficiency and modularity [6]. The results obtained by analyzing 26 couples of subjects show that the structure of the hyper-brain networks corresponding to situations in which individuals play cooperatively is significantly different from cases of couples playing in a "selfish" way. Specifically, the hyper-brain network obtained from a couple of players both playing as defectors exhibits the best modular separation into two clusters corresponding to the ROIs of the two distinct brains. On the contrary, the ROIs of the two brains are more intertwined when the two players adopt cooperative or tit-for-tat strategies. We also found that the modifications of the connectivity between ROIs in the frontal and pre-frontal areas of the couples brains are the main responsible of the structural changes discriminating collaborative from selfish behaviors. Finally, we tested the possibility to predict the outcome of a game from the structural analysis of the hyper-brain network obtained from signals recorded during the decision-making process. This suggests that EEG hyper-scanning and hyper-brain networks allow the direct observation of neural signatures of human social interactions, and might play a key role in understanding the cerebral processes generating and generated by social cooperation or competition.

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### The influence of the energetic constraints in a stochastic model of catalytic reaction networks

A. Filisetti*, A. Graudenzi, R. Serra, M. Villani, D. De Lucrezia, I. Poli

*European Centre for Living Technology, Venice, Italy*

The life that we know today is the result of billions of year of evolution. The first forms of life were surely simpler than today and different scenarios such as "the RNA world", the "metabolism first"approach, and the lipid world, have been proposed to investigate the broad subject of the origin of life. However, in all these cases the emergence of autocatalytic sets of molecules seems to have played an important role. Based on combinatorial rationales, in 1986 Stuart Kauffman demonstrated that the emergence of autocatalytic sets is bound to occur, if the molecular diversity is higher than a certain threshold. Such an emergent propriety has been observed also in several other theoretical models that consider the dynamics as well [2-6]. Nevertheless, observing actual autocatalytic sets in wet lab experiments remains a very difficult task. On the one hand, it could be possible that the simplification introduced by the in-silico models are unrealistic with respect to the biological systems, on the other hand the real environmental conditions proposed by the theory may be not correctly implemented in real experiments. In order to get a better understanding of the reasons of such discrepancy between model-based expectations and actual experiments, we introduced a new model which is inspired by that of Stuart Kauffman and by the dynamical modifications proposed by Bagley, Farmer etc., but which allows us to relax some of their limitations. In particular, the dynamics of the interactions between the molecules is stochastic, based on the well-known Gillespie algorithm [8] with asynchronous updating. This model has no limits to the growth of the number of different species (except for those related to finite computing recourses), which are created by suitable constructor operators from the existing ones. The introduction of an asynchronous update of the system leads to a difficulty in representing the reactions graph related to the activity of the system. For this reason we introduce a temporal window such that if a reaction does not occur again within the temporal window, it is removed from the reaction graph. It is important to notice that this description is very different from the one provided by means of a deterministic approach (e.g. by means of a set of ODEs) in which we would observe a graph containing all the possible reactions. We also developed a simplified deterministic version of the model [12], which is interesting per se and which also provides a guidance to drive the more demanding simulations of the stochastic system in interesting regions of the wide parameter space. The model was described in detail elsewhere [10-11] and in this work we focus on the introduction of energy within the model. Biological systems are taken far from the equilibrium by means of a continuous flow of matter and energy; while the influence of the incoming flux of the former has been described in our previous works [9-12], energy has not been previously taken into account. Therefore, we here assume to have two different kinds of reactions, the endoergonic reactions, which need an energized reactant to occur and the neutral reactions that do not have such a need. Note that exergonic reactions may also occur, but in the

present description of the model there is no coupling between exergonic and endoergonic reactions, so the effect of the former are equivalent to those of neutral reactions. Temperature is assumed to be kept constant by coupling with a heat bath. It is assumed that the energy is brought into the system by means of an incoming flux of energy carriers that rapidly diffuse into the system releasing energy to the non-energized molecules that are promoted to an energized state. In particular, our aim is to understand the influence on the dynamics of the system of the rate of energy intake, which is of course related to the value of the incoming flux of energy carriers. We simulated different reaction networks ensembles varying this parameter and observing the different behaviours. What we observe is a non obvious effect: the production of new species actually depends on the energy intake in a non-linear way: there is a level which leads to a maximum production of new species in autocatalytic sets, which declines if the energy input is further increased. Finally, although we observe an enhanced activity in accordance with the presence of the ACSs, these are not robust structures and in some cases they continue to disappear and reappear. This may be a possible explanation of why it is so difficult to observe the emergence of such structures in a wet lab experiment. Furthermore, the structural properties of the system are not sufficient to guarantee the emergence of ACSs: a right tuning of the dynamical key parameters of the system is thus fundamental to observe interesting behaviors and this could be a further indication about the difficult in observing them in a laboratory.

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### Stability of Boolean and continuous dynamics

F. Ghanbarnejad*, K. Klemm

*Universität Leipzig, Germany*

Gene-regulatory dynamics has mathematical descriptions by continuous concentrations evolving according to rate equations versus discrete concentration variables coupled by so-called Boolean networks. The present work identifies and to some extent resolves an inconsistency between notions of stability in state-continuous and state-discrete models of gene-regulatory systems. Boolean networks arise as a discretization of time and state variables in continuous regulatory systems described by differential equations. The binary discretization faciliates computational and analytical treatment of these systems while often conserving the stylized behaviour of interest. Despite recent success in Boolean modeling of real systems [see e.g. Albert & Othmer, JTB (2003); Li et al, PNAS (2004)], the mathematical prerequisites and consequences of the discretization are not understood systematically. One of the difficulties may be rooted in inconsistent notions of stability. Stability in state-continuous systems is well-defined as resilience against small displacements in state space. This stability concept, however, is not applicable to the Boolean dynamics because infinitesimally small neighbourhoods in state space cannot be suitably defined. Therefore most studies of stability in Boolean networks resort to flip perturbations: the state of one dynamical variable is changed and the spreading or healing of the damage is tracked. Here we analyze the stability of the Boolean (state-discrete) network dynamics comparing to the continuous counterpart. We find that Boolean and original continuous models describing essentially the same

system lead to different predictions of stability because of their inconsistent stability criteria. To demonstrate this point, we study stability of trajectories in random Boolean networks for different values of the average sensitivity $\langle s \rangle$ of the Boolean functions. Under flip perturbations, we recover the well-known transition from healing to non-healing behaviour at sensitivity $\langle s \rangle = 1$. In the corresponding continuous dynamics, however, stable behaviour is observed for almost all values of $\langle s \rangle$ except for the region around $\langle s \rangle = 1$. Then as the most interesting result, the so-called chaotic regime in Kauffman networks is actually stable when applying the established notion of stability for dynamical systems. As a consequence, noise resilience and sensitivity to switching environmental inputs are not conflicting. Rather they are compatible properties arising naturally in networks with sufficiently complex functions of their nodes. A more detailed account of this work is available as e-print arXiv:1103.4490 [physics.bio-ph].

### Why do metabolic networks look like they do?

P. Holme*, M. Huss

*Umeå University, Sweden*

This year a decade has passed since the discovery that metabolic networks are scale-free. I will make a brief review of research relating network topology and function in metabolic reaction systems with a focus on our contributions. I discuss the hypothesis that network clusters correspond to functional modules. Metabolic network, however represented, are not as distinctly modular as the cartoon picture of intricately wired subsystems with few I/O-terminals. Does this reflect a trade-off between functionality and robustness, or is it an inevitable consequence of non-enzymatic reaction kinetics, or something else? I also discuss optimal levels of representations - if one uses a multiplex, directed, and perhaps bipartite, representation one can encode more information, but standard methods are harder to apply. If one goes for a simple-graph representation with vertices connected by undirected edges, then how can one encode as much functional information as possible? I will also mention how one can use other types of reaction systems, like reactions in planetary atmospheres, as null-models of metabolic networks. Finally I look forward and discuss open questions within reach with current and future data sets.

### Delineating signaling network from cancer related pathways

C. Lahiri*, M. I. Ashraf, R. Sabarinathan

*Technische Universität München, Germany*

Cancer is a phenomenon of abnormal growth, invasion and translocation of a group of cells. The reasons of cancer being the abnormalities in the genetic material, the ways it can happen could be many. A number of pathways have been shown to be affected wherein numerous proteins are known to be involved. While several reports exist on the role and importance of these individual proteins, the most indispensable of these playing major roles in evoking such abnormalities has not been worked out in detail. We have adopted a theoretical approach to build a protein interaction network of these and other associated signal transduction proteins from where we find a skeleton of the network delineating those which could be thought to be the most indispensable ones.The backbone comprises EGFR, CDK2, RAF1, RB1, STAT3, CTNNB1, CDKN1B, EP300, SMAD2, TGFB1, PCNA and SOS1 all of which are directly reported to be involved in regulating cell growth and/or adhesion between cells. Our method is the first of its kind to figure out, albeit theoretically, potential proteins encoded by these signaling pathways of cancer for therapeutic targets.

### Multi-scale modularity in brain dynamics

D. Remondini*, S. Stramaglia, W. Liao, G. Castellani, D. Marinazzo

*Bologna University, Italy*

We study fNMRI signals of spontaneous neural activity in human brain, with a time resolution of 1 sec and a spatial resolution corresponding to about 5000 voxels, for a period of about 500 sec. Our aim is the characterization of the topological architecture of the resting brain by combining different complex networks methods, at different temporal and spatial scales. We characterize the time correlation structures at different time windows, showing a non trivial multi-scaling, and the resulting network obtained for different correlation

thresholding values. The effective connectivity network, obtained by Granger causality analysis, is also characterized for the resting brain, and compared with those resulting from Transfer entropy. Our results show a highly organized modular architecture and associated topological properties of the human brain even in the absence of specific stimuli or behaviors.

### Randomizing genome-scale metabolic networks

A. Samal*, O. C. Martin

*Universite Paris-Sud, Orsay, France and Max Planck Institute, Leipzig, Germany*

A network observed in a particular context may appear to have "unusual" properties. To quantify this, it is appropriate to randomize the network and test the hypothesis that the network is not statistically different from expected in a motivated ensemble. However, when dealing with metabolic networks, the straightforward randomization of the network generates fictitious reactions that are biochemically meaningless. Here we provide several natural ensembles for randomizing such metabolic networks. A first constraint is to use valid biochemical reactions. Further constraints correspond to imposing appropriate functional constraints. We explain how to perform these randomizations and show how they allow one to approach the properties of biological metabolic networks. An implication of the present work is that the observed global structural properties of real metabolic networks are likely to be the consequence of simple biochemical and functional constraints.

http://arxiv.org/abs/1012.1473

### An integrative framework for gene regulatory network inference

A. Sîrbu*, H. J. Ruskin, M. Crane

*Dublin City University, Ireland*

Building models for gene regulation has been an important aim of Systems Biology over the past years, driven by the large amount of gene expression data that has become available with the development of high throughput measurement techniques. Models represent regulatory interactions between genes and transcription factors, and can provide better understanding of biological processes, and means of simulating both natural and perturbed systems (e.g. those associated with disease). While qualitative models have been successfully built for several gene regulatory networks (GRNs), quantitative modelling is still limited, due to data issues such as noise and restricted length of time series, where these are typically used for GRN reverse engineering. These issues create an under-determination problem, with many models possibly fitting the data, so that, at present, reliable quantitative modelling is not possible. However, large amounts of other types of biological data and knowledge are available, such as knockout experiments, annotations, binding site affinities for transcription factors and so on, and it has been postulated that integration of these can improve model quality obtained. However, integration has not been fully explored, to date. In this work we present a novel integrative framework for different types of data that aims to enhance GRN model inference. This is based on evolutionary computation and uses different types of knowledge to derive a customised mutation operator and complex evaluation criteria in order to distinguish between candidate models. Specifically, the inferential algorithm uses information from (i) knockout experiments, (ii) annotations of transcription factors, (iii) binding site motifs (expressed as position weight matrices) and (iv) DNA sequence of gene promoters, to drive the algorithm towards more plausible network structures. Additionally, the evaluation basis is extended to include (i) structure information indicated by binding site affinities, (ii) correlation to gene expression time series and (iii) error on noise added data. This framework is applied to both synthetic and real gene expression data, for which the effect of the integration is discussed. Models obtained by data integration display a larger amount of direct interactions, and can achieve improvement, (for synthetic datasets), and stability, (for real datasets), in simulation.

### A morphospace for biological computating

R. Solé*

*University Pompeu Fabra, Barcelona, Spain*

Computation is defining trait of biological systems and a broad framework that captures the complex adaptive nature of molecules, cells and organisms. Computation is also at the core of the genotype-phenotype mapping,

since it provides a natural framework to define function in a self-consistent way. The study of existing biological systems (from signalling cascades to ant colonies or brains) as well as the evolution of synthetic in silico networks performing computations reveals a number of nontrivial patterns of organization, sometimes in clear conflict with standard view of engineering or optimization. In spite of our increasing knowledge, there is a lack of a theoretical framework where computation and its possible forms is integrated within a general picture. Synthetic biology provides a new avenue where engineered molecular circuits can be implemented to perform non-standard com- putations. Here we review recent advances in the domain of multicellular synthetic computing and suggest a potential morphospace of computational systems including both standard and non-standard approximations.

### The effect of metabolic theory on life histories

Y. Song*, S. Scheu, B. Drossel

*Darmstadt University of Technology, Germany*

We explore the consequences of metabolic theory on life histories and life history evolution. We use a mathematical model for an iteroparous species and its resources, taking into account the allometric scaling of consumption, metabolism and mortality with consumer body mass. Mortality is assumed to be density-dependent, and the dynamics of resources are modelled explicitly. We find that populations that have more or faster growing resources have a shorter life span and a higher mortality, and that populations with a larger adult biomass have a larger number of offspring per female and a larger biomass density. When we allow the adult body mass to evolve, it increases with time without limits. When we allow the offspring body mass to evolve, it becomes smaller. Both trends result from the allometric scaling of mortality and are kept in limits by trade-offs other than those included in our model.

# III. Policy, Planning and Infrastructure

### Visualising and Capturing Volatility in Rank-Value Systems: Applications to City and Firm Size Distributions

M. Austwick*, O. O'Brien, M. Batty

*University College of London, UK*

An element in a rank-scale system can exhibit volatility over time in its ranking and/or the underlying value. Characterising these properties allows us to differentiate between those systems which exhibit hierarchy-preserving value volatility, those which show hierarchy disruption resulting from small value changes, and those which are highly volatile or stable in both parameters. In general, these volatility statistics will vary with time, so such an assessment can identify the point at which a system changes character. Size-rank relations in cities and firms appear relatively stable in aggregate, but the paths of individual components can be highly volatile in both rank and value. For example, in the top 100 cities comprising the US urban system, only 21 of the original top 100 in 1840 still remain in the top 100 in the year 2000. The average rank half-life of a city (the number of years taken to fall or rise by 50 ranks) is 90 years. By comparison, the top 100 firms of the Fortune 500 lists from 1955 to 1995 show a rank half-life of 26 years, despite the fact that there is remarkable stability in their rank-size relations. This implies a change at the aggregate level which is much smoother than at the individual level. In this paper we develop a series of statistical indicators to measure this volatility in rank and value, and then classify individual elements (and the system as a whole) according to these measures. We define a series of statistics to track elements over time: rank/value mean and standard deviation; summed absolute rank/value changes; and equivalent statistics scaled to give proportional changes, in order to disentangle the effect of small-number noise in the tail. Similarly, for a power-law-like rank-value distribution, we would expect a large proportional change in value to be required for a change in rank for the larger entities. We thus begin to classify the elements comprising these systems and the systems themselves using these statistics. As we move from individual to aggregate, we are also able to identify clusters of similar elements within a system, and similar systems across different datasets. Our analysis is strongly motivated by visualisations of the dynamics - in rank-time space (as clocks), in rank-value space (as graphs), in rank-value-time spaces (3D pseudosurfaces) - and how the act of animating the systems passage through time accentuates dynamics but makes long-term trend spotting more difficult. This research takes place as part of the EPSRC-funded ENFOLDing project on Global Dynamics, and we will discuss the potential of this work to inform our research on migration, trade, development and security.

### Comparing the values of key input parameters for pedestrian stream models to life measurements

M. Davidich*, G. Koester

*Siemens Research, Munich, Germany*

Simulations of pedestrian streams imitate the behavior of crowds in different infrastructures, such as buildings or urban spaces, for statistical and economical purposes, but above all to improve the safety of the population. To do this successfully crowd behavior must be faithfully reproduced. But how do we decide which phenomena must be captured and how do we measure success of failure? The answers to these questions must be based on real observations, ideally, observations in a life environment and not just a laboratory frame or, even less desirable, pure literature studies. Here, we analyse data extracted from videos taken on a major German railway station. We investigate whether the data from our measurements matches well known and widely used values from literature such as the distribution of free-flow velocities and the fundamental diagram. We finally demonstrate how the measured values are used in a pedestrian stream simulator to calibrate the model to a specific scenario.

### Modelling a network rural municipalities: an individual-based approach

S. Huet*, G. Deffuant

*Cemagref LISC, France*

Modernity is associated with the vast movement of populations from rural territories to the cities, now taking place all over the world. Yet, the population is now increasing in French rural municipalities! The last French Census has confirmed this trend, which could be the sign of a new stage in modern demography.

Indeed, since the eighties, several indicators converge to show that the rural areas tend to be more and more attractive. However, this trend is far from homogenous: some regions or counties continue to see their population decreasing within the global increase. In the framework of the European project PRIMA we developed an individual-based model to study this evolution at low scale, considering networks of rural municipalities. We adopted a microsimulation approach, already adopted in other contexts for analysing policies' impacts (e.g. Ballas et al. 2005, Holme et al. 2004, Moeckel et 2003). We first initialise the individuals using the different statistical data available at municipality level (Gargiulo et al. 2010). The individuals change of state mainly according to probabilities which are derived from data. However, some changes are based on simple decision functions which have to be calibrated on various data issued from the French Census or Labour Force Survey. To be more precise, the model considers individuals members of households living in a dwelling situated in a rural municipality. The individual is born, grows up, forms couple or divorces, has babies, moves from a residence to another. She also chooses a profession (statistically correlated with her parents' jobs) and searches for a job in a municipality or in a urban area. The jobs are offered by the municipalities. Regarding the jobs offered in the service sector, we consider a part linked to an external action and another part linked to the size of the population of potential consumers for the municipality considered. This last endogenous offer part is directly computed from the size of the population and the distance to a service pole of the municipality through a generalized linear model calibrated on data. The rest of the job offer is exogenously defined through scenarios. Other exogenous scenarios rule the migration in and out the rural municipalities. This model has been implemented on a set of seven rural municipalities of the Cantal department, starting in 1990. This first application allows us to identify the different types of evolution of the municipalities according to their characteristics (their size, their age pyramid, their commuting network, ...) and their policy choices. More precisely, we are interested in understanding better the dynamics leading to the development or on the contrary to the decrease and may be disappearance of municipalities and settlements. This approach will be discussed with the stakeholders living in the considered municipalities. In parallel, we study the model in more abstract settings, in order to study its sensitivity to the various parameters.

### Calibrating a complex social model

M. Lenormand*, G. Deffuant, S. Huet

*Cemagref LISC, France*

Calibrating a complex social model is a very important step in the modelling process, because it makes the model simulations compatible with available data at different dates. However, for complex models, it is generally a nightmare very rarely done! We propose a processing chain addressing this challenge and apply it on a particular individual-based model of demographic and activity evolution. More precisely, the process aims at identifying the values of free parameters (e.g. local birth rate, couple splitting rate, susceptibility to move, to accept new jobs...) minimising the differences between statistics observed in the model and census data (e.g. differences in the age pyramid, the distribution of household types, the distribution of activities...), at the census dates. The novelty of the process is to include a sensitivity analysis (Morris, 1991) in an Approximate Bayesian Computation procedure (Marjoram et al, 2003). The principle is to be more careful when sampling sensitive parameters, which decreases the number of useless simulations (outside the thresholds of error) and enhances the precision of the sampling. This approach is illustrated with an individual based model developed in the European project PRIMA with 6 parameters to calibrate and 6 criteria to optimize for two dates of census observation. We assess the quality of the calibration with Census data for variables not used in the calibration, such as the annual number of births and deaths.

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### Modelling the Antonine Plague - Epidemics on the Road and Sea Network of the Roman Empire

D. Löb*, M. Ditter

*Institut für Festkörperphysik, TU Darmstadt*

In the latter half of the second century A.D., a pandemic known as the Antonine Plague ravaged the Roman Empire. Although it is known that it claimed on the order of millions of lives and killed two Roman emperors, its severeness and therefore its contribution to the decline of the Empire are still a subject of controversy

among historians. We propose a stochastic epidemics model on the travel network of the Roman Empire to solve some of the open questions surrounding the plague that historiography alone cannot answer. As a part of our investigations we composed the first comprehensive representation of the Roman travel network fit for use in numerical simulations, using data from Roman road maps (mostly Itinerarium Antonini) and the historiographic literature. With our model we were able to reproduce key aspects of the plague, such as its recurring nature and duration. Since we intend to provide hypotheses testing functionality to historians, our model is benchmarked quantitatively using literary sources and archaeological evidence.

**Accidental Politicians: how Randomly Selected Legislators can improve Parliament Efficiency**

A. Pluchino*, C. Garofalo, A. Rapisarda, S. Spagano, M. Caserta

*Dipartimento di Fisica e Astronomia, Catania University, and Sezione INFN*

In ancient Greece, the cradle of democracy, governing bodies were largely selected by lot. The aim of this device was to avoid typical degenerations of any representative institution. In modern democracies, however, the standard is choosing representatives by vote through the party system. Debate over efficiency of parliament has therefore been centred on voting systems, on their impact on parliamentary performances and, ultimately, on the economic system. In this paper, rediscovering the old Greek wisdom and recalling a famous diagram about human nature by C.M.Cipolla, we show how the injection of a measure of randomness improves the efficiency of a parliamentary institution. In particular, we develop an agent based model of a prototypical Parliament and find an analytical expression, whose predictions are confirmed by the simulations, that determines the exact number of randomly selected legislators, in an otherwise elected parliament, required to optimize its aggregate performance (number of approved acts times average social gain). This result is in line with the recent discovery that the adoption of random promotion strategies improves the efficiency of a human hierarchical organization.

**Efficient Promotion Strategies in a Hierarchical Organization**

A. Rapisarda*, A. Pluchino, C. Garofalo

*Dipartimento di Fisica e Astronomia, Università di Catania*

The Peter principle has been recently investigated by means of an agent-based simulation and its validity has been numerically corroborated. It has been confirmed that, within certain conditions, it can really influence in a negative way the efficiency of a pyramidal organization adopting meritocratic promotions. It was also found that, in order to bypass these effects, alternative promotion strategies should be adopted, as for example a random selection choice [1]. In this paper, within the same line of research, we study promotion strategies in a more realistic hierarchical and modular organization and we show the robustness of our previous results, extending their validity to a more general context. We discuss also why the adoption of these strategies could be useful for real organizations.

[1] A. Pluchino, A. Rapisarda and C. Garofalo, The Peter Principle revisited: a computational study, Physica A 389, 467 (2010)

**Modelling the evacuation of communicating agents**

M. Smyrnakis*, T. Galla

*University of Manchester*

We model and simulate the dynamics of crowd evacuation in a decision making context, based on extensions of continuous social force models and of cellular automata. In particular we consider situations in which agents evacuate rooms, bridges or corridors with several exits. Each agent then needs to make a decision on which exit route to choose, trying to optimise their own payoff, i.e. their chances of safe escape. Overall crowding and limitations in the geometry lead to potentially competitive strategic interaction between individual evacuees. Agents make their decisions based on information available to them (e.g. local degree of crowding, distance from the different potential exits, local direction of flow) and within the physical constraints imposed on them by other agents. The available information may change over time, and agents may revise their decisions as the evacuation progresses, using a myopic adaptation rule. We will also examine the impact of communication

between pedestrians and how the number of agents with access to communication devices (e.g. mobile phones) can influence the total evacuation time.

**Social network structure, collective learning and avoiding herd behaviour**

C. J. Watts*, N. Gilbert

*CRESS, University of Surrey, UK*

The information cascades model of Bikhchandani et al (1992; 1998) demonstrated how the capacity for learning from others can lead to herd behaviour and the emergence of fads and fashions. This is shown for a population of agents making decisions on some issue, such as whether or not to adopt some innovation, given a personal and direct information source of imperfect reliability and knowledge of past decisions by themselves and others. Recent Bayesian analysis (Acemoglu et al, forthcoming) has shown that a population or collective can avoid herd behaviour if organised into a social network. We employ here instead an agent-based simulation, derived from the information cascades model. An agent-based simulation model has the advantages of being able to incorporate various social network structures very easily, and make the workings of the model more visual. We also present results of several experiments. We confirm the potential for social networks to avoid herd behaviour, including the relationships between network size, network density and collective learning performance. In addition, we find that there exists an optimal rate of learning from others for each of a number of network structures, with Erdos-Renyi random networks achieving its best decision-making performance at a lower rate to that for regular grids. This suggests that human agents can improve decision making not only by their choice of the rate at which they consult others, but also by their choice of practices that determine the structure of social interaction networks. This has implications for learning and decision making in groups, organisations and societies, including science policy.

**Citier: Bigger, Denser, Greener**

H. Youn*, L. M. A. Bettencourt, K. Anna, G. B. West

*Santa Fe Institute, Santa Fe, USA*

Human societies are faced with unprecedented rapid urbanization, and hence, recognize the necessity of understanding the economic and environmental sustainability of their growth trajectories. Carbon emissions, among all issues of sustainability, are at once the largest and most critical components of national economic footprints. Only recently, however, have cross sectional data of Carbon emissions in cities become available, which enables us to analyze the metropolitan emission at a macroscopic level. Here we give a quantitative assessment of Carbon emissions of USA metropolitan areas in terms of urban scaling. Our analysis on three independently collected data sets shows the systematic reduction of emissions not only on urban density, which has long been believed to be a major role in economics, but also on the size, expressed as a simple power law. This reduction is more significant for the transportation sectors. The emissions of residential use, on the other hands, show little economies of scale. We believe that our large-scale analysis puts forward a way of categorizing, comparing and estimating urbanization to be further exploited by policy initiatives.

# IV. Collective Behavior, Society and Crisis

### Multi-layer networks in international maritime trade

S. Caschili*, F. Medda

*University College London, UK*

Network modelling has been used as a magnifying glass to observe the interactions between agents at different levels of granularity. In economics the focus of our magnifying glass ranges from the analysis of single customer choices, to trade of goods between nations, and economic frictions in regional economic zones. Each system level has a certain degree of entropy, which is determined by mutual interactions among the agents, as well as external factors that in turn are part of upper and lower system levels. In network analysis, common approaches focus on the analysis of one single marking factor (among many) through a single layer modelling, while a comprehensive synthetic paradigm that takes into account the most prominent factors is missing. In this context we propose the application of a hierarchical multilayer network model for the maritime shipping system whose layers are composed by agents (nations, ports, and carriers) that not only interact horizontally within their layer but also vertically with lower and upper network layer elements. We study the influence of extreme events in these layers and the resilience to errors and attacks, which creates cascade effects in the upper and lower layers. Our aim is to provide a meaningful description of the propagation of these effects (both positive and negative) at different economic scales in maritime shipping and analyse their impacts on local, national and global economies.

### Post-mortem examination of the international financial network

M. Chinazzi*, G. Fagiolo, J. A. Reyes, S. Schiavo

*Sant'Anna School of Advanced Studies, Pisa, Italy*

In this paper we use network analysis to portrait the spread of the recent financial crisis and link its severity to the position of countries within the network of different financial instruments. We claim that by looking at network indicators one can derive a clearer picture about the fragility of different countries compared to the standard country-specific measures of vulnerability. Using recent CPIS data collected by the IMF we test this hypothesis by looking at the (ex-post) predictive ability of standard vs network-based measures of capital account openness. The paper is thus close in spirit to Kali and Reyes (2010), who look at whether trade linkages act as a channel of contagion during financial crises. The availability of recent financial data allows us to look directly to the role played by the international financial network. The source of bilateral financial data is the Coordinated Portfolio Investment Survey (CPIS) performed by the IMF. For each of the country participating to the survey the CPIS reports information on the amount of foreign assets held, broken down by country of issue. It is therefore possible to reconstruct a network of financial relationships linking countries on the basis of the stock of the various assets held by each country. The CPIS data now spans the years 2001-2008 reporting end of the year cross-border holdings of securities between the 74 countries that participate to the survey (reporters) and 237 potential partners. Interestingly, on top on information on total assets, the survey distinguishes between long- and short-term bonds as well as equities. By exploiting this additional information it will be possible to test whether the position within the networks defined by different financial instruments have had heterogeneous effects on the spread of the crisis. Other relevant data are those assembled by Lane and Milesi-Ferretti (2007): this database contains data on gross foreign asset and liability positions for 178 economies plus the euro area as an aggregate over the period 1970-2007. Although there is not network information on these data (we just know the amount of foreign assets and liabilities, not the geographic allocation thereof), they can be useful to build country-specific measures of vulnerability. Finally, we make use of other conventional datasets such as the World Development Indicators from the World Bank, also used by Kali and Reyes (2010) to derive their set of controls. The analysis proceeds in two sequential steps. First of all, we make use of the CPIS data to describe the structural properties of the international financial network (IFN) and their changes in the build-up of the crisis. In previous work (Schiavo et al., 2010) we have documented the hub-and-spoke structure of the IFN, as well as the presence of a "rich club" characterized by strong linkages and clustering. All this suggests that a shock hitting one of the core countries will be quickly transmitted to all member countries, whereas contagion to the periphery will be slower. Exploiting the most recent waves of the CPIS survey we thus wish to compare the main features of the IFN over time, in order to look at whether significant changes occurred in the period that preceded the crisis that could have facilitated its diffusion. Since the CPIS offers a snapshot of the data at the end of the year, comparing 2006, 2007 and 2008 can possibly give us some useful information. In particular, it will be interesting to see whether anything significant happened between September 2008 (when Lehman Brothers collapsed) and the end of the year (when data are collected). Moreover, by exploiting the information on

different kind of instruments (equities, short-term bonds, long-term bonds) we can trace the position of key countries (primarily the US, but also others) in the different IFNs. The second step entails analyzing the predictive capacity of network-based measures of financial integration above and beyond standard, country-specific, indexes of financial vulnerability. More formally, we are going to relate contagion during the recent financial crisis to the variables usually employed to measures vulnerability (see for instance Sachs et al., 1996; Cavallo and Frankel, 2008). Contagion can be defined in different ways: as a dichotomous variables taking values 0/1, using stock market performance (as in Kali and Reyes, 2010), or other measures of banking stress such as the share of nonperforming loans in the economy; another possibility is to measure the time the crisis took to hit the country using Lehman's collapse as the t=0 and looking for a relevant date/event in each country. Standard controls would be basically the same used by Kali and Reyes (2010), namely bank reserves to assets ratio, inflation, GDP growth, current account balance, government expenditures, to which we can possibly add some measures of private sector leverage, share of short- to long-term debt and the like.

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### Using a Data-Integration Model to Stage Abstraction in Voter Turnout

B. Edmonds*

*Manchester Metropolitan University Business School, UK*

Modellers who are attempting to understand complex and complicated social phenomena are often faced with the following dilemma: choosing a simple model that can be analytically understood (rigour) or a complex model that relates more directly to the available evidence. However good science requires both relevance and rigour. An approach to circumvent this dilemma is described illustrated by a case study from the social sciences. In this approach the representational and abstraction processes are separated in a two-step modelling method. There is a representational step which produces a complex model, and then this model is itself abstracted to a simpler model. First a "Data-Integration Model"(DIM) is built which uses micro-scale evidence (including expert opinion and qualitative accounts) to specify micro-level behaviour and is validated at the macro-level against aggregate statistics following the "cross-validation"approach. The aim of the DIM is to produce a dynamic simulation that integrates as much of the available evidence as possible, in other words is a sort of computational description. The DIM is context-specific to the modelling target and the evidence that relates to this. The DIM is likely to be slow and complex, however, unlike the root social phenomena, its workings can be totally inspected and limited computational what-if experiments conducted on it. These can be used to inform researcher in how to abstract to simpler models that can be checked against the DIM. This is illustrated with a case study on voter turnout. Here evidence as to the many reasons that influence people vote are used to inform the behavioural rules of the agents in a rich agent-based simulation of social networks, households and influence. In the resulting model there are no simple causes in general but rather given particular regions of the parameter space coherent causal explanations can be formulated.

### Is the gravity model able to predict the topological properties of the international-trade network?

M. A. D. Esterling*, G. Fagiolo

*Sant'Anna School of Advanced Studies, Pisa, Italy*

In the last years there has been a surge of interest in complex-network approaches to the study of international trade. Understanding the topological properties of the International-Trade Network (ITN), defined as the graph of import/export relationships between world countries in a given year, has turned out to be crucial in order to explain issues such as economic globalization and internationalization, the spreading of international crises, and the transmission of economic shocks. In fact, bilateral trade linkages are known to be one of

the most important channels of interaction between world countries. Nevertheless, they can only explain a small fraction of the impact that an economic shock originating in a given country can have on another one. Therefore, a complex-network analysis, by characterizing in detail the topological structure of the network, can go far beyond the scope of standard international-trade indicators (such as "openness to trade"), which instead only account for bilateral-trade direct linkages. Trade paths connecting any pair of non-direct trade partners may then shed light on the likelihood that economic shocks might be transmitted between any two countries, and possibly help explaining macroeconomic dynamics (Fagiolo et al., 2009). Despite we know a lot about the topological properties of the ITN, in its binary/weighted and undirected/directed descriptions (Fagiolo et al., 2010), as well as about commodity-specific international trade networks (Barigozzi et al., 2010), little is known about plausible theoretical models that can explain the observed topological properties of the ITN. In this paper, we expand upon Fagiolo (2010) and ask whether the workhorse economic theoretical and econometric model of international trade, i.e. the gravity model (GM), is able to satisfactorily reproduce and explain the observed ITN topology and weighted-network structure. The GM aims at explaining international trade flows using a gravity-like equation obtained as the result of a standard equilibrium model. The term "gravity" depends on the fact that the equation is similar to Newton's formula: the magnitude of aggregated trade flows between a pair of countries is proportional to the product of country sizes (e.g. the masses, as proxied by GDPs) and inversely proportional to their geographic distance, interpreted as proxies of trade-resistance factors, e.g. tariffs. The econometric implementation of the GM also includes set of country-specific explanatory variables, e.g. population, area, land-locking effects, etc., as well as a set of link-specific variables (i.e., geographical contiguity, common language, common religion, colony relation, bilateral trade agreements, etc.). The gravity model can be fitted to the data using different econometric techniques, ranging from simple ordinary least squares applied to the log-linearized equation, to two-stage Poisson estimations where the probability of having zero trade flows is also estimated. Nonetheless, a common feature of most estimation techniques is that they achieve high R-squared coefficient of determination, i.e. a quite satisfactorily goodness of fit. Motivated by the high performance of gravity model (GM) estimations, this paper analyzes to what extent GMs are able to explain the statistical properties of the binary and weighted ITN. We employ an international-trade dataset provided by Subramanian and Wei (2007), recording aggregate bilateral imports reported by the Direction of Trade Statistics at the International Monetary Fund from 1950 to 2000. We fit bilateral trade flows with an augmented gravity equation using three fitting procedures: standard OLS, Poisson pseudo-maximum likelihood (PPML), and two-stage zero-inflated Poisson (ZIP) models. In particular, the ZIP model, as opposed to standard OLS, explicitly estimates the probability of observing zero flows, which is extremely high in trade data and can severely bias estimates. We use GM predictions of trade flows with OLS, PPML and ZIP to build predicted binary (adjacency) and weighted trade matrices. We then compute standard network statistics (e.g. node-degree and strength distributions, clustering, assortativity coefficients, etc.) on both observed and predicted networks to study whether predicted ones match over the years observed patterns, i.e. to ask whether the GM satisfactorily explains the ITN architecture and its evolution over time. We also perform extensive Monte Carlo simulations to estimate confidence intervals around predicted network statistics. Our results suggest that overall the GM fits quite well, on average, the observed ITN structure over time, especially for what concerns first-order (local) properties, like node strengths or observed disassortativity. In particular, PPML fits provide a very good description of the average node-strength evolution. In contrast, higher-order statistics such as weighted node-clustering, can hardly be reproduced by the GM. We argue that this can depend on the very nature of the GM, which is aimed at explaining bilateral trade flows only (i.e. very local node properties) and does not account for indirect trade-interaction patterns emerging in the network, as motifs, cycles, and triangles. Finally, our results indicate that most of weighted-network properties strongly depend on the binary structure. Therefore, GM estimations that do not take as given the binary structure can hardly reproduce correlation patterns (Squartini, Fagiolo and Garlaschelli, 2011a,b). This strongly militates in favor of the need to explore international-trade models that explain link formation (as opposed to those, like the GM, that focus on the estimation of trade-flow levels).

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**Predicting technological progress**

J. D. Farmer*

*Santa Fe Institute, Santa Fe, USA*

Technological progress requires innovation, which by definition is new and unpredictable. Nonetheless, several "laws" have been proposed to describe the rate of technological progress. By testing on a database giving the unit cost and production of 62 different technologies as a function of time, we show that technological progress is indeed predictable, and that production is a better predictor of unit cost than time. We predict, for example, that electricity generated using solar energy is likely to become cheaper than coal in about twenty years. A theory of technological progress predicts a power law relationship between production and time, and that the exponent depends on the (suitably defined) complexity of the design.

**Validation in opinion dynamics modelling: Social Impact Theory and the presidential elections case study**

A. Fonseca*, J. Louçã

*ISCTE, Lisbon University Institute, Portugal*

Opinion formation modelling often suffers from a lack of empirical data validation. Actually, the research on social dynamics from the statistical physics perspective has been mainly theoretical. The current availability of large datasets and the ease by which Internet social data can now be collected makes some validation of theoretical social models a less difficult task. We propose a novel method for evaluating social dynamics modelling using on-line data gathering. The method includes three distinct phases: (1) data collection, (2) parameter adjustment and (3) multi-agent modeling. Specifically, we tested the significance of Social Impact Theory, originally proposed by Latané (1981), for characterizing political opinion formation during electoral periods. This well known mathematical model was tested using more than 4 millions of tweets collected from the 1st October to the 21st January 2011, concerning the Portuguese presidential elections occurred in January 2011. Following the data collection, two distinct on-line communities were inspected: the general Twitter users community, and the traditional news media that were accessible through Twitter feeds. Two specific parameters from the Social Impact Theory model were analyzed: persuasiveness and supportiveness. These parameters were adjusted to the empirical data series collected from both Twitter and traditional media. Finally, a multi-agent model was conceived representing the overall population. Media noise, represented by news, was injected in the model. The opinion dynamics, known from pools during the campaign, was simulated by adjusting model parameters. This operation was performed on six separate empirical series respecting the talk about the six electoral candidates. The complete process allowed concluding about the explanatory power of Social Impact Theory, and, on the other side, allowed characterizing opinion dynamics in this specific case study. Our presentation will detail each phase of the method, illustrated using the dataset available at http://work.theobservatorium.eu/presid2011.

**How to detect and quantify collective emotions in cyberspace ?**

J. Hołyst*

*Warsaw University of Technology, Poland*

Emotions are an important part of most societal dynamics. As with face to face meetings, Internet exchanges may not only include factual information but also emotional information; how participants feel about the subject discussed or other group members. The development of automatic sentiment analysis has made possible a large scale emotion detection and analysis using text messages collected from the web. Here results of two years studies performed in the frame of EU Project CYBEREMOTIONS (Collective Emotions in Cyberspace) will be presented. The Project associates nearly 40 scientists from Austria, Germany, Great Britain, Poland, Slovenia and Switzerland. The results include an automatic collection and classifying sentiment data in various e-communities, a qualitative and quantitative sentiment data analysis and data driven modeling of collective emotions by ABM, complex networks and fluctuation scaling paradigms, development of emotionally intelligent ICT tools such as affective dialog systems and graphically animated virtual agents that communicate

by emotional interactions. Emergence of collective emotions in cyber-communities will be demonstrated by applying four different methods and using independent datasets that include several millions of records: (i) emotional avalanches distribution observed in BBC blogs, and Digg data; (ii) non-random emotional clusters distribution observed in Blogs06, BBC Forum, Digg and IRC channels; (iii) persistent character of sentiment dynamics observed for IRC channels using the Hurst exponent analysis; (iv) causal sentiment triad distribution found in Network Motif Analysis.

### Common features of short-time dynamics of multi channel communication in work groups

S. Itaya*, N. Yoshinaga, P. Davis, R. Tanaka, T. Konishi, S. Doi, K. Yamada

*NEC Corporation, Japan*

In recent years, a great variety of personal communication tools have evolved. In addition to telephone and fax, we now use e-mail, blogs, facebook and twitter. The dynamics of communication appear to be becoming more complex. On the other hand, in analysis of human behavior, it is often found that although there may be large individual variety, regularity can be observed in the statistical characteristics of sufficiently large numbers of individuals and events. The discovery of regular statistical behavior allows us to make simpler models of the dynamics of social groups. Studies of e-mail records, such as the Enron corporation email corpus, have revealed universal characteristics in the statistics of e-mail communication activity on long time scales of days to months. We have studied e-mail communications in an organized group on short-time scales. Well-timed responses are important for maintenance of human relationships with communications. However, there has been little work on analyzing short time scale activity, minutes to hours, which is important for understanding the dynamics of communication in daily work and daily life. In previous work (presented at ECC2010), we analyzed and compare two different e-mail data sets, one from own NEC C&C Innovation Research Laboratories (CCIL) and another from Enron. We identified different regimes in the distribution of response time intervals, which were qualitatively similar in the two data sets, suggesting that universal properties of human task handling on short time scales are manifest in the statistical features of communication activity within work groups. In our latest work, we have analysed email records in combination with records of face-to-face meeting on short time scales, using data from office sensor network implemented with wireless tags. We show evidence that for a work environment where people are located physically close together, the mix of face-to-face and email communications together give response time distributions which have a better quantitative match with the Enron email distributions. This suggests that allowing for the mix of face-to-face and email communications gives a more universal response time distribution. We discuss how this universal response time distribution could be explained by properties of human interaction.

### Étoile Cascades Ideas

J. Johnson*, P. Bourgine, M. Kolhase, J. Louçã, A. Willis, D. Hales

*The Open University, UK*

A new project began in February 2011 called Étoile Cascades Ideas, or Enhanced Technology for Open Intelligent Learning Environments: Complex Adaptive Systems for Creating And Distributing Education and Scientific Ideas. Étoile is a remarkable new ICT architecture that is both adaptive to changing users and user requirements and scalable with low cost for each new user. Étoile has emerged over the last five years in response to the Complex Systems Societys perceived need for multidisciplinary postgraduate education in complex systems science. Today most students are educated in traditional domains such as mathematics, physics, computing, biology, sociology, psychology, economics, philosophy, and so on. Those who come to study complex systems are generally ill-prepared because they need knowledge across such domains. On graduation, almost all of us know almost nothing about almost everything. This makes it necessary for students in complex systems science to study outside their parent disciplines in areas with different histories and different cultures. It is difficult to achieve an appropriate balance between breadth and depth of knowledge. Certainly no-one can know everything about everything, so in the science of large complex multi-subsystem systems there will be the need for teams of specialists with deep knowledge in their own particular areas, and they will need generalist knowledge across the areas in order to communicate with each other. A sociologist may not be a medal-winning mathematician but they need to know enough mathematics to communicate with the specialist on the team. Similarly a computer scientist may not write award-winning papers on economics, but they need to know enough to communicate with the specialists. We have identified the following key areas where education is urgently needed: mathematics, computing, physics, social systems and biological

systems. Of course this list could be expanded and as it stands it reflects a bias towards the physical sciences. But we have to start somewhere. Étoile is intended to provide ultra-low-cost education for large numbers of complex systems students and researchers. The way étoile works is remarkably simple. In education success is determined by learning outcomes –what students can do. Often this is assessed by giving students tasks or having them answer questions. So, we hypothesise a web-based system in which questions are transmitted to students and their answers are returned. To be scalable these questions have to be automatically assessed. Étoile uses innovative intelligent automatic assessment methods that go far beyond the usual multiple choice questions, making the question-answer part of the system scalable. But what if the student cannot answer the question? We provide a wealth of heterogeneous learning materials such as books, movies and software that can be accessed through the homogeneous form of the URL. These URLs form an ecology in which those best adapted for answering the question thrive while those poorly adapted for answering the question struggle to survive. To illustrate the dynamics of the ecology we give a thought experiment. Suppose for a given question the ecology is seeded with junk URLs such as fastcars.com or holidays.com. A student unable to answer the question could look at these and find they are not helpful for answering the question. Thus they must search the internet for something better adapted to enabling them to answer the question. It is assumed that doctoral students have sufficiently good study skills to do this. When the student submits their answer they also submit the URLs used to provide that answer. The URLs returned this way are better adapted than the junk URLs and will fare better in the ecology. This thought experiment shows that the ecology will evolve with the URLS best adapted to answering the questions thriving above less well adapted URLS. This architecture is remarkably adaptive. Suppose the question changes –then, at worst, the URLs in the database become junk URLs and the system self-reboots. Suppose a link to some excellent learning resource breaks (as happens frequently) –then that URL instantly becomes poorly adapted and dies. This adaptability is even more subtle because clusters of URLs and students can emerge. For example clusters of French URLs may be attractive to clusters of francophone students. Then those URLs are better adapted to those students, and this can be the basis of personalised education –students are provided with URLs that are most likely to be best adapted to their current knowledge and learning styles. Of course if the population of users changes –as it will –then new clusters emerge and the system again adapts. There are many more interesting technical properties to étoile that will be discussed in the full paper. For example, apart from the URLs there are other ecologies. These include ecologies of questions and answers, where some questions are better adapted to the needs of the research community than others. Also the basic étoile model can be augmented by social networking and related information and learning dynamics. To see how étoile might be used consider a new student starting with a PhD supervisor in October. The supervisor tells the student to self-test in mathematics, physics, computing and social systems using the Complex Systems Society Étoile website. The student shows the supervisor a printout of the downloaded results. In those areas where the performance is below the standard required by the supervisor the student is instructed to self-educate using étoile, redo the test before the Christmas break and show that they have reached the required standard. What the students study and the standard they are required to reach is determined locally by the supervisor. Already we know supervisors find this attractive because for very little work they can ensure that their students learn the essentials for their PhD studies. Étoile is funded as a three-year coordination action project by the Future and Emerging Technology unit of the European Commission (FET). In this paper we will set out in detail the theoretical properties of the étoile architecture and outline the experiments we plan. Also we discuss the technical and social challenges these involve. This will provide the basis for future papers that will report the results of these experiments as we move from theory to implementation. We hope étoile will provide an example of a new direction in the development of ICT systems in which the requirements of a system can evolve with the changing needs of changing populations of users. 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### The complexity of collaborative research: Critical mass and policy implications

R. Kenna*, B. Berche

*Coventry University, UK*

The notion of critical mass in research is one that has been around for a long time without proper definition. It has been loosely described as some kind of threshold group size above which research standards significantly improve. The extended notion that benefit accrues through increasing scale lies behind calls for greater concentration of resources into a small number of research institutions. However no evidence for such a threshold has been found and critical mass has never been measured –until now. We present a new, simple, sociophysical model which explains how research quality depends on research-group structure and in particular

on size. Our model predicts that there are, in fact, two critical masses in research, the values of which are discipline dependent. Research quality tends to be linearly dependent on group size, but only up to a limit termed the "upper critical mass". The upper critical mass is interpreted as the average maximum number of colleagues with whom a given individual in a research group can meaningfully interact. Once the group exceeds this size, it tends to fragment into sub-groups and research quality no longer improves significantly with increasing size. There is also a lower critical mass, which small research groups should strive to achieve stability. Our theory is tested using empirical data on the quantity and quality of scientific research groups, for which critical masses are determined. Lower critical masses range from about 15 researchers for law and geography to 3 for foreign languages and about 2 or fewer for pure mathematics. For theoretical and experimental physics, the lower critical masses are estimated to be about 6 and 13, respectively.

**Online Worlds as Socio-economic Laboratories: Multi-relational Organization of Large-scale Social Networks**

M. Szell, R. Lambiotte*, S. Thurner

*Namur University, Belgium*

Quantification of collective human behavior poses a unique, century old challenge. The establishment of a fully experimental and falsifiable social science of group dynamics is significantly complicated by two factors: 1) Societies constitute a complex system, displaying multi-relational long-range interactions, 2) Data is of poor availability and quality, or measured only on very specific aspects of social life. Complex systems cannot be understood without their contexts and boundaries, together with the interactions between these boundaries and the system itself. These issues appear in a significantly more positive light when complete data on human societies is available, such as in massive multiplayer online games. Players reside and act within an online society and make up their own goals - ranging from earning virtual money or making friends to waging wars. We have developed such an open-ended online game, played by over 350,000 users. Practically all (anonymized) information of all player actions and interactions over the past five years is available. As one of the examples demonstrating the potential of using this virtual world as a socio-economic laboratory, we analyze the complete, multi-relational, socio-economic network between the players. We extract networks of six different types of one-to-one interactions. Three of them carry a positive connotation (friendship, communication, trade), three a negative (enmity, armed aggression, punishment). We first analyze these types of networks as separate entities and find that negative interactions differ from positive interactions by their lower reciprocity, weaker clustering and fatter-tail degree distribution. We then proceed to explore how the inter-dependence of different network types determines the organization of the social system. In particular we study correlations and overlap between different types of links and demonstrate the tendency of individuals to play different roles in different networks. As a demonstration of the power of the approach we present empirical large-scale evidence for structural balance theory, by focusing on the specific multiplex network of friendship and enmity relations.

**Globalization and international integration in the world trade web**

G. Fagiolo, R. Mastrandrea*

*Sant'Anna School of Advanced Studies, Pisa, Italy*

The issues of globalization and international integration have received a great deal of attention in the last decade. However, we are still far from reaching a consensus on fundamental questions such as: (i) what do we exactly mean by globalization? (ii) how can one measure globalization? (iii) what level of globalization did we attain? (iv) do we live in a fully globalized world, or can we expect some further increase of the globalization level in the future? Despite several conflicting measures of globalization and international integration have been proposed so far (Arribas et al., 2009), they do not seem to fully capture the high level of complexity displayed by the evolution of social, economic, and financial relationships among world countries in the last 50 years. What appears to play a crucial role in defining any measure of globalization and international integration are in fact the properties of the unfolding network of complex interactions among world countries. These interactions involve trade of commodities and services, but also financial and investment flows, migrations and human capital. On the contrary, in recent years an increasing body of literature has addressed the study of international trade and financial flows between countries in the frame of complex-network analysis (Fagiolo et al., 2009; Schiavo et a.l, 2010). These contributions highlight the importance of indirect relationships between countries and show that the architecture of the complex web of interactions between countries have been evolving over the years in a non trivial way. In turn, this topological architecture may explain to

a great extent country growth and the development patterns of some relevant groups of countries better than traditional international-trade indicators (Reyes et al., 2010). In this paper we try to bridge the two aforementioned streams of literature by proposing a series of statistical indicators that can begin to grasp concepts like globalization and international integration from a complex-network perspective. We employ data on international trade bilateral flows from 1948-2000 and build a sequence of weighted-directed versions of the international-trade network (ITN), aka the World Trade Web (WTW), to study network-based distances between countries (nodes in the network). We study both a binary-directed representation of the ITN (where a link is either present or not according to whether the corresponding export flow is positive or zero) and a weighted-directed version where links are weighted by export flows (possibly rescaled by total yearly trade so as to de-trend the series). We then study the distributions of binary and weighted distances between nodes (countries). Distances are defined in the binary case as the minimum (directed) path length (PL) between any two nodes. We also define a symmetrized distance measure obtained by computing PLs in the symmetrized version of the binary network, in order to overcome directionality issues. In the weighted case, we compute minimum PLs by assigning to each link a dissimilarity weight obtained as some inverse transformation of the original weights $f(w(i,j))$, with $f' < 0$. We explore the statistical properties of the PL distributions across node pairs over the observed period to assess whether they display some shift towards a more concentrated pattern with time-decreasing means. We interpret diminishing average distances and more concentrated distribution as the evidence for an increasing integration and world globalization. We also ask the extent to which country average distances to all the other countries in the sample is correlated with country per-capita GDP and GDP growth. A positive correlation would strongly militate in favor of a virtuous circle wherein countries that become closer to all the others over the years also enjoy on average larger incomes and growth. Furthermore, following Arribas et al. (2009), we compare distance-based measures of globalization and integration with more traditional ones, to understand the extent to which they better capture the complexity of the ITN and its non-trivial evolution. Finally, we perform some robustness checks and extend the analysis in several ways. First, we explore how our results depend on using non de-trended export flows. This will shed light on whether the huge increase in nominal and real trade flows over the years has an impact on distance-based trade measures. Second, we study how our trade-induced distance measures correlate with geographical distance between countries: this would shed some light on whether geographical distance, interpreted as a proxy of trade-resistance factors (e.g., tariffs) and known to be a strong determinant of bilateral trade flows, also explains a good deal of trade-induced distances between countries in the world, and whether this impact has changed over the years. To strengthen this analysis, we also fit a reduced gravity model to bilateral flows (using country GDPs and geographical distance only) to understand whether country size and distance are able to explain why certain countries are closer in the ITN space and why it is so. Third, we exploit another trade-flow database, covering a shorter time-horizon but allowing for product disaggregation (Barigozzi et al, 2010) to study whether distances between countries differ across different product-specific networks. Preliminary analyses for the binary-undirected case reveal that the majority of shortest paths have length 1 or 2, while just very few countries are placed at distance 3 or 4 one from each other. It is possible to observe a cyclical behavior for 1/2-distances until about 1965, than the effect of globalization is clearly shown by the increasing of 1-length shortest paths. At the aggregate level the average distance seems very stable and slightly decreasing. Moreover, we explore in more detail the evolution of the average distance of some target countries over time. We find that countries can be grouped in different classes, as to whether their mean distance have been decreasing or increasing, or has remained quite stable for many years. We interpret this heterogeneity in the light of geographical, institutional, cultural, political, and historical differences. For the weighted case, we explore different functional forms for the aforementioned weight-dissimilarity transformation. If we stress the importance of very small weights for the whole network structure, we find that the mean distance is increasing over time. On the other hand, a linear and decreasing transformation of weights, which does not penalize smallest ones too much, shows a pattern very close to the binary one.

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### Japanese Inter-Firm Network and Unprecedented Earthquake

T. Mizuno*, W. Souma, T. Watanabe

*University of Tsukuba, Japan*

We clarify the relationship between firm growth and inter-firm network. We analyze the dataset including 600,000 companies and 3 million links in this study. It is observed that firm size follows Zipfs law and firm growth shows a tent shape. On inter-firm network, degree distribution of network link follows a power law. We can find that many firms often change clients every year. Especially, in highly competitive industries, the fluctuation of the number of client of each firm is violent. We show that the violent fluctuation generates the tent shape of firms growth using a simple dynamical network model. We clarify that distribution of in-degree that expresses the number of client generates the firm size distribution with Zipfs law. On March 11, an unprecedented earthquake and tsunami attacked many firms in northeast Japan. Japanese inter-firm network is a small world characterized by short path lengths. Therefore, the firms except the northeast district were also hard hit. We will also talk about the change of the network after the earthquake and the recovery of Japanese economy.

### The Modelling of Human Crowd Behaviour: Where Physics meets Cognitive Science

M. Moussaid*, D. Helbing, G. Theraulaz

*University of Toulouse, France*

Human crowds display a rich variety of self-organized behaviours, ranging from the spontaneous organization of traffic flows under everyday life conditions, to the emergence of crowd turbulence at extreme density. To understand the mechanisms underlying these phenomena, it is necessary to elaborate a model of pedestrian behaviour. In this contribution, we will demonstrate that a reliable description of pedestrian behaviour lies at the crossroad between physics and cognitive science. We will show that two simple cognitive rules based on visual information can describe the motion of pedestrians well. In particular, these two rules are sufficient to reproduce the self-organized properties of crowds observed below a certain density threshold. As the density of people increases, however, body contacts between neighbouring people occur, and the underlying mechanisms change. During overcrowding, intentional avoidance behaviours are replaced by unintentional physical interactions, which can be described by using Newtonian repulsion forces. Therefore, the large variety of crowd movements results from a density-dependant balance between physical effects and cognitive procedures.

### Apportioning value to the unmeasurable: approaches to placing a measure on scientific collaboration

L. O'Neill*

*Montrose Associates, London*

Considerable work has been done to examine the nature and extent of international collaboration across the scientific community. To date collaboration has primarily been measured in terms of numbers of papers produced and papers cited –expressed most recently in its report Knowledge, Networks and Nations released by the Royal Society in March 2011, as well as ongoing studies through international research institutes and bodies such as OECD. As the emerging economies - notably but not exclusively China, Brazil and India - gain greater prominence in the sphere of research and development, the nature of that collaboration is evolving and itself needs to be understood. Interdependency of research is challenged, however, by national policies and in particular the growing threat of protectionism as the centre of gravity across the research community begins to shift. This will place increasing pressure on existing governance structures, including reporting standards and the behaviours of academic and teaching institutions, in a world where the volume - and tempo - of information is forever increasing. This talk will explore the opportunities afforded by complexity approaches for establishing an alternative metric to paper publication for placing a measurable value on collaborative research. It will consider the boundaries between transactional and transformational information sharing and will aim to identify clear and manageable criteria for reconsidering the existing regulations and governance

structures as they apply in this sphere.

**Bursts, long-range correlations and scaling behaviour in online communication**

P. Panzarasa*, B. Kujawski

*Queen Mary University of London, UK*

Research has long suggested that the dynamics of a large number of real-world systems, from gene expressions to electrical systems and Internet traffic, exhibit a bursty nature. Pronounced levels of activity are typically observed over short periods of time followed by long periods of inactivity. Systems with bursty patterns of activity on a wide range of time scales can display long-range correlated fluctuations in time. The emergence of these correlations in a vast array of empirical domains suggests that long persistent memory can be regarded as a fingerprint of complex systems. Research has also shown that, in a vast array of complex systems, bursty activity is rooted in the heavy-tailed distributions of the time intervals between consecutive events. Despite the vast body of research conducted on many physical and social systems, however, there have been few studies of the degree to which bursts, long-memory processes, and scaling behaviour can be detected at, and emerge from, different levels of a complex system. Here we take a step in this direction, and investigate patterns of human activity within an online forum in which communication occurs, and can be assessed, at three intertwined levels: the individual users, the discussion groups, and the whole systems levels. To this end, our analysis is based on a unique longitudinal network dataset from a forum in which users post messages to a number of groups or threads, each devoted to a discussion topic. Results show that users quickly establish and adopt a social norm to regulate the timing of their online gatherings. Fluctuations of activity in the forum appear to be partial to trends and to have long persistent memory: an increase in online activities is more likely to be followed by another increase than a decrease, and vice versa. To shed light on the sources of bursts we examine heterogeneity in users activity by measuring the scaling behaviour of the inter-event time distributions for individual users, groups, and the whole forum. Heterogeneity and a scaling regime are also found for the distributions of the length of sessions of ongoing discussions and of the length of periods of continuous inactivity. To gain a better understanding of the principles responsible for the dynamics of online activity at different levels of the forum, we conduct a number of numerical simulations of a zero-crossing model in which users behaviour is constrained by an increasingly richer and more realistic set of rules. Results show that when posting of messages is driven by reciprocity and a popularity-based preferential choosing mechanism, the power spectra and inter-event time distributions of the simulated and actual forums appear to be remarkably similar at all levels of the system. We investigate how the behaviour of the system at the macro level can be regarded as emergent from the behaviour at the micro level of the individual users, and discuss the implications of our findings for research on complex systems and communication.

**Stochastic Market Efficiency**

O. Peters*, A. Adamou

*Imperial College, London, UK*

It is argued that the simple trading strategy of leveraging or de-leveraging an investment in the market portfolio cannot outperform the market. Such stochastic market efficiency places strong constraints on the possible stochastic properties of the market. Historical data confirm the hypothesis.

**Critical London: self-organization of urban flow**

G. Petri*, P. Expert, H. J. Jensen, J. W. Polak

*Imperial College, London, UK*

Understanding and characterising the patterns of human mobility and their relationship with the scaling and dynamical features of urban environments is a fundamental challenge for today's science and society. Epidemiology, traffic engineering, urban design, as well as socio-political and resource management models, all rely on mobility models to provide meaningful quantitative predictions. Although recent advances have shed light on the characteristics of individual mobility, the role and importance of emerging human collective phenomena across time and space is still unclear. Against this backgroud, we report an example coming

from vehicular traffic and show evidence that the London road traffic network is in a self-organized critical state. We show that the fluctuations of both the flow and traffic density fields exhibit power spectra of the form $1/f^{\alpha}$ with $\alpha \sim 1$ over several orders of magnitude and algebraically decaying spatial correlations $C(t,r) \sim r^{-\beta} with \beta \sim 0.25$ across the whole system. As a direct consequence of being in a critical state, the traffic flow is dominated by very uncontrollable fluctuations on all scales. This phenomenon is not taken into account in existing urban transport network models, highlighting important weaknesses in the conventional modes of traffic analysis. Finally, we discuss our results in the light of similar studies on traffic dynamics (e.g. highways and traffic control) and scaling of cities, investigating the implications of network flow fractality and possible strategies to mitigate the control issues.

### A nowcasting approach using GPS data to compute the empirical fundamental diagram

B. Armando, B. Giorgini, S. Rambaldi*, R. Gallotti, L. Giovannini

*University of Bologna, Italy*

In the next future large amount of data on individual vehicle positions and speed will be available from modern ICT systems[song2010]. This perspective opens the possibility of experimental studies of traffic or human mobility on a whole urban network to point out criticalities and phase transitions. A prototype model, developed under Pegasus Project sponsored by Italian Industry Ministry, has been proposed for Rome. The system is based on the real time reconstruction of the speed, density and flux on the whole metropolitan area road network using a low sampling rate gps data set. One interesting question is to study the existence of a fundamental diagram for a road network as it has been proposed by C.Daganzo and N.Geroliminis[geroli2007]. We present some results on the single vehicle trajectories reconstruction from low sampled GPS data (the spatial scale is $\simeq 1\ km$ ), that are recorder for insurance reason. This procedure allow to estimate the instantaneous road velocity, density and flux for a "homonegeous" sub-network of the Rome urban road network and to compute empirically the fundamental diagram. We point also out the existence of hysteresis phenomena as expected from theoretical models. We also discuss the experimental results in comparison with microscopic numerical simulations using simple car following dynamics. These results follow the research line of a physical statistical approach to urban traffic dynamics[bazzani2010] in order to describe the macroscopic properties and the non-equilibrium states of the system connected with the complexity of the microscopic dynamics.

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### Human mobility on a network

M. Szell*, R. Sinatra, G. Petri, V. Latora, S. Thurner

*Medical University of Vienna, Austria*

Understanding the statistical patterns of human mobility, predicting trajectories and uncovering the mechanisms behind human movements is a considerable challenge and an important issue in many different contexts, such as in traffic management, epidemics spreading or geo-marketing strategies. Although the recent availability of massive datasets on human movements has boosted the research in the field, a comprehensive set of human behavioral data of an entire society is still missing, including information about different spatial scales or socio-economic constraints. Here we study mobility of a large number of human players using complete social and economic data from a Massive Multiplayer Online Game, where players move on a network-shaped universe. In this "social Petri dish", we are able to investigate the connection between network-topological properties, socio-economic factors, and patterns of mobility. Players limit their social and economic activities to certain areas, significantly constraining their motions. We propose a method for detecting these socio-economic regions by directly incorporating measured movement dynamics. Moreover, we uncover that the time-order of visited locations is the driving mechanism indispensable to understand and reproduce fundamental statistical properties of human trajectories.

### Agents in Your Space: Dynamics & Emotion Spreading in Social Networks

B. Tadic*, M. Suvakov, M. Mitrovic

*Jozef Stefan Institute, Ljubljana, Slovenia*

Communications in on-line social networks have demonstrated their impact on real life and conversely, users real-life behavior is reflected onto events in the virtual world, which are recorded on the Web servers. This puzzling spiral may lead to new social phenomena, that we have just began to witness. To explore mechanisms underlying these phenomena here we use some ideas from physics of complex dynamical systems and agent-based modeling. We analyze two sets of the empirical data from MySpace networked dialogs and introduce a model of the emotional agents interacting along links of the network, which represents real connections of users in MySpace [1]. Extensive simulations reveal different patterns of emotion spreading and other complexity measures when the system is driven by pink-noise signal, which is inferred from the empirical data. [1: M. Šuvakov et al., in preparation 2011]

### Human Mobility and Social Networks

D. Wang*, C. Song, A. L. Barabási

*Northeastern University and Dana Farber Cancer Institute, Boston, USA*

Our understanding of how individual mobility patterns shape and impact the social network is limited, but is essential for a deeper understanding of the organization of society as a whole. This question is largely unexplored, partly due to the difficulty in obtaining large-scale society-wide data that simultaneously capture the dynamical information on individual movements and social interactions. Here we address this challenge by tracking the trajectories and communication records of 6 Million mobile phone users. We find that the similarity between two individuals movements strongly correlates with their proximity in the social network. We further show that individual mobility could indeed serve as a good predictor of the structure of the network, and spatial co-location strongly impacts the organization of social network. We believe our findings on the interplay of individual mobility patterns and social network provide significant insights towards a deeper understanding of not only human dynamics but also network evolution.

### Geometric origin of scaling in large traffic networks

M. Popovic, H. Stefancic, V. Zlatic*

*Institute Rudjer Boskovic, Croatia*

Large scale traffic networks are an indispensable part of contemporary human mobility and international trade. Networks of airport travel or cargo ships movements are invaluable for the understanding of human mobility patterns , epidemic spreading, global trade and spread of invasive species . Universal features of such networks are necessary ingredients of their description and can point to important mechanisms of their formation. Different studies point to the universal character of some of the exponents measured in such networks. Here we show that exponents which relate i) the strength of nodes to their degree and ii) weights of links to degrees of nodes that they connect have a geometric origin. We present a simple robust model which exhibits the observed power laws and relates exponents to the dimensionality of 2D space in which traffic networks are embedded. The model is studied both analytically and in simulations and the conditions which result with previously reported exponents are clearly explained. We show that the relation between weight strength and degree is $s(k) \sim k^{3/2}$ , the relation between distance strength and degree is $s^{d(k)} \sim k^{3/2}$ and the relation between weight of link and degrees of linked nodes is $w_{ij} \sim (k_i k_j)^{1/2}$ on the plane 2D surface. We further analyse the influence of spherical geometry, relevant for the whole planet, on exact values of these exponents. Our model predicts that these exponents should be found in future studies of port networks and impose constraints on more refined models of port networks.

# V. Interacting Populations

### Mobility in bi-stable evolutionary dynamics can invert the direction of selection

P. M. Altrock*, A. Traulsen, F. A. Reed

*Max-Planck-Institute for Evolutionary Biology, Plön, Germany*

In diploid organisms, heterozygote disadvantage is a component of natural selection. In evolutionary games, similar stability patterns are observed in the stag-hunt game; In single isolated populations, both cases exhibit bi-stable evolutionary dynamics where coexistence/polymorphism is unstable [1]. For the case of two populations that exchange migrants one can analytically characterize such systems with migration rate acting as a control parameter [2]. Non-vanishing, but small gene-flow due to mobility of individuals can counterbalance selection, migration between populations can maintain polymorphism. When demographic fluctuations are accounted for, the migration-selection equilibrium is reflected in a drastic change of the average extinction times: Sufficiently low rates of migration considerably delay the extinction event. Furthermore, small networks of interacting populations show a shift to increased levels of stability that sensitively depend on the graph structure. In the population genetics of pest management, such bi-stable dynamics have been proposed as a drive to stably and reversibly establish linked alleles with desired properties such as disease resistance [2,3]. Here, our theoretical predictions can be used to estimate and optimize strategies of genetic pest management.

[1] Fisher, Proc. Royal Soc. Edinburgh 42, 321 (1922) [2] Altrock et al., J. Theor. Biol. 267, 62 (2010) [3] Curtis, Nature 218, 368 (1968)

### The Joker effect: cooperation driven by destructive agents

J. A. Cuesta, A. Arenas*, J. Camacho, R. Requejo

*Universidad Carlos III de Madrid, Spain*

Understanding the emergence of cooperation is a central issue in evolutionary game theory. The hardest setup for the attainment of cooperation in a population of individuals is the Public Goods game in which cooperative agents generate a common good at their own expenses, while defectors "free-ride" this good. Eventually this causes the exhaustion of the good, a situation which is bad for everybody. Previous results have shown that introducing reputation, allowing for volunteer participation, punishing defectors, rewarding cooperators or structuring agents, can enhance cooperation. Here we present a model which shows how the introduction of rare, malicious agents—that we term jokers—performing just destructive actions on the other agents induce bursts of cooperation. The appearance of jokers promotes a rock-paper-scissors dynamics, where jokers outbeat defectors and cooperators outperform jokers, which are subsequently invaded by defectors. Thus, paradoxically, the existence of destructive agents acting indiscriminately promotes cooperation.

### Thresholds for epidemic spreading in networks

C. Castellano*, R. Pastor-Satorras

*Istituto dei Sistemi Complessi,CNR, Italy*

We study the threshold of epidemic models in quenched networks with degree distribution given by a power-law. For the susceptible-infected-susceptible model the activity threshold $\lambda_c$ vanishes in the large size limit on any network whose maximum degree $k_{max}$ diverges with the system size, at odds with heterogeneous mean-field (HMF) theory. The vanishing of the threshold has nothing to do with the scale-free nature of the network but stems instead from the largest hub in the system being active for any spreading rate $\lambda > 1/\sqrt{k_{max}}$ and playing the role of a self-sustained source that spreads the infection to the rest of the system. The susceptible-infected-removed model displays instead agreement with HMF theory and a finite threshold for scale-rich networks. We conjecture that on quenched scale-rich networks the threshold of generic epidemic models is vanishing or finite depending on the presence or absence of a steady state.

### Sparse coding of conflict dynamics in an animal society

B. Daniels*, D. Krakauer, J. Flack

*Santa Fe Institute, Santa Fe, USA*

Collections of individuals with incompatible objectives leads to conflict, and each individual is motivated to understand the patterns of observed conflict to guide decisions about future involvement. In order to

predict future conflict events using limited cognitive machinery, the past must be distilled into a compressed representation. In this study, we compress time series data describing fights in a model animal society, applying a sparse coding technique similar to the type used in neuroscience to discover compressible features in visual scenes. Sparse coding discovers correlated groups of individuals that can be used to predict future fights as accurately as other data compression methods while requiring less information storage. We also analyze the distribution of metastable solutions to the sparse problem as a proxy for studying the effects of differing compressed representations in a population of individuals.

**Strategic Timescales in an Animal Society**

S. Dedeo*, D. Krakauer, J. Flack

*Santa Fe Institute, Santa Fe, USA*

Variability on multiple timescales is a fundamental feature of complex systems. Such variability becomes of particular interest when it is associated with systems in conflict – where self-regulation and feedback is complicated by the existence of competing, mutually contradictory goals. The timescales of conflict may be associated with exogenous forces such as environmental cues or physiological limitations. But when the system is composed of cognitively sophisticated agents, these scales may also be associated with the strategies that individuals and subgroups use to promote, manage, and take advantage of conflict. We report here on new analyses of a highly-resolved time series that can disentangle these two broad phenomena. The second-to-second behavior of the agents in our model system – 48 socially mature pigtailed macaques – was studied over the course of four months, enabling our analyses to search for strategic timescales over three orders of magnitude, from tens of minutes to multiple days. The strategic timescales we uncover are associated with different functional groups of the colony, suggesting that the cognitive "spectra" of a society and its subgroups can be an important way of understanding conflict.

**Cyclic dominance in adaptive networks**

G. Demirel*, R. Prizak, P. N. Reddy, T. Gross

*Max Planck Institute for the Physics of Complex Systems, Germany*

The Rock-Paper-Scissors(RPS) game is a paradigmatic model for cyclic dominance in biological systems. Here we consider this game in the social context of competition between opinions in a networked society. In our model, every agent has an opinion which is drawn from the three choices: rock, paper or scissors. In every timestep a link is selected randomly and the game is played between the nodes connected by the link. The loser either adopts the opinion of the winner or rewires the link. These rules define an adaptive network on which the agent's opinions coevolve with the network topology of social contacts. We show analytically and numerically that nonequilibrium phase transitions occur as a function of the rewiring strength. The transitions separate four distinct phases which differ in the observed dynamics of opinions and topology. In particular, there is one phase where the population settles to an arbitrary consensus opinion. We present a detailed analysis of the corresponding transitions revealing an apparently paradoxical behavior. The system approaches consensus states where they are unstable, whereas other dynamics prevail when the consensus states are stable.

**Why do metabolic networks look like they do?**

P. Holme*, M. Huss

*Umeå University, Sweden*

This year a decade has passed since the discovery that metabolic networks are scale-free. I will make a brief review of research relating network topology and function in metabolic reaction systems with a focus on our contributions. I discuss the hypothesis that network clusters correspond to functional modules. Metabolic network, however represented, are not as distinctly modular as the cartoon picture of intricately wired subsystems with few I/O-terminals. Does this reflect a trade-off between functionality and robustness, or is it an inevitable consequence of non-enzymatic reaction kinetics, or something else? I also discuss optimal levels of representations - if one uses a multiplex, directed, and perhaps bipartite, representation one can encode more

information, but standard methods are harder to apply. If one goes for a simple-graph representation with vertices connected by undirected edges, then how can one encode as much functional information as possible? I will also mention how one can use other types of reaction systems, like reactions in planetary atmospheres, as null-models of metabolic networks. Finally I look forward and discuss open questions within reach with current and future data sets.

**Evolutionary dynamics of genome segmentation in multi-particle viruses**

J. Iranzo*, S. C. Manrubia

*Centro de Astrobiología (INTA-CSIC), Spain*

The origin and evolutionary meaning of viral genome segmentation is a classical source for a long series of questions and inspiring hypotheses in evolutionary biology. In particular, the case of multi-particle viruses is specially striking, since genome segments are separately encapsidated in independent particles and complementation among all of them is necessary for an infection to occur. This implies that a large enough number of viral particles must enter the same cell so that the whole genome becomes represented. Despite this apparent limitation, multi-particle viruses are widespread among those infecting plants, including genera whose genome is split in up to eight segments. In contrast, there are no known cases of animal multi-particle viruses in nature. From an evolutionary perspective, the existence of this kind of viruses and its asymmetry in host distribution could be understood by taking into account a trade-off between opposite selective pressures. On the one hand, benefits of a segmented genome have been classically explained in terms of improved recombination ability and faster genome replication, although recent experiments support the idea that higher stability of the viral particle is achieved when segments are individually packed [1]. On the other hand, large multiplicity of infection (i.e., large number of entering viral particles per cell) is required for the infection to persist, so that extinction supervenes if transmission bottlenecks occur. An experimental evidence of such trade-off was found in recent years by evolving an animal virus towards a multi-particle form when it was allowed to transmit at high multiplicity of infection [2]. In this work we analyze in depth by means of a simple model the trade-off between multiplicity of infection and benefits of segmented genome quantified as an increase in their stability. Our results show how the number of segments a viral population can maintain is governed by a set of phase transitions that depend on both viral and environmental factors. In the case of bipartite genomes, we obtain exact results characterizing the transition from coexistence of complete and segmented forms to the extinction of the complete form. In more general cases, we have studied the dynamics by which different genome segments can be merged and split again as well as the resulting competition among overlapping segments. Taken as a whole, these findings give us insight into the origin, evolution and organization of segmented viral genomes in the context of multi-particle viruses.

[1] Ojosnegros S. et al. (2011) Viral genome segmentation can result from a trade-off between genetic content and particle stability. PLoS Gen 7(3): e1001344. [2] Garcia-Arriaza J, Manrubia SC, Toja M, Domingo E, Escarmis C. (2004) Evolutionary transition toward defective RNAs that are infectious by complementation. J Virol 78: 11678-11685.

**Evolutionary Game Theory in Growing Populations**

A. Melbinger*, J. Cremer, E. Frey

*Ludwig-Maximilians Universität, Munich, Germany*

Existing theoretical models of evolution focus on the relative fitness advantages of different mutants in a population while the dynamic behavior of the population size is mostly left unconsidered. We present here a generic stochastic model which combines the growth dynamics of the population and its internal evolution [1]. Our model thereby accounts for the fact that both evolutionary and growth dynamics are based on individual reproduction events and hence are highly coupled and stochastic in nature. We exemplify our approach by studying the dilemma of cooperation in growing populations and show that genuinely stochastic events can ease the dilemma by leading to a transient but robust increase in cooperation.

[1] A.Melbinger, J. Cremer, E. Frey, Phys. Rev. Lett. 105, 178101 (2010)

**How random is social behaviour?**

N. Perony*, B. König, G. Kerth, F. Schweitzer

*ETH Zurich, Switzerland*

We study the relation between animal motion and social behaviour, both from the perspective of the individual and that of the group. Evidently, in most animal species social contacts result from spatial encounters, and

conversely in animal societies individual movement is constrained by the underlying social structure of the group. However, few attempts exist at considering the relationship between these two intimately interwoven dimensions. We specifically investigate to what extent the interaction dynamics of both a population of wild house mice (Mus musculus domesticus) and two colonies of Bechstein's bats (Myotis bechsteinii) in their natural environment can be explained by simple rules of interaction. In order to accurately describe the use that animals make of their habitat, we extend the concept of "landscape of fear", which represents the way in which the movement of individuals and populations is influenced by their environment (notably their predators), by introducing a more general perceptual landscape. We use the discrepancy between the dynamics of motion according to a null hypothesis and the observed one to build a landscape accurately describing the intensity of space use across the domain studied. This unveils how an animal may alter its spatial behaviour according to the social constraints it is subject to. Based on these insights, we introduce simple multi-agent models driven by stochastic dynamics to reproduce both the habitat use and the social structure of mice and bats, and compare the results to our real data sets of more than 20'000 and 20'000'000 individual observations for the bats and mice, respectively. All data come from long-term field studies on animals tagged individually with RFID microchips, and genetically monitored to allow for an extensive knowledge of the populations' dynamics. From these unique data sets, we extract both the spatial and the social dynamics of the populations, and combine these two perspectives to embed the animal social networks into space. We obtain new insights as to how movement is influenced by social constraints, and how the interplay of both gives rise to different social structures, influencing the size and dynamics of social groups.

### Evolutionary search processes in simple replicator populations

M. Stich*, S. C. Manrubia

*Centro de Astrobiología (CSIC-INTA), Spain*

RNA molecules, through their dual identity as sequence and structure, are an appropriate experimental and theoretical model to study the genotype-phenotype map and evolutionary processes taking place in simple replicator populations. In this study, we relate properties of the sequence-structure map, in particular the abundance of a given secondary structure in a random pool, with the number of replicative events that an initially random population of sequences needs to find that structure through mutation and selection. For common structures, this search process turns out to be much faster than for rare structures. Furthermore, search and fixation processes are more efficient in a wider range of mutation rates for common structures, thus indicating that evolvability of RNA populations is not simply determined by abundance. We also find significant differences in the search and fixation processes for structures of same abundance, and relate them with the number of base pairs forming the structure. Moreover, the influence of the nucleotide content of the RNA sequences on the search process is studied. Our results advance in the understanding of the distribution and attainability of RNA secondary structures. They hint at the fact that, beyond sequence length and sequence-to-function redundancy, the mutation rate that permits localization and fixation of a given phenotype strongly depends on its relative abundance and global, in general nonuniform, distribution in sequence space. The results have important implications for models describing the emergence of function in the context of the RNA world scenario for the origin of life.

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### Collective motion from local attraction

D. Strombom*

*Uppsala University, Sweden*

Many animal groups, for example schools of fish or flocks of birds, exhibit complex dynamic patterns while moving cohesively in the same direction. These flocking patterns have been studied using self-propelled particle models, most of which assume that collective motion arises from individuals aligning with their neighbours. Here, we propose a self-propelled particle model in which the only social force between individuals is attraction. We show that this model generates three different phases: swarms, undirected mills and moving aligned groups.

By studying our model in the zero noise limit, we show how these phases depend on the relative strength of attraction and individual inertia. Moreover, by restricting the field of vision of the individuals and increasing the degree of noise in the system, we find that the groups generate both directed mills and three dynamically moving, 'rotating chain' structures. The diversity of patterns generated by social attraction alone proves as rich as in those models including alignment, and is a potential explanation of the dynamics of natural flocks.

### A three-dimensional model of ant-nest construction

G. Theraulaz*, A. Khuong, A. Perna, C. Jost, J. Gautrais

*CNRS, Université Paul Sabatier, Toulouse, France*

The amazing abilities of social insects to solve their everyday-life problems, also known as "swarm intelligence", have received a considerable attention the past twenty years. Among their collective behaviors, nest building is certainly the most spectacular. Not only the characteristic scale of the nests is typically much larger than the size of the individuals but some of the architectures built by insect colonies can also be highly complex. All along the evolution of these animals, there has been a whole set of innovations in terms of architectural designs and construction techniques that proved to be efficient to solve a large number of problems such as controlling the nest temperature, ensuring the gas exchanges with the outside environment or adapting the nest structure to various colony sizes. One of the fundamental questions is: how large-scale patterns are generated by the actions and interactions of individual insects? To investigate this issue, we focused on the early stages of nest construction in the ant Lasius niger. This experimental paradigm was used to disentangle the coordinating mechanisms at work and characterize the individual behaviors (transport and assemblage of construction material). We then developed a 3D model implementing the mechanisms detected on the individual level and showed that they correctly explain the construction dynamics and the patterns observed at the collective level for various conditions. The model also revealed that complex helicoidal structures connecting nearby chambers emerge from a constant remodeling process of the nest architecture.

### GLEaM, a global stochastic simulation model of influenza epidemics: its application to the 2009 A/H1N1pdm

M. Tizzoni*, P. Bajardi, C. Poletto, J. J. Ramasco, D. Balcan, B. Gonçalves, H. Hu, N. Perra, V. Colizza, A. Vespignani

*ISI Foundation, Torino, Italy*

The 2009 A(H1N1) pandemic represented the first pandemic in history that could be monitored and studied in real time through sophisticated and realistic computational models. These models aimed at assessing the impact of the disease on a large scale and understanding the measures needed to control it. We illustrate the results obtained through GLEaM, a global epidemic and mobility model, based on a metapopulation approach that integrates high resolution demographic and mobility data worldwide. The model was first used to estimate the transmission potential of the 2009 A(H1N1) pandemic during the early phase of the outbreak and then to forecast the influenza activity patterns of the 2009-2010 fall/winter season. Here, we focus on the assessment of the model predictions through the comparison between the simulated scenarios and the observed pandemic activity during the fall/winter wave. The good agreement between simulations and surveillance data collected by monitoring systems in several countries confirms the valuable role of large computational epidemic models in pandemic preparedness and management.

### Pool and Peer Punishment: From Theory to Experiments

A. Traulsen*

*Max-Planck Institute for Evolutionary Biology, Germany*

Costly cooperation cannot be maintained under Darwinian selection, unless a stabilizing mechanism is present. Punishment targeted at non-cooperators can stabilize costly cooperation and ensure the success of a common project when incentives to exploit the efforts of others are present. Punishment mechanisms can be classified into pool-punishment, where the punishment act is performed by a third party, and the more common idea of individual peer-punishment, where individuals ensure the good conduct of others. A theoretical approach

to this problem shows that both punishment mechanisms can evolve when the common project is voluntary rather than obligatory. When both peer punishment and pool punishment are present, the presence of second order punishment determines the outcome. We have tested these predictions using methods from experimental economics. We found that pool-punishment prevails over peer-punishment when those who cooperate, but do not punish are also subject to punishment. While this situation seems to be very stable, "efficiency is traded for stability", stable co-operation comes at a price since taxes for the pool punishment system have to be paid even in the absence of defectors. Our results suggest how organized punishment could have displaced individual punishment. Based on joint work with Karl Sigmund, Hannelore De Silva, Christoph Hauert, Torsten Röhl, and Manfred Milinski.

### Evolutionary consequences of social interactions among individuals

B. Trubenova*, R. Hager

*University of Manchester, UK*

Traditional quantitative genetics assumes that an individuals phenotype is determined by both genetic and non-genetic, environmental factors. For many animals, part of the environment is social and provided by parents, siblings or other social partners. When expression of genes in these individuals affects trait expression (e.g. behaviour or some other life-history trait) in a focal individual, indirect genetic effects are said to occur. In other words, indirect genetic effects on a focal phenotype are caused by genes expressed in interacting individuals. To date, few studies have investigated the important evolutionary consequences of interactions between direct and indirect genetic effects. Here we advance on previous research using mathematical modelling and show that the effects of an individuals genotype on its phenotype can be dramatically altered due to the interactions with other individuals, with profound consequences for trait evolution. Our model shows that both direct and indirect genetic effects can crucially depend on both population size and average trait value. Using agent-based simulations, we demonstrate the effects of social interactions for the evolution of cooperation and discuss the important implications for the rate and direction of trait evolution.

### Non-local models of swarming

M. S. Turner*, D. Pearce, G. Rowlands

*University of Warwick, UK*

Swarming is a non-equilibrium phenomenon observed throughout the animal kingdom; flocking in birds, swarming in insects [1], shoaling in fish and herding in mammals. Most previous attempts at understanding this phenomenon postulate that members of a swarm align their velocity with those of their immediate neighbours [2]. Such local models seem plausible, mainly on the grounds that it is unfeasible for an individual to follow the positions and velocities of all $N$ members of an arbitrarily large swarm. These models typically contain an alignment term and a noise term. This leads to phenomena reminiscent of phase transitions in statistical physics. However, both metric-based and metric-free versions of these models have undesirable features, e.g. the density $\rho$ of the swarm decreases in time in the absence of an *ad hoc* long range attraction or a finite spatial system size. Here we analyse the possible role of a biologically plausible global measurement of the swarm in which each individual responds to a projection of the swarm. A simple class of candidate models arises naturally in which there is an additional parameter controlling the strength of response to the projection. We analyse this model in 2D and show that it leads to swarms that remain localized. By requiring the strength of the noise, alignment and projection terms to sum to unity we can examine the behaviour of the system through a two dimensional phase diagram . We find that the order parameter $\alpha = \sum_{i=1}^{N} |\mathbf{v}_i|$ has a maximum for some characteristic combination of alignment and projection (and hence, noise) strengths. Our model suggests a mechanism for swarms to self-select a particular density at which the swarm is marginally opaque. We show that the opacity reaches a plateau, with a characteristic value that is typically order unity, as the size of the swarm is increased. This leads to a scaling relationship between the number of individuals in a swarm its density; in 2D this is $\rho \sim N^{-1}$ , with the corresponding result in 3D being $\rho \sim N^{-1/2}$ . We argue that some evidence for the latter scaling result already exists [3]. Our model therefore makes several experimentally testable predictions. It would also appear to provide emergent biological function given that marginal opacity provides for rapid, long range information transfer.

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**Emergence of responsive strategies in iterative games**

L. A. M. Vaquero*, J. A. Cuesta, A. Sanchez

*Universidad Carlos III de Madrid, Spain*

Direct reciprocity is one of the most important mechanisms to promote cooperation. It acts when players interact repeatedly and thus emerges in iterative games. The aim of this work is to perform a systematic study of the emergence of responsive strategies in iterative games, as a result of successive invasions of resident strategies by new ones, which are incorporated to the game at a very low rate. For the sake of simplicity we have considered only the 16 pure strategies which opt to cooperate or defect depending on the actions of the two players in the previous round. Evolution proceeds through a replicator rule in a finite (albeit large) population. The result of the invasion process is a weighted and directed graph whose vertices are the different equilibria attained (either pure or mixed). The dominant strategies can then be inferred from this graph. On the one hand, with this work we extend previous studies analysing the role of different strategies and their interactions in the Iterated Prisoner's Dilemma game to a wide range of games, and on the other hand, we fully characterize the process by which the different strategies emerge and combine.

# VI. Complexity and Computer Science

### Effective complexity of finite binary strings and stationary process realizations

N. Ay*, M. Mueller, A. Szkola

*Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany*

Effective complexity (EC) measures the information content of the regularities of an object. It has been introduced by M. Gell-Mann and S. Lloyd. The regularities are modeled by means of ensembles - probability distributions on finite binary strings. The minimal Kolmogorov complexity over an appropriate set of ensembles determines the value of effective complexity of a binary string. We present a definition of EC in terms of algorithmic information theory and demonstrate how it fits into the context of algorithmic statistics. Related measures of complexity are Kolmogorov minimal sufficient statistics or sophistication. The measures mainly differ in the choice of model classes for algorithmic statistics used to describe the regularities. We give an overview of basic properties such as effective simplicity of incompressible binary strings and existence of strings that have EC close to their lengths. The corresponding results have appeared independently in the context of algorithmic statistics. As a new result we present a remarkable relation between EC and Bennett's logical depth: If the EC of a string exceeds a certain explicit threshold then that string must have astronomically large depth; otherwise, the depth can be arbitrarily small. Further we investigate EC of binary strings generated by stationary - in general non computable - processes. It can be shown under some conditions that long typical process realizations are effectively simple. Our work aims to extend the mathematical foundations of complexity that have been initiated at the Santa Fe Institute. We believe that it is useful to establish relationship to the independently developed notions of complexity in algorithmic information theory. In particular, our new results can be formulated and are valid for different variants of complexity that quantify regularities. Starting with the results of our asymptotic analysis we intend to clarify the link between EC as an algorithmic concept and probabilistic measures of complexity such as predictive information, also known as excess entropy and effective measure complexity. In the case of Shannon entropy and Kolmogorov complexity such a correspondence is stated in the theorem of Brudno.

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### Optimal phenotypic plasticity in a stochastic environment: Does Maximum Informational Entropy minimizes the cost/benefit ratio?

P. Coquillard*, A. Muzy, F. Diener

*Université de Nice-Sophia Antipolis, Nice, France*

Phenotypic plasticity refers to the ability of genetically identical organisms to change their phenotype in response to environmental change in space and time. Two analogous models of three epistatic genes are designed to address the question of the optimal phenotypic variance as a response to a fluctuating environment while optimizing the cost/benefit ratio and satisfying a fixed energetic expense (plasticity cost). The differential entropy is used (i) in a numerical model as a metric of the phenotypic variance reduction in the course of the fitness optimization, and (ii) applying the MaxEnt theorem, in an analytical model to optimize parameters under the constraint of limited energy availability. Both models provide comparable results, showing that the optimal cost/benefit ratio belongs to a wide interval in which some small differences between individuals should not substantially modify the fitness. As a consequence, even in the case of an ideal population close to the optimal plasticity, a certain level of genetic diversity can be long conserved, consistent with what has been shown by empirical studies. We conclude that a part, still to be determined, of genetic diversity within populations probably stem from environment fluctuations. Lastly, it results from this work that species confronted by monotonous factors should be less plastic than the vicariant species experiencing heterogeneous environments.

### Joint Utilization of GIS and Health Care Data in Dynamic Simulation Models

G. Schneckenreither*, P. Einzinger, M. Landsiedl, M. Scheuringer, F. Breitenecker

*Vienna University of Technology, Austria*

The consumption of health services depends on local properties like physician density and the range of provided services. For simulation and construction of dynamic models it is a challenge to incorporate such data with

maximum efficiency. Usually we can differentiate between the acquisition, preprocessing and integration of data into a dynamic model. For example it can be of advantage to relate health care data to their spatial context, especially during simulation of agent-based (AB) models (where local interactions are of major concern by default). This can be achieved by incorporating a geographic information system (GIS) into the spatial domain of an AB model. We present a descriptive statistical approach of using a GIS database with data from the OpenStreetMap project together with data on hospital utilization for Austria in order to visualize the relations between residence of patients and the locations of their inpatient treatments. In a more dedicated dynamic model a large set of health care data must be integrated with or without spatial context, preprocessed and incorporated into the dynamic model. We show an example for structure and level of detail of these data on the basis of an existing database on Austrian health care reimbursement claims data. Typically (spatial) granularity is limited for privacy reasons, for example to the level of zip codes. An agent population with a high level of detail has to be generated by stochastic means and at the same time the dynamic behavior of agents must (statistically) map the available data. To allow high model validity the approach incorporates data from all obtainable sources with potentially different levels of granularity. This includes GIS data, health care billing data and data from public statistics up to expert knowledge. We link a database of preprocessed health care and spatial data with dynamic simulations of an agent-based model and discuss advantages and disadvantages of different approaches regarding performance and functionality. Currently we are analyzing the visualization possibilities of the dynamic simulation output.

### Software evolution: from inhomogeneous evolution to coarse-grained dynamics

C. J. Tessone*, F. Schweitzer, M. Zanetti

*ETH Zurich, Switzerland*

Based on the analysis of the dependency network of several Java projects, we develop a novel model of network growth which considers both: an attachment mechanism and the addition of new nodes with a heterogeneous distribution of their initial degree, $k_0$ . Empirically we find that the cumulative distributions of initial and final degrees in the network, follow power-law behaviours: $1 - P(k_0) \propto k_0^{1-\alpha}$ , and $1 - P(k) \propto k^{1-\gamma}$ , respectively. For the total number of links as a function of the network size, we find empirically $K(N) \propto N^{\beta}$ , where $\beta \in [1.25, 2]$ (for small N), while converging to $\beta \sim 1$ for large $N$ . This indicates a transition from a growth regime with increasing network density towards a sustainable regime, which prevents a collapse due to ever increasing dependencies. Our theoretical framework allows us to predict relations between the exponents $\alpha$, $\beta$, $\gamma$, which also link issues of software engineering and developer activity. These relations are verified by means of computer simulations and empirical investigations. They indicate that the growth of real Open Source Software networks occurs on the edge between two regimes, which are either dominated by the initial degree distribution of added nodes, or by the preferential attachment mechanism. Hence, the heterogeneous degree distribution of newly added nodes, found empirically, is essential to describe the laws of sustainable growth in networks. Interestingly, a complementary view of the software evolution can be studied by recourse of the datasets: that of the inheritance trees. Being Java an object-oriented language, the software is developed as an abstract representation where classes inherit, reimplement and add functionalities of another. In this representation, which has underlying the same complex network described above, a different kind of dynamics emerge. And so, from a topological viewpoint, both emerging networks differ. We link these two dynamics and explain the how the dynamics of the first one renormalise into the second one.

### Adaptive Neural Chaos Control for Autonomous Robots

M. Timme*

*Max Planck Institute for Dynamics and Self-Organization, Germany*

Controlling sensori-motor systems in higher animals or complex robots is a challenging combinatorial problem, because many sensory signals need to be simultaneously coordinated into a broad behavioural spectrum. To rapidly interact with the environment, this control needs to be fast and adaptive. Present robotic solutions operate with limited autonomy and are mostly restricted to few behavioural patterns. Here we introduce chaos control as a new strategy to generate complex behaviour of an autonomous robot. In the presented system, 18 sensors drive 18 motors by means of a simple neural control circuit, thereby generating 11 basic behavioural patterns (for example, orienting, taxis, self-protection and various gaits) and their combinations. The control signal quickly and reversibly adapts to new situations and also enables learning and synaptic

long-term storage of behaviourally useful motor responses. Thus, such neural control provides a powerful yet simple way to self-organize versatile behaviours in autonomous agents with many degrees of freedom.

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**Time-Aware Centrality in Contact Network Analysis**

E. Yoneki*, D. Fay, J. Kunegis

*University of Cambridge, UK*

Understanding the dynamic structure of contact networks is critical for designing dynamic routing algorithms, epidemic spreading and message passing algorithms. Time dependent networks are characterised by time dependant paths which are characterised by the order in which the paths occur. For example, a path between 3 nodes A→B→C does not imply a reverse path exists; A→B→C provides no information about how C may communicate with A. However, in many applications a static graph is constructed which represents typically the proportion of time a link was seen between two nodes. These static graphs often lose the time information which is critical in contact networks. At a specific time and from a specific node there is a single static network representing the paths between the root node and the rest of the network. JD is used in our work to look for commonalities in these specific static networks and to provide an average static network where appropriate. That is, we are looking for modes of operation in contact networks. Joint diagonalisation (JD) is a technique used to estimate an average eigenspace (i.e. eigenvectors and eigenvalues) between a set of matrices. Whilst it has been used successfully in many areas to track the evolution of systems via their eigenvectors; its application in network analysis is novel. This is surprising given the close link between eigenvectors and communities in networks. The key focus in this work is the use of JD on matrices of spanning trees of a network. These spanning trees are formed by propagating a message through the network and recording the routes taken. This is especially useful in the case of real-world contact networks in which a single underlying static graph does not exist. The average eigenspace may be used to construct a graph which represents the 'average spanning tree' of the network or a representation of the most common propagation paths. We then examine the distribution of deviations from the average and find that this distribution in real-world contact networks is multi-modal; thus indicating several 'modes' in the underlying process/network. Through Gaussian mixture of models this mode are identified and is found that these correspond to different times. Thus, JD may be used to decompose the behaviour, in time, of contact networks and produce average static graphs for each time. We also demonstrate that this is not the case for randomly generated networks which result in a uni-modal distribution; thus JD may be used to examine the consistency of real world graphs with a view to targeting different strategies at different times. This may be viewed as a mixture between a dynamic and static graph approach to contact network analysis. Finally we demonstrate its usefulness by identifying which nodes at a particular time are optimal for viral message passing. By using spanning trees the methodology takes advantage of a sampling mechanism present in many real-world networks; it might not be possible to record all contacts but it is often possible to flood a message in a network and record the paths taken. It is hoped that in future this technique will aid in the design of time specific algorithms for time dependent networks.

# Posters

**From synthetic biology to xenobiology: Challenges and perspectives.**

C. G. Acevedo-Rocha*

*Max Planck Institute of Biochemistry, Germany*

In order to understand the challenges of synthetic biology the concept of the "minimal cell"is analyzed by integrating the latest studies regarding comparative genomics and genome reduction projects of a plethora of natural and industrially-relevant microorganisms. Here it is important to distinguish the difference between gene essentiality and persistence because genes tend to persist, shaping the organization, architecture, modularity and functionality across genomes. The implications of mobile genetics elements, genome evolution and metagenomics for synthetic biology and genomics are also discussed. The introduction of xeno-nucleic acids and xeno-compounds as noncanonical components of living systems is also described. This will help consolidating xeno-biology as an emerging discipline whose aim is the construction of a parallel world driven by the combination of efforts in experimental and directed evolution as well as combinatorial and rational design of synthetic organisms. Finally, I argue why this approach will not only serve as an important biosecurity tool, but also as an important measure to draw the limitations and potentials of synthetic biology.

**The struggle for space: A new mechanism to viral extinction.**

J. Aguirre*, J. A. Cuesta, J. A. Capitán, S. C. Manrubia

*Centro de Astrobiología CSIC-INTA, Madrid, Spain*

RNA viruses, by producing large progeny numbers affected by high mutation rates, promote quick adaptation to changing environments. However, this strategy often ushers in an arms race between the virus and the host cells. The design of protocols to control the propagation of viral infections is a hard enterprise, mainly because of the limited knowledge of the mechanisms leading to viral extinction.

Recently, we developed a model [1] to study the two-dimensional growth of an RNA virus population in the framework of quasispecies theory [2], paying special attention to the effects of spatial competition on its diversity. Following this line of research, we now present a new mechanism to cause extinction of a propagating infection due to competition to infect susceptible hosts [3]. This new model describes the dynamics of a phenotypically heterogeneous population of viruses producing large amounts of progeny and infecting host cells able to develop defenses against infection. Furthermore, it is based on empirical observations and protocols often used to study in vitro viral spreading in cellular monolayers, as well as in well-established biological grounds. When there are no limitations in the number of susceptible cells available, we observe a positive feedback runaway mechanism where host resistance and viral progeny production grow unboundedly. In contrast, physical space limits the advantage that the virus can obtain from increasing offspring numbers, and infection clearance may result from an increase in host defenses beyond a finite, critical threshold.

Our results might be relevant to better understand propagation of viral infections in crops or in tissues with mobility constraints, as plant leaves, and the implications that environments with different geometrical properties might have in devising effective control strategies.

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**Creating Semantic Networks Using Semantic Spaces**

M. Ahat*, Y. V. Hoareau, M. Bui, S. B. Amor

*Ecole Pratique Des Hautes Etudes, France*

Semantic space is an algebraic model for representing text documents as vectors of identifiers such as index terms. These vectors, which represent documents, provide us with a mean of calculating the "semantic distances"among documents. Connecting the documents with the semantic distances forms a document network, which we call a semantic network. While this seems to be a straightforward idea, the methods to calculate and selecting the distances should be well thought over, since the resulting semantic network may vary accordingly. In this work we propose three methods to create semantic networks: distance threshold based, number

threshold based and double connection based method. To test those methods, we have used a collection of over 4300 resumes from INRIA research report. The resulting networks not only show the overall structure of the whole corpus, but also present a semantic navigation map among the documents as well. We also compare the results of those three methods and discuss their differences, advantages and shortcomings from one another.

### Identifying and modeling patterns of tetrapod vertebrate mortality rates in the Gulf of Mexico oil spill

F. Antonio*, R. D. S. Mendes, S. Thomaz

*Maringá University State, Brazil*

The accidental oil spill in the Gulf of Mexico in 2010 has caused perceptible damage to marine and freshwater ecosystems. The large quantity of oil leaking at a constant rate and the long duration of the event caused an exponentially increasing mortality of vertebrates. Using data provided by NOAA and USFWS, we assessed the effects of this event on birds, sea turtles, and mammals. Mortality rates (measured as the number of carcasses recorded per day) were exponential for all three groups. Birds were the most affected group, as indicated by the steepest increase of mortality rates over time. For sea turtles and mammals, an exponential increase in mortality was observed after an initial delay. These exponential behaviors are consistent with a unified scenario for the mortality rate for tetrapod vertebrates.

### Modelling Urban Dynamics as Complex Systems

G. A. Aranda-Corral*, J. Borrego-Díaz, A. Blanco-Escudero, M. Gomar-Acosta

*Universidad de Huelva, Spain*

Contemporary cities are, in essence, Complex Systems (CS) extremely interesting to investigate. A key feature is that Urban Environments provide big databases which are useful to analyze and to understand partial views of their own structure and dynamics. This represents an emergent research field where the generation and use of physical and digital information from cities is applied to design new applications, services and urban plans, as well as, to analysis social behaviors in cities. This field is multidisciplinary, in nature, where Computer Science, Urban Studies, e-Government, media studies, Open Data strategies and Web Services play important roles. Digital information about cities have different reliability. Current initiatives based on OpenData (e.g. ParisData, http://opendata.paris.fr/) aim to process this information, hoping to build useful mashups for cities. The aim of this work is to describe our experience analyzing WWW Data and Web Services, which are needed to simulate urban phenomenas, specifically urban catastrophes, and it is based on every modern city has a digital mirror where researches can access to information (and knowledge) about the city. The analysis have been developed into the context of "eCompleXcity project". One goal of this project is to study Complex Systems associated to Urban Informatics and Computing. We are interested in simulating urban processes by means of Multiagent Systems (MAS). MAS point of view of CS is quite natural because it considers that each module/node of system is an agent. From the Agent point of view, we can formally define its own behavior, as well as, its interaction with other agents. CS can evolve along time and new properties and behaviors emerge. Powerful tools to design CS in a high abstraction level are available. These tools also let us to create big scalable simulations(experiments) and this means a key point for MAS. Our framework has been applied to a case study: simulation of flooding caused by Katrina's hurricane in New Orleans.

### Synchronization and Emergence

F. M. Atay*

*Max Planck Institute for Mathematics in the Sciences, Germany*

Many natural and man-made systems are intrinsically complex entities consisting of a large number of interacting components. A key concept in this context is Emergence, that is, the question of how novel dynamics arise from the interaction of simple units. This talk will study emergence in the context of a particular but important behavior of networked systems, namely synchronization. Complete synchronization refers to the case where all units in the network display identical behavior. On the one hand, synchronization serves to amplify the output signal from the network; on the other hand, the complexity of the system is apparently

reduced, since the behavior is now spatially homogeneous. For instance, in diffusively-coupled systems, the synchronized network behaves exactly like the individual isolated units, so no new behavior emerges from synchronization. How can one then reconcile the concepts of synchronization and emergence? I will present two mechanisms as answer. The first mechanism is the presence of time delays in the network and the second one is non-diffusive coupling. In the first case, the units are only aware of a past state of the network, in the second case their interaction is not designed for cooperation. Hence, it is not obvious that such systems can synchronize their actions at all. It surprisingly turns out that both systems can indeed exhibit synchronization under appropriate conditions. Furthermore, the synchronized network can display a rich range of complex behavior much different from that of individual units. The complexity can manifest itself temporally, as in chaotic oscillations, or spatially, as in the recently-discovered phenomenon of chimera states, where both synchronized and incoherent behavior co-exist in the same system at different spatial locations.

### Topological instabilities in complex glass-forming networks

V. Balitska*, O. Shpotyuk, R. Golovchak

*Lviv State University of Vital Activity Safety, Ukrain*

Chalcogenide compounds prepared by alloying from a melt are known to possess unique ability to form glassy-like networks distinguished by full saturation of interatomic covalent bonding, they attaining three distinct phases dependently on relation between average number of bonds and Lagrangian constrains per atom: floppy, elastically rigid but unstressed and enthalpically-stressed rigid. The floppy networks clearly reveal topological instabilities showing strict relaxation towards thermodynamically equilibrium state. This process proceeds in time tending sometimes to a few decades as in a case of vitreous arsenic selenides. That is why its guiding is one of a necessary condition to ensure high reliability for these network solids in possible device applications. In this report, we shall consider mathematical formalism to describe evolution "stretched"kinetics (non-exponential) in real glassy-like compounds using classical first-order rate equation.

### Characterizing spatial interactions in European R&D network communities

M. Barber*, T. Scherngell

*Austrian Institute of Technology, Austria*

Collaborations between firms, universities, and research organizations are crucial in the modern knowledge-based economy. Systems of such collaborations constitute R&D networks, which may be meaningfully segmented using recent methods for identifying network communities, subnetworks whose members are more tightly linked to one another than to other members of the network. We identify communities in the European R&D network using data on joint research projects funded by the fifth European Framework Programme. We characterize the identified communities according to their thematic orientation and spatial structure. By means of a Poisson spatial interaction model, we estimate the impact of various separation factors –such as geographical and technological distance –on the variation of cross-region collaboration activities in a given community. The European coverage is achieved by using data on 255 NUTS-2 regions of the 25 pre-2007 EU member-states, as well as Norway and Switzerland. The results demonstrate that European R&D networks are not homogeneous, showing distinct, relevant substructures characterized by thematically homogeneous and spatially heterogeneous community groups.

### A mathematical approach to medical complexity

M. Barons*

*University of Warwick, UK*

Health is a complex interaction of individual characteristics, treatment characteristics and organisational characteristics of the healthcare delivery system. Complexity science studies such systems to understand them and to discover if the emergent behaviour we see can be directed or controlled. Tailoring treatments to patients has potential to improve patients quality of life and reduce resource consumption. The power of mathematics is used to drive efficient and provably robust machine learning, which has the capacity to predict outcomes in the case of complex interactions, such as in healthcare. The ability to predict outcomes

for patients will enable the tailoring of their treatments to their individual needs. In this talk I will illustrate some of the approaches being taken in the endeavour to tailor treatments to patients, using datasets form a medical trial of a new treatment for back pain, and an observational study of cardiovascular rehabilitation.

**Self-avoiding walks based approximation method for epidemic disease spreading**

F. Bauer*, J. Lizier

*Max Planck Institute for Mathematics in the Sciences, Germany*

The problem of identifying the most effective nodes in a network for seeding disease spreading (or other types of information spreading such as rumours) has gained much recent attention. Exact solutions to this problem are possible but computationally prohibitive. Several approximation methods have been proposed. Ideally, such a method should accurately infer the number of resulting infections from each initially infected node, therefore also accurately order nodes in terms of their spreading effectiveness, and be computationally efficient. The previously proposed methods (based on degree, k-shell decomposition analysis and dynamical influence) are not usually based on the underlying disease spreading problem, rather measures of network topology. As such, they typically infer only the ordering of effectiveness of nodes but do not estimate number of infections, and indeed there is potential for the ordering they infer to be improved. We introduce a new method to approximate the number of infections resulting from a given initially infected node, based on counting the number of self-avoiding walks (of various lengths) to each other node in the network. This provides an advance over existing inference methods by taking the underlying problem into account and therefore providing estimation of actual numbers of infections. Additionally, in simulating infections on various real-world networks with the SIR model, we show that our self-avoiding walks based method improves the inference of effectiveness of nodes over a wide range of infection rates compared to existing methods. We also analyse the trade-off between estimate accuracy and computational cost of our method, showing that good accuracy can be obtained at reasonable cost.

**Time Varying Interactions in Voter and Language Change Models**

G. Baxter*

*Universidade de Aveiro, Portugal*

Neutral diffusion-like models have been proposed for an extremely broad range of applications, including population genetics, ecology, magnetism, opinion dynamics and language change. Many of these models can be described in a single framework, and the probability of consensus/fixation and the time to reach this state, among other statistics, can be calculated using similar methods. I will consider the effect on such models of variations with time of the interaction strengths. In the example of the Voter Model, this corresponds to agents whose propensity to change their opinion varies with time. For language change, it means that speakers' learning rates change with time. This models the effect of ageing, in which young people adapt quickly and older people tend to become almost unchanging in their language use. The mean consensus time varies with the period of change of the interaction strengths, being shortest (and corresponding to the time found in the homogeneous case) for very quickly changing interaction rates, and longest for very slowly changing rates (which corresponds to heterogeneous but static interaction strengths). For intermediate regimes, the consensus time can be found by calculating the – time dependent – mean time between interactions for each agent/speaker, then using a Fokker-Planck Equation method with reduction to a single centre-of-mass variable. This method also allows accurate estimation of the probability to reach consensus/fixation from inhomogeneous initial conditions.

**Questionning the relevance of standard models for large-scale diffusion phenomena**

D. Bernardes*, M. Latapy, F. Tarissan

*CNRS/UPMC, Paris 6, France*

Diffusion phenomena such as computer virus epidemics, information spreading in a social network or files transferred in a P2P network are ubiquitous in complex networks. Their study addresses both applied and theoretical questions and it has been a very active area of research for decades. Recently the interest in this

field has been renewed with the emergence of large scale on-line activity and the data they provide. More precisely, the current challenge is to validate and refine current diffusion/epidemic models (SI, SIR, etc) for these large scale complex networks. Using real world data from P2P networks we compare diffusion models vs adoption models for this scenario. We begin by constructing an _interest graph_ from the file request traces, where the spreading takes place. We proceed confronting usual theoretical hypotheses such as homogeneous infection rates and adoption thresholds to develop a methodology for the study of this processes. Finally we discuss the relation between these processes and the underlying network structure.

### Agent-based modelling in prediction of environmental influence on drug release

M. Bezbradica*, H. J. Ruskin, M. Crane

*Dublin City University, Ireland*

Complex modelling using cellular automata methods has enabled a deeper insight into the molecular level effects of the processes underlying the dissolution of various drug formulations. These processes are, among other factors, directly dependent on environment, particularly on acidity and influence on hydration potential of solute, effects which have not been modelled much to date. In the presented work, we model this dependence and investigate the influence of environmental transitions, using a probabilistic approach applied to the dissolution of coated microspheres. Ethylcellulose/pectin coatings are used to shield the active substance during transition through multiple different environments with the goal of providing targeted dosage delivery. Individual drug dissolution phenomena are modelled separately, for each environment, and their cumulative effect on release rates is measured. One advantage of this approach is the ability to observe, independently, the influence of local interactions on the global system behaviour. The cellular automata space is three-dimensional, allowing for realistic representation of the spherical geometries in the problem, while transitions between cell states are governed by a combination of physical and statistical laws, which define the deterministic and stochastic aspects of the system. Erosion and swelling processes are represented using different probabilistic distributions and drug particles as the active agents, with diffusion through the system following a random walk. When exposed to different environmental elements, dissolution profiles investigated show marked difference, reflected in changes in diffusivity and porosity. An observation of how these changes evolve, (both highly desirable and non-trivial for in vitro pharmaceutical research), is possible using visualisation, which allows the system state to be captured at each time point. Moreover, model calibration and validation of results, against in vitro data, is achieved through collaboration with Sigmoid Pharma Ltd., and this is also reported upon.

### Prediction in computational models of complex systems

F. Boschetti*, J. Symons

*CSIRO CMAR, Australia*

Computational models of complex systems are currently used to support decision making in a number of real world problems at the intersection of technical, economic, ecological and social issues. This places a considerable responsibility on the modeling and complex system science community, since modeling outcomes, understood as predictions, can impact policy making and thus the life of millions. Several authors claim that this use of computer modeling is unwarranted because it cannot provide reliable predictions of complex dynamics. This criticism can be summarized in four points: a) computational models have a very poor prediction track record; b) most model predictions are not testable because of their conditional nature; c) behind an appearance of objectivity, model outcomes reflect the modelers subjective beliefs and assumptions and d) certain scientific activities are not designed, and should be expected to, provide predictions. This criticism is based on the crucial assumption that a prediction is desirable, but not necessary; that is, a prediction is an ideal or discretionary input to, not a requirement for, decision making. The purpose of this paper is to suggest that models should be viewed as predicting tools. We do so by following two lines of argument. First, we stress that prediction is an essential component to any planning and that it is implicit even in approaches which claim not to require it. Second, we highlight the close link between prediction and explanation in the everyday use of computer modeling. If we were to accept that a prediction is essential to any decision making, then the crucial question would shift from can model predictions be trusted? to how do

model compare to other approaches to prediction?, which we address in this work.

### Travelling waves in the brain: a network's approach to their propagation

V. Botella-Soler*, M. Valderrama, B. Crépon, V. Navarro, M. L. Van Quyen

*Universitat de València, Spain*

Slow waves constitute the main signature of sleep in the electroencephalogram (EEG). This pattern consists of a large-amplitude low-frequency (¡1Hz) oscillation that emerges from the synchronization of large groups of neurons and propagates through the cerebral cortex. While recent findings have demonstrated its functional role in shaping and strengthening neuronal networks, a large-scale characterization of the slow waves remains elusive in the human brain. For the first time we have studied the propagation of such waves from intracranial EEG recordings in humans. By reconstructing the propagation networks we find that the majority of the slow waves tend to start in frontal regions of the brain while they have a tendency to end in posterior and temporal regions.

### A statistical model of constrained evolution for protein interaction network

A. Bottinelli*, M. Gherardi, M. C. Lagomarsino, B. Bassetti

*Uppsala University, Sweden*

Proteins participating into a protein-protein interaction network can be grouped into homology classes following their common ancestry. On the other hand, the laws governing such partitioning have a high degree of universality, depending on genome size only and not on genome-specific features, thus can be regarded as evolutionary constraints on the growth mechanism of genomes. We define a statistical model describing the joint growth of the network and the partitioning under the constraint of a stochastic innovation/duplication process chosen in the class of the "Chinese restaurant"processes, and we study this model through a combined mean-field and simulation approach. We ask whether the collective trends of genome partitioning can affect the growth of the network and its final topology. We find that the scaling of the number and population of homology classes affects mean-field network properties such as mean degree and degree distribution. We are currently studying correlations between class composition and network properties. Further work on this model will include a comparison with empirical data, aiming to qualitatively predict the structure and dynamics of ancestral networks.

### Effect of water level in a prey -predator interaction

S. M. Bouguima*, N. C. Fellah

*University of Tlemcen, Algeria*

Water level may influence local community dynamics. We examine how seasonal variations in water level affect the outcome of prey- predator interactions in Parloup Lake in the south of France. We propose a new model to describe the annual cycle of persitence by using continuation theorem of coincidence degree.

### Self-adaptability in glass-forming network systems: computational cluster-modeling approach

V. Boyko*, O. Shpotyuk, M. Hyla, R. Golovchak

*Lviv Scientific Research Institute of Materials of SRC "Carat", Ukrain*

Self-adaptive glasses possessing intermediate-phase networks having just three Lagrangian constrains per atom (as high as dimensionality of real space –the condition needed to avoid stress), are known to be most attractive in practical application because of unique non-aging ability. Adaptability concept was examined for complex germanium-arsenic-selenium/sulphur glasses within developed Cation-Interlinking Network Cluster Approach (CINCA). Ab initio quantum mechanical calculations were performed with RHF/6-311G* basis set to determine cluster-forming energies for different structural configurations statistically possible in the glasses. In

case of germanium-selenium/sulphur glasses, it was shown that directly linked edge- and corner-shared germanium tetrahedrons are basic network-forming blocks, the former being more energetically preferential. These over-constrained tetrahedrons are specifically interconnected within more extended blocks forming a so-called outrigger raft structural motive. Despite over-constrained nature, these blocks are distributed in a network via optimally-constrained links, giving only a pseudo-reversibility window in glasses ranging between mean coordination of 2.4 and 2.5. In contrast, the real optimally-constrained phase should be formed by corner-shared arsenic pyramids in arsenic-selenium/sulphur glasses. This composition is probably stretched beyond stoichiometry, provided optimally-constrained ring-like As-rich clusters are formed.

### Complex dynamics for a reduced model of human EEG

D. Bünte*, F. Frascoli, D. T. J. Liley

*University of Technology Hamburg-Harburg, Germany*

Liley's mesoscopic mean-field theory of mammalian cortex electro-rhythmogenesis describes the salient features of brain function based on the bulk interactions between inhibitory and excitatory neuronal populations within cortical macrocolumns [1]. Recently, a method for cataloguing the possible qualitative dynamical features of this model and other nonlinear systems has been proposed [2], with the aim of establishing stronger connections between the dynamical patterns observed in neural field models and their neurobiological foundations. In this poster, a state space reduction of Lileys model is briefly described with the behavior of a number of different parametric instantiations illustrated to show that many of the important features of the original equations are preserved. For a range of physiologically meaningful values of parameters, it is found that local interactions between neuronal populations are sufficient to produce a biologically compelling, diverse dynamical landscape of brain activity. A number of highly nontrivial mechanisms for the birth of complexity are present in these reduced equations, among which we particularly note: i) chaos, generated by a Shilnikov saddle-node bifurcation, that acts as an organizing center for the parameter space, ii) appearance of stable and unstable resonant bifurcation points responsible for quasiperiodic oscillations within EEG bands, iii) existence of a number of oscillatory phenomena with biological relevance, such as mixed mode oscillations and multistability and iv) bursts and seizure-like dynamics for extended ranges of parameters. These diverse topologies in regions responsible for the emerging dynamics together with the corresponding physiologically common shapes of rhythmic long term patterns show the potential of the model to reproduce highly complex dynamics of brain function. Based on this reduced model there are some speculative questions that we would like to propose in this poster. Firstly, is it possible to define a maximal number of degrees of freedom in neural field models that are sufficient to capture the relevant activity of mammalian cortex at rest? The high dimensionality and large parameter spaces of many of the existing models and theories of cortical dynamics discourages an in-depth, rigorous mathematical analysis, which are typically performed for models of spike generation. And, secondly, how do some of the findings presented here enrich our knowledge of the biological basis for rhythmic brain activity? For instance, our analysis points to resonances in human EEG being triggered by a physiological cause rather than being the product of complex synchronization mechanisms [3].

[1] Liley DTJ, Cadusch PJ, and Dafilis MP: A spatially continuous mean field theory of electrocortical activity. Network: Comput. Neural Syst. 2002, 13:67–113 [2] Frascoli F, Van Veen L, Bojak I, Liley DTJ, Metabifurcation analysis of a mean field model of the cortex. accepted in Physica D, arXiv:1008.4043. [3] Palva JM, Palva S, Kaila K, Phase Synchrony among Neuronal Oscillations in the Human Cortex, J. Neuroscience, 2005, 25:3962-3972

### Optimal navigation in complex networks

D. O. Cajueiro*

*Universidade de Brasília, Brazil*

Recent literature has presented evidence that the study of navigation in complex networks is useful to understand their dynamics and topology. Two main approaches are usually considered: navigation of random walkers and navigation of directed walkers. Unlike these approaches ours supposes that a traveler walks optimally in order to minimize the cost of the walking. If this happens, two extreme regimes arise one dominated by directed walkers and the other by random walkers. First, we try to characterize the critical point of the transition from one regime to the other in function of the connectivity and the size of the network. Second, using the subway network of Boston and the London rapid transit rail as proxies for complex networks, we show that the centrality measures inherited from the approach of optimal navigation may be considered if

one desires to evaluate the centrality of the nodes using other pieces of information beyond the geometric properties of the network. Furthermore, evaluating the correlations between these inherited measures and classical measures of centralities such as the degree of a node and the characteristic path length of a node, we have found two classes of results. While for the London rapid transit rail, these inherited measures can be easily explained by these classical measures of centrality, for the Boston underground transportation system we have found nontrivial results.

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### Automatic optimization of experiments with digital output

M. F. Calabria*, J. I. Deza, R. R. Deza

*Universidad Nacional de Mar del Plata, Argentina*

The phenomenon of noise-enhanced signal transmission (or noise-enhanced propagation) has been a subject of theoretical and experimental research for more than a decade. Intimately related as it is to the phenomenon of array-enhanced stochastic resonance, it relies for its appearance on the cooperation of noise and coupling. Hence in any experiment involving the phenomenon, the systems parameters must be adjusted in order to maximize its response to a low-frequency signal. As a mock-up of synaptic transmission between neurons, we considered some time ago a chain of damped and unidirectionally coupled bistable oscillators (double-well potentials) [1]. A low-frequency signal was fed at the input of the first unit, its output fed with coupling intensity $\epsilon$ ' as input to the next unit, and so on. Moreover, independent additive Gaussian white noises with intensity D were injected at each element, thus building a cascade representative of a transmission line with noise. The theory was formulated with an analogical focus, measuring the signal-to-noise ratio (SNR) at the output of the last unit, and a region was numerically found in the ($\epsilon$ ', D) plane such that the output SNR expressed in dB was largest. Having recently developed a custom data acquisition and control hardware [2] and as a step in our experimental program, we committed ourselves to verify that prediction and find an equivalent region that maximizes the output response of a chain of Schmitt triggers to a low-frequency signal. We automatically optimize the units input parameters with the goal of achieving maximal coherence between the last oscillators response and the input signal. The optimization is carried out by means of a genetic algorithm, using as measures of input–output coherence either the Hamming distance or the mutual information, and as input parameters the signal-to-noise ratio and the switching threshold of each oscillator. In the uniform case, the optimal setup is basically the same, regardless of which coherence measure is employed.

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### A complexity approach to the output-unemployment relationship

P. Caraiani*

*Institute for Economic Forecasting, Romanian Academy, Romania*

One of the key relationships in macroeconomics is the one between unemployment and output, which results in the well known Okun coefficient. However, the standard approach assumes a linear relationship between the two variables. Although some work has been undertaken in the direction of nonlinear modeling, the departure from the initial approach is rather small, as the new models consider the relationship switching between two linear states or that the coefficients are time-varying. We propose here a reevaluation of this key relationship using concepts and techniques from physics, like mutual information, phase space or recurrence plots, as well as from signal theory, like wavelet decomposition. The approach tries to reveal the more complex as usually viewed relationship between unemployment and production by trying to go beyond the boundaries of mainstream macroeconomics.

### Co-evolution of strategies and update rules in the prisoner's dilemma game on complex networks

A. Cardillo*, J. Gomez-Gardenes, D. Vilone, A. Sanchez

*University of Zaragoza, Zaragoza, Spain*

In the past five years, many papers have been published on evolutionary games on complex networks. However, up to few years ago, no one has ever tried to study systems in which both the strategy of players and the

way they choose it (i.e. the update rule) could change simultaneously. I will present the results of a paper, published in late 2010 on New Journal of Physics, which extends the pioneering work of Moyano and Sanchez on co-evolution of strategy and update rule on regular lattices. Using the paradigmatic game of Prisoner's Dilemma, I will examine the emergence of a collective behavior such cooperation in systems that undergo an evolutionary process, in which players could change both their strategy and update rule. Several scenarios, in terms of both network topologies and update rule, have been considered in order to span the widest set of conditions available. After a brief introduction on the basics of game theory and complex networks, I will present the results of the paper which shows how co-evolution helps in the survival of cooperation even when the temptation to defect is relatively high.

### Mythological Networks

P. M. Carron*, R. Kenna, C. Von Ferber

*Coventry University, UK*

Although qualitative notions of universality exist within the field of comparative mythology, there is no classification system to facilitate comparison of myths. The concept of universality also lies at the heart of statistical physics and network theory. Here, we apply network theory to a variety of mythologies to quantify their characteristics. In this way, myths can be classified and compared across different cultures. We also compare mythological networks to other networks, both actual and fictitious in an effort to discover where they are positioned along the spectrum from the real to the imaginary.

### Multi-layer networks in international maritime trade

S. Caschili*, F. Medda

*University College London, UK*

Network modelling has been used as a magnifying glass to observe the interactions between agents at different levels of granularity. In economics the focus of our magnifying glass ranges from the analysis of single customer choices, to trade of goods between nations, and economic frictions in regional economic zones. Each system level has a certain degree of entropy, which is determined by mutual interactions among the agents, as well as external factors that in turn are part of upper and lower system levels. In network analysis, common approaches focus on the analysis of one single marking factor (among many) through a single layer modelling, while a comprehensive synthetic paradigm that takes into account the most prominent factors is missing. In this context we propose the application of a hierarchical multilayer network model for the maritime shipping system whose layers are composed by agents (nations, ports, and carriers) that not only interact horizontally within their layer but also vertically with lower and upper network layer elements. We study the influence of extreme events in these layers and the resilience to errors and attacks, which creates cascade effects in the upper and lower layers. Our aim is to provide a meaningful description of the propagation of these effects (both positive and negative) at different economic scales in maritime shipping and analyse their impacts on local, national and global economies.

### Heterogeneous team efficiency: Impact of power games on cross-fertilisation

A. Castiaux*

*University of Namur, Belgium*

Innovation teams are more and more built to join complementary competencies. As a matter of fact, it is hoped that an heterogeneous composition of the team will generate through cross-fertilization innovative ideas that a team made of homogeneous profiles would not be able to produce (e.a. Alves et al. 2007). For example, two organisations with complementary knowledge and competences can decide to build together an innovation project to which they will allocate human resources in order to favour knowledge transfer. However, differences between innovation team members also lead to misunderstanding and possibly divergent views concerning the project objective. Power struggles can happen and reduce if not stop the project progress, or, at least, the benefits awaited from cross-fertilisation. To study this tension, we use agent-based simulation. We consider an innovation team made of two sub-teams, each belonging to a different organisation or community. In each

sub-team, we have a leader and ordinary members. Team members can be fully dedicated to the project or have more or less aligned other interests. They can have different level of loyalty to their organisation. The key point we want to study in the paper is the impact of power games on project progress and cross-fertilisation efficiency. Cross-fertilisation can only happen if the sub-teams collaborate. The model includes two collaboration possibilities: regular coordination meetings and temporary exchanges of personnel. Concerning the modelling of power rules, we differentiate two power levels: in the project and in each sub-team. Power in the project is the way power is shared between the two partnering organisations in the framework of the project. The project can be directed either by one of them (dominated project) or by both sharing the decision-making process concerning the evolution of the project objective(s) (shared project). The power exercise in a given sub-team depends on the kind of leadership style in each component. Referring to literature about leadership (Lewin et al. 1939), three leadership styles are possible: democratic, where decisions are discussed with members but the leader keeps the final authority, autocratic (where the leader decides alone) or "laissez faire"(where the leader follows the decision emerging from members). This gives, either for a shared or a dominated project, 18 leadership configurations that we compare looking at two performance variables: the rate of progress in the project (measured by the time needed to achieve initial objectives) and the level of shared knowledge (measured by the inverse of the cognitive distance remaining between the two sub-teams).

**Critical phenomena in heterogeneous k-core percolation**

D. Cellai*, A. Lawlor, J. P. Gleeson

*University of Limerick, Ireland*

The k-core architecture of complex networks often gives important insights into the topological properties of real networks. A k-core is defined as the network subset which survives after a culling process consisting in removing recursively all the vertices (and adjacent edges) with less than k neighbours. This procedure is repeated until no vertex can be extracted any more. The process can have two outcomes: either all the vertices have been removed or some are left. In the latter case, the nodes left constitute the k-core. Particularly interesting is the outcome that a k-core analysis can give to understand in the resilience of networks under random damage. A few years ago, Dorogovtsev et al. (Phys. Rev. Lett. 96, 040601, 2006) developed analytical formalism to calculate k-cores in randomly damaged networks. A recent work by G. J. Baxter et al. (Heterogeneous-k-core versus Bootstrap Percolation on Complex Networks, Dec 2010, arXiv:1012.4336v1) has extended the concept of k-core to mixtures of vertices types, proposing an analytical formalism to deal with heterogeneous k-cores. In this model, each vertex has a given internal rule which prescribes the maximum number of edges that the vertex must be connected to in order to be extracted in the culling process. In our work, we focus on binary mixtures of vertices types and study some relevant cases. We find new critical phenomena and calculate the relevant phase diagram. In particular, we identify a new scaling scenario and calculate critical exponents which are different from the ones of known percolation transitions. This result gives insights into the percolation problem and constitutes a step towards a more effective infrastructure network protection.

**Modelling adoption and evaluation in an online community**

C. Chen*, A. Martins

*CNRS/EHESS, France*

This talk presents an empirically parametrised and validated model of adoption and evaluation in the online book-sharing community, aNobii. The model is based on a Bayesian framework for modelling opinion dynamics in social networks, in which the opinion of agents is dependent not only on the (publicly visible) opinion(s) of their neighbour(s), but on the degree of confidence they have in their neighbour(s)' opinion and in which the publicly visible opinion of agents is not necessarily identical to agents' actual opinion. Through analysis of data from the online social network, aNobii, we validate this framework and show that for a given set of items and an initial set of social connections it can be used to predict the future adoption and evaluation of the items and the evolution of the social network.

**Model of origin of moving capable organisms complex behavior at the early stages of evolution.**

O. I. Chesnokova*, A. V. Melkikh

*Ural Federal University, Russia*

Processes which took place at the early stages of evolution stay one of a biological fundamental question. Nowadays there are several classical model of chemical stage of evolution, when replicators were able to dislocate as a

result of Brownian motion only. Along with that models there are multitude of various unicellular locomotion detailed models (amoeba, etc.). In this case living systems behavior becomes much more complicated. How did the transformation from simple to more complicated motion types occurred? What circumstances impart significant advantage to organisms having directed motion ability under natural selection? This work offers a model based on automaton game theory. Automata living in a two-dimensional space, where two types of resources are distributed, make up a simulated system. Those resources are energy necessary for any activity and material necessary for automaton replication. Having various structures automata population magnitude dynamics in competitive environment was simulated. Automata do not interact directly but through intermediary of resources. Automaton can accumulate both types of resources. The aim of automaton is surviving and replication. Therefore, it is crucial for automaton to replenish energy reserve regularly and accumulate certain amount of material for replication. Automata likewise resources are subjected to Brownian motion. Automaton has two types of receptors for both resources types concentration gradient measuring. Automaton makes choice in three action options: a) save energy –do not move directly; b) move in the line of energy gradient; c) move in the line of energy gradient. One of possible events: "a reward"(one of or both resources gaining) or "a punishment"(no gaining, but energy costs) appear from every selected action. Automaton can learn –make an optimal behavior strategy versus environment, using this information. Proposed model allow researching of automaton behavior and its ability for adaptation to complicated environment. It is shown that ability to direct movement impart significant advantage under large resources concentration gradient and relatively small energy costs for movement. Optimal automaton behavior strategies under different environment are derived.

### Phase transition in competing retail stores

G. Chevereau*, E. Bertin, G. Lambert

*ENS de Lyon, France*

We consider a simple model in which a set of agents randomly visit one of two competiting retail stores selling the same perishable products (typically food). The satisfaction of agents concerning a given store is related to the freshness of the products they bought in their few last visits. Agents then choose with a higher probability the store they are most satisfied with. Studying the model both through numerical simulations and mean-field analytical methods, we find a rich behaviour with continuous and discontinuous phase transitions between a symmetric phase where both stores maintain the same level of activity, and a phase with broken symmetry where one of the two shops attracts more customers than the other.

### Affective interactions in online communities

A. Chmiel*, J. Sienkiewicz, M. Thelwall, G. Paltoglou, K. Buckley, A. Kappas, J. Hołyst

*Warsaw University of Technology, Poland*

We focus on the influence of emotion on the behavior of Internet forum users and the vitality of online debates. We collected a large set of records describing comments expressed in diverse cyber communities such as blogs, fora and the Digg community. The text was then evaluated using classifiers that were able to extract the value indicating the emotional valence. We show that affective interactions do exist in Internet communities and they lead to attractive forces. As result of collective behaviour there are clusters of comments possessing a similar level of emotional valence that are much longer than it would be if they were created by a random process The presence of a longer cluster of coherent emotional expressions increases a possibility to attach to this cluster a comment with the same emotion. In this sense a homophily between participants expressing various emotional valences exists We show that emotions are important for the community life since the level of the initial emotional valence determines the total length of discussion. Majority of comments posses a negative emotional valence and threads starting from a larger number of negative comments last longer so negative emotions can be treated as a kind of discussion fuel. In the course of time the density of negative comments is usually decaying and for longer discussions the difference between the emotional level in the beginning and in the end is larger. Since the BBC Forum consists of a number of threads, we can also observe a local activity of a user in a specific thread and his/her average local emotion expressed in this thread. Users can take part in many threads, thus their local and global activities and corresponding emotions can be very different. One can ask: how user's emotions expressed in the thread are connected to the willingness to be activate in a given discussion? We shown that an increase of activity in the discussion in a particular thread

leads to more negative average emotions of user expressed in this thread.

### Social Representation for Endogenous Control in Multi-Agent Systems

G. Clair*, L. L. De Carvalho, F. Armetta, S. Hassas

*Université Claude Bernard, Lyon, France*

Control of emergence in multi-agent systems (SMA) is a hard and well-known problem. Organizations and properties emerge from the agents interactions, the base units of the system. These interactions are complex so the final organization and its characteristics are impossible to predict only from the analysis of the agents local behavior. To control these systems two ways can be considered, exogenous control and endogenous control. Exogenous control means that the control is created and injected in the system from the outside. The control is static and can not evolve during the life of the system. A lot of exogenous control methods have been developped, from the conception of the system where all the key elements like agents possible actions are defined, to the calibration where all the parameters of the system are tuned to find the best combination before it is run. We could also cite dynamic exogenous control methods where the behavior of the system is learned with previous simulations or when the user is asked to correct the state of the system during its execution. In opposite, endogenous control tends to let the system developing its own control system without external directives. To construct this kind of control, elements like observation, dynamic, learning have to be defined. Our objective is to find theoritical basis in computer sciences, cognitive science and psychology to build a model for endogenous control in multi-agent system. We explicit the main principles of cognitive development to understand the intelligence and control construction for one individual person. We also present the social representation and explain how it could emerge from individuals shared knowledge to represent the social organization in order to better adapt the group to its environment. The social representation is an emerging mean for the group of individuals to indirectly control itself. Finally we use these elements as a basis to construct a model for endogenous control in multi-agent systems. The control system emerges in the system from the group of agents like social representations from group of individuals, and is used to guide the global behavior of the system through influencing the agents local behavior.

### A new structure in complex networks for modelling the mesoscale: Multilevel networks

R. Criado*, J. Flores, A. G. Del Amo, M. Romance

*Universidad Rey Juan Carlos, Spain*

The new concept of multilevel network is introduced in order to embody some topological properties of complex systems with structures in the mesoscale which are not completely captured by the classical models. This new model, which generalizes the hyper-network and hyper-structure models, fits perfectly with several real-life complex systems, including social and public transportation networks. We present an analysis of the structural properties of the multilevel network, including the clustering and the metric structures. Some analytical relationships amongst the efficiency and clustering coefficient of this new model and the corresponding parameters of the underlying network are obtained. Finally some random models for multilevel networks are given to illustrate how different multilevel structures can produce similar underlying networks and therefore that the mesoscale structure should be taken into account in many applications.

### A new structure in complex networks for modelling the mesoscale: Multilevel networks

R. Criado*, J. Flores, A. G. Del Amo, M. Romance

*Universidad Rey Juan Carlos, Spain*

The new concept of multilevel network is introduced in order to embody some topological properties of complex systems with structures in the mesoscale which are not completely captured by the classical models. This new model, which generalizes the hyper-network and hyper-structure models, fits perfectly with several real-life complex systems, including social and public transportation networks. We present an analysis of the structural properties of the multilevel network, including the clustering and the metric structures. Some analytical relationships amongst the efficiency and clustering coefficient of this new model and the corresponding parameters of the underlying network are obtained. Finally some random models for multilevel networks are

given to illustrate how different multilevel structures can produce similar underlying networks and therefore that the mesoscale structure should be taken into account in many applications.

**Stochastic resonance for information flows on hierarchical networks**

A. Czaplicka*, J. Hołyst

*Warsaw University of Technology, Poland*

Flows of information between individuals or groups belong to most important problems related to communication efficiency. We consider a simple model of package delivery on networks with hierarchical structures. This kind of topology corresponds to the scheme of connections observed in many real systems. We take into account the influence of two types of noise. The first one is related to dynamics of packets and the second one has an influence on network topology. In both cases we observe resonance-like phenomenon in our system, i.e. for an intermediate level of noise the system performance is maximal.

**Statistical study by rank of the periods of government in different societies and countries**

M. Del Castillo-Mussot*, A. R. Chacon, G. G. Naumis

*UNAM, México City, Mexico*

Data was collected on the time length of the power rulers in some societies, including: Popes, Germany, Spain, México, Roman emperors, the kings of France, etc., all in very different time periods. Then, regardless of the various processes involved in the change of government leaders (coup, death by accident or illness, resignation, etc.), we performed a statistical study of the respective periods of government by classifying them by rank. Although power laws of the Zipf type have been used to fit rank distributions in different fields like in economy, geophysics, genetics, soft-matter, networks, arts, etc., these fits usually fail at both ending tails. Therefore, we employed a two exponent beta function-like formula [1] to obtain an excellent fitting function in most cases. We also calculated the time correlation function for each society or country.

[1] Martínez-Mekler G, Martínez R. A., del Río M. B., Mansilla R., Miramontes P., Cocho G. (2009), Universality of Rank-Ordering Distributions in the Arts and Sciences. PLoS ONE 4(3): e4791.

**Exact static patterns in a fractional diffusion–reaction system**

J. I. Deza*, R. R. Deza, H. S. Wio

*Universidad Nacional de Mar del Plata, Argentina*

Diffusion-reaction systems are a paradigm in the research on nonequilibrium phenomena, its origins being associated to people like A. Kolmogorov, R. A. Fisher, and A. M. Turing. Besides its applications in chemistry and physics, the diffusion–reaction framework has been a useful approach for understanding (among other issues) morphogenesis and population dynamics, cardiac tissue physiology, and neural signaling. Viewed from the theory of stochastic processes, diffusion is characterized by a linear time-dependence of the variance. Often, however, one finds examples of anomalous diffusion, in which the variance grows as a power $\alpha$ of time: in fractal substrata there is "subdiffusion" ($\alpha < 1$), whereas in chaotic systems and search processes involving Lévy walks there is "superdiffusion" ($\alpha > 1$). Whereas in the theory of stochastic processes, diffusion is adequately described by random walks, anomalous diffusion calls for a description in terms of continuous-time random walks, which consider a (non $\delta$-like) waiting-time distribution for the random walk. Now, it is a marvel of scientific endeavor that again and again, apparently useless mathematics comes to the rescue when physics is at the crossroads: this time, fractional calculus. It occurs indeed, that the continuous-time random walk description of anomalous diffusion is equivalent (from a macroscopic point of view) to a PDE with fractional time derivative [1]. Here we report on the analytical finding of exact static nonequilibrium patterns in a model fractional diffusion-reaction equation on a bounded domain. We consider the hot-spot model [2], which mimics general bistable diffusion–reaction models (e.g. those with a cubic reaction term) through a piecewise-linear "reaction term". The original equation is converted into a spatially fractional diffusion–reaction equation. The fact that the domain is bounded allows using the Laplace transform method when the (spatial) fractional derivatives are defined in the sense of Caputo.

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Singapore, 1994.

**Recent developments on the KPZ equation**

H. S. Wio, J. A. Revelli, C. Escudero, R. R. Deza*

*Universidad de Cantabria, Italy*

It is well known that in the literature associated to growth processes there is a reiterated claim indicating that "the KPZ equation is in fact a genuine kinetic equation describing a nonequilibrium process... that cannot be derived from an effective free energy;..". In opposition to such a statement, here we present a variational formulation for the Kardar-Parisi-Zhang (KPZ) equation leading to a nonequilibrium potential (a kind of thermodynamic-like potential in a far from equilibrium situation) for the KPZ as well as a general form for such thermodynamic-like potential of generalized KPZ and other related kinetic equations [1]. Its knowledge allows us to prove some global shift invariance properties previously conjectured by other authors, and also discuss a few results about the form of the stationary probability distribution function for arbitrary dimensions. In addition, we can extract some strong constraints for the choice of real-space discrete representation schemes , by means of the exploitation of the known fact that the KPZ equation results from a diffusion equation (with multiplicative noise) through a Hopf–Cole transformation. It implies a tight relation between the discrete forms for the diffusive and the nonlinear terms, i.e. they cannot be independent. Whereas the nearest-neighbor discrete representation passes the resulting consistency tests, several known examples in the literature do not. We propose a consistent and highly accurate scheme, and emphasize the importance of the Lyapunov functional as a natural starting point for a real-space discrete representation. As an extremely relevant byproduct, in the light of these findings, the mainstream opinion on the relevance of Galilean invariance in determining the KPZ scaling properties, as well as the fluctuation–dissipation theorem (peculiar of 1D) is challenged [2,3,4]. The results of thorough numerical analysis strongly indicates, in good agreement with some recent theoretical arguments, that the Galilean invariance does not seems to play the relevant role usually assumed in the literature for determining the KPZ universality class. Finally, we discuss a new perspective from a path integral point of view that can shed some light over the KPZ dynamics, and the existence of a critical dimension.

[1] H.S. Wio, Int. J. Bif. Chaos 18, 2813 (2009). [2] H.S. Wio, J.A. Revelli, R.R. Deza, C. Escudero and M.S. de La Lama, Europhys. Lett. 89, 40008 (2010). [3] H.S. Wio, J.A. Revelli, R.R. Deza, C. Escudero and M.S. de La Lama, Phys. Rev. E 81, 066706 (2010). [4] H.S. Wio, J.A. Revelli, R.R. Deza, C. Escudero and M.S. de La Lama, Phil. Trans. Royal Soc. A 369, 396 (2011).

**Complexity of the Schelling segregation model**

N. G. Domic*, E. Goles, S. Rica

*Universidad Tecnica Federico Santa Maria, Chile*

In this work, we will present both numerical and exact analytical results related to the dynamical complexity of Schelling's segregation model for two populations. In this context, segregation appears as a consequence of discrimination measured by the local difference between two populations. The model defines a tolerance criteria on the neighborhood of an agent, which indicates whether it is able to move to a new place or not. Basically an agent will be more tolerant if more of his neighbors share his own state, and vice versa. Based on a given swap criteria (priority list, sequential or random swapping, etc.), the model will then choose two agents with opposite states and swap them. Our work is focused on two different aspects related to Schelling's model: its segregation properties and the prediction complexity. For the first aspect we introduce a decreasing energy functional, that is strictly related to the agents network and the tolerance parameter. To study the second aspect, we define the following prediction problem: Given an initial configuration and one specific site in a D-dimensional lattice, then, will this site state change after a finite number of iterations using a specific swapping strategy? (more iterations imply higher complexity). Depending on the lattice dimension and the tolerance parameter the number of computer steps required to answer the prediction problem does vary, making the problem easier or harder to solve. Our contributions: (i) We characterize the segregation properties of a D-Dimensional lattice where D = 1, 2, 3 for all the possible tolerance parameters, and for the Moore and Von Neumann neighborhoods. (ii) We prove that the energy functional is strictly decreasing when the tolerance parameter is bigger than half of the agents vicinity. (iii) When the tolerance parameter is equal or a little less than the half of the agents vicinity size (the energy functional is non strictly decreasing) we observe that segregation patterns minimize the interface of zones from different agents optimally, so the system may

also segregate efficiently in this case. (iv) For a one dimensional lattice we prove that the prediction question is easy to answer, and in a parallel computer the question can be answered in logarithmic time. (v) When the tolerance parameter is near to its extreme values in 2 or 3 dimensional lattices, we prove that we can easily answer our prediction problem, otherwise its difficult.

### Incorporating Public Responses to Risk Communication into Epidemiological Models

J. A. Earnest*

*University of Glasgow, UK*

The purpose of this project is the development of a theoretical framework that describes how individuals and communities change their behaviour in response to risk communication from social network sources regarding infectious disease events. The goal of this framework is to effectively integrate psychosocial information into a stochastic computational epidemiological model to increase its predictive ability. GLEaM is a Global Epidemic and Mobility model that simulates epidemics at the worldwide scale. GLEaM integrates socio-demographic and population mobility data in a spatially structured manner. GLEaM does not currently integrate behavioural change or risk communication response information into its function. This project investigates the process by which behavioural and psychosocial responses to communication about disease are known to alter infection dynamics during pandemic events, as it is necessary to integrate these behavioural responses into GLEaM in order to accurately simulate disease processes. The literature was examined to ascertain how and why changes in behaviour in response to disease-related risk perception occur, considering risk communication, information sources, and social network variables; also noting the nature of the behaviour change. The structure of the model was analysed to find areas that allowed this behavioural information to be integrated into the model allowing for more sophisticated output upon simulations. The structure and processes of the model appear to be able to accommodate behavioural change and additional socio-demographic information that will increase the predictive validity of the model. This demonstrates the ability of social network and behavioural change information to inform existing computational models which lack information on the psychosocial determinates of behaviour change related to infectious disease.

### Using a Data-Integration Model to Stage Abstraction in Voter Turnout

B. Edmonds*

*Manchester Metropolitan University Business School, UK*

Modellers who are attempting to understand complex and complicated social phenomena are often faced with the following dilemma: choosing a simple model that can be analytically understood (rigour) or a complex model that relates more directly to the available evidence. However good science requires both relevance and rigour. An approach to circumvent this dilemma is described illustrated by a case study from the social sciences. In this approach the representational and abstraction processes are separated in a two-step modelling method. There is a representational step which produces a complex model, and then this model is itself abstracted to a simpler model. First a "Data-Integration Model"(DIM) is built which uses micro-scale evidence (including expert opinion and qualitative accounts) to specify micro-level behaviour and is validated at the macro-level against aggregate statistics following the "cross-validation"approach. The aim of the DIM is to produce a dynamic simulation that integrates as much of the available evidence as possible, in other words is a sort of computational description. The DIM is context-specific to the modelling target and the evidence that relates to this. The DIM is likely to be slow and complex, however, unlike the root social phenomena, its workings can be totally inspected and limited computational what-if experiments conducted on it. These can be used to inform researcher in how to abstract to simpler models that can be checked against the DIM. This is illustrated with a case study on voter turnout. Here evidence as to the many reasons that influence people vote are used to inform the behavioural rules of the agents in a rich agent-based simulation of social networks, households and influence. In the resulting model there are no simple causes in general but rather given particular regions of the parameter space coherent causal explanations can be formulated.

### Categories as the Method to Study Development of Urban Settlement Systems

P. Em*

*The Institute of Geography of The Russian Academy of Sciences, Russia*

In the first part of XX century, S. Mac Lane formed the theory of categories [1]. Categories predict that we should study object with its transformations to itself and to other types of objects. That is invariant with

isomorphism. Therefore, categories could be satisfied method to analyze development of urban settlement systems. We assumed that isomorph objects can broad cross from one condition to another and back assisted by graphic figure –arrow. These arrows fix correspondence between elements of two objects and save their structure. Thats why if some elements of one object change for their modes from another structure of first one will not change. It is actual to decide problems of the theory of central places. In case of changing this system invariants will save their form. Assuming this, we arose necessity to indicate what kind of relations between elements of urban settlement system save in the case of modifications. The central places system can change modification with preservation of isostatic equilibrium. There we can use topologic valuation which helped us find new regularities and features of this type of systems.

### How to hide imprinted genes from the mother?

J. Engelhardt*, S. J. Prohaska, P. F. Stadler, J. Wilkins

*University of Leipzig, Germany*

Sexual reproduction in diploid organisms leads to conflicts between distinct levels of selection, e.g., that of individual organisms and alleles. While the selective forces are well understood at the population genetics level, the intricate molecular mechanisms that have evolved as a consequence of such conflicts are not. One of them is genomic imprinting, an epigenetic mechanism that encodes heritable information "on top of" the DNA sequence through reversible modifications such as cytosine methylation. It modulates the level of expression of alleles in dependence of their parent of origin. The Kinship theory [Wilkins et al. '03] provides an evolutionary explanation of the origin and maintenance of imprinted gene expression based on the fact that maternally and paternally derived alleles are subject to different inclusive fitness effects. Imprinted genes involved in early mammalian development are well characterized. Paternally derived alleles favor fast growth, at the expense of the mother. Maternally derived alleles favor preservation of resources for her other offspring. The magnitude of this conflict depends on the likelihood that the mother's other offspring will share the same father. The conditional expression of alleles at an imprinted locus is initially set through differential DNA-methylation in the male and female germ lines. In the early embryo, the genome undergoes massive reprogramming by maternal store-proteins, which undermine the effects of paternal epigenetic marks. The only elements of the paternal genome to escape this reprogramming are imprinted genes and certain transposons [Lees-Murdock et al. '08]. The preservation of transposon silencing is likely driven by negative selection against activation and the resulting genome instability. The "retrotransposon-mimicry hypothesis" [Wilkins '05] predicts that the escape from maternally-directed reprogramming is due to common features between paternally-imprinted genes and retrotransposons. We evaluate the above named hypothesis using computational methods.

### Modelling Social Integration through Bayesian Statistics

Z. Engin*

*London Centre for Social Studies, UK*

Social integration is a very complex and multi-dimensional phenomenon, characterised by a large dose of uncertainty which should be properly addressed and quantified. The main policy challenge is to develop a clear sense of what interventions are most needed in a given context taking into account all the sensitivity involved from the demographical, economical, sociological, geographical and political perspectives. Since the problem involves non-linear dynamics and high dimensional search spaces, a probabilistic approach using distributions of thoughts and ideas could be a way forward. A Bayesian approach is therefore highly justifiable since it allows subjective interpretations through formal, mathematically rigorous characterisation of beliefs in the form of distributions. The fact that in most cases, researchers have to deal with high-dimensional/unbounded search spaces with many latent variables and incomplete/uncertain data, classical objectivist/frequentist approaches to statistical modelling is often combined with subjective expert opinion in order to update any previous knowledge of some phenomenon. Bayesian thinking provides a wealth of methods to perform the same task relying on axiomatic reasoning providing rational strategies for updating any existing knowledge in the light of new incoming data. The outcome of this type of analysis, posterior distributions of the model parameters, can be tailored according to the task at hand. This can be achieved through the hierarchical modelling whereby the complexity of the search space is reduced by collapsing parameters based on the required form of the outcome, and also by the exchangeability of the parameters which allows the orientation of the analysis to be steered according to the types of available data. In the context of social integration, this would allow rational reductionisms in order to handle the search space consisting of all the demographic, social, economic and

political sub-parameters. This paper serves as a proof of concept study for the design of a multi-methodological research to conceptualise the problem of social integration through the use of Bayesian philosophy. The steps for a rigorous analysis using simulation based methods to test such models are also proposed.

### Fragmentation of dynamic, weighted social networks

E. Zu Erbach-Schoenberg*, S. Bullock, S. Brailsford

*University of Southampton, UK*

A phenomenon often observed in small social networks is the fracturing of the network into two components, following a disagreement between two individuals. Surprisingly, even if other individuals do not explicitly "take sides" in favour of one or other of the disagreeing individuals, the "information bottleneck" resulting from the disagreement event can be sufficient to fracture the network into two disconnected components. This happens by reinforcing the existing community structure within sub-components of the local social network, while decreasing the strength of the interactions between these network sub-components. We investigate this phenomenon in an agent-based model in which agents interact according to a weighted social network. This social network is subject to change, driven by the interaction dynamics it constrains. In our model, each individual can initiate a gathering. Which individuals are invited to a particular gathering and whether they decide to attend depends on the weighted edges between relevant nodes. If two individuals co-attend a gathering, this leads to an increase in the weight of the edge between them. All edges are subject to slow decay and therefore can only persist if they are continuously reinforced. Furthermore, we assume that each individual has a finite capacity for contacts and therefore assign a maximum capacity for the sum of all edge weights to each individual. Using social network data describing a university Karate club, originally presented in Zachary (1977), we demonstrate how this algorithm can fracture the network or keep it connected, depending on the introduction of a negative edge. This shows the way in which reinforcing an information flow bottleneck in the network can make it unstable, without the need for individuals to differ in their references, or in their prior ideological positions. We show that the fractured social network matches the observed break down of the club, described in Zachary (1977). We are therefore able to confirm Zachary's theory of information bottlenecks leading to fission of small groups in a dynamic setting. Furthermore, we investigate the the sensitivity of this behaviour to varying system parameters and differing protocols governing individual social behaviour.

### Self-organising Nebula Clouds: A Hybrid Approach Proposal

R. Esteves*, R. N. Marinheiro

*Instituto Universitário de Lisboa ISCTE, Portugal*

Existing commercial cloud computing solutions use homogeneous resources concentrated in large data centres. The implementation of Cloud computing on resources that are heterogeneous, geographically dispersed, often with limited capacities, and which availability and performance cannot be centrally defined (described as Nebula Clouds by Chandra and Weissman, 2009), requires a more complex management system. Also, traditionally used centralised resources management system becomes a bottleneck when the number of nodes in a cloud increases. This paper proposes and analyses a hybrid model based on decentralised self-organisation of the participant resource nodes and with a centralised auditing and feedback system. This model uses heterogeneous nodes deployed on geographically distributed machines, and an organised service emerges from their self-organisation. Inspired in insect-based algorithms like de Melo and Araújo 2011, and Zhang and Zhang 2010, a new self-organisation approach is proposed. A central system audits the overall cloud and its evolution, sending triggering adjustments in order to have the emergent structure aligned with the overall objectives. The geographically dispersed testing platform, the self-organisation algorithms and the testing conditions are described. The obtained results are discussed and compared with other cloud services, and future work is proposed.

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### A complex systems approach to the educational system in Switzerland

R. Frei*

*Imperial College, London, UK*

The study of complex systems in biological, social, and engineered systems has lead to considerable insights about how such systems function. This enables us not only to observe and understand, but also to actively design systems which will be capable of successfully coping with complex and dynamically changing situations. The methods and mindset required for this approach have been described under the name of "Enlighted Evolutionary Engineering"by Yaneer Bar-Yam. A typical illustration scenario for the complex systems approach are educational systems with their diverse levels of scale and complexity. Based on the general case made by Bar-Yam, the author of this paper applied the complex systems approach to the educational system in Switzerland, which she thoroughly knows due to her own education and her involvement in educational projects over several years. This application case confirms that the complex systems approach is valid. Indeed, many recommendations made for the general case have already been implemented in the Swiss education system, such as offering a variety of ways towards professional qualifications, and using a diversity of actions to provide for the individual students' needs. To address existing problems and difficulties, further steps would make sense, including the shifting of responsibility from individual teachers towards small teams which may include psychologists and other experts, and the agreement on a consistent education system structure across the country. Our increasingly complex society requires us to acquire new methods and mindsets to tackle today's and tomorrow's challenges. The complex systems approach carries great potential, but it needs scientists and engineers from pluri-disciplinary backgrounds to join forces and explore new perspectives. This paper contributes to the further establishment complex systems approach by shedding light on an area which concerns us all, which is a frequent topic of discussion and dispute among politicians and the public, where billions of dollars have been spent without achieving the desired results, and where it is difficult to directly derive consequences from actions taken. The analysis of the education system's different levels, their complexity and scale will clarify how such a dynamic system should be approached, and how it can be guided towards the desired performance.

### Susceptibility of the international trade to local crises

A. Fronczak*, P. Fronczak

*Warsaw University of Technology, Poland*

It is a common believe that no nation is an isolated economic island. All nations participate in the global economy and are linked together through trade and finance. Here, we analyze international trade being the network of import-export relationship between world countries. We show that in each year over the analyzed period of 50 years (since 1950) the network is a typical representative of the ensemble of maximally random weighted networks whose directed connections (bilateral trade volumes) are only characterized by the product of the trading countries GDPs. It is meaningful, that the famous gravity model of trade proven to be empirically strong through econometric analysis naturally emerges from our approach. Our approach, however allows for a more in-depth analysis of international trade than the one offered by the gravity model. In particular, given the observed quasistatic time evolution of this network, we show that bilateral trade fulfills a simple fluctuation-response theorem describing susceptibility of trade volume to changes in GDPs of trade partners. We argue that the theorem provides valuable quantitative insights into mechanisms underlying the emergence of world-wide crises.

### Cluster analysis of the population in Japan

S. Fujimoto*, T. Mizuno, T. Ohnishi, C. Shimizu, T. Watanabe

*Kanazawa Gakuin University, Japan*

We investigate the distribution of the city population with the data of the national census in 2000 and 2005 of Japan. In Japan, the population decline began in 2004 ahead of developed countries. In order to predict

the future of developed countries, it is important that the situation in Japan is examined. The data consists of a 500m grid square and the population in each cell is given. The cities are defined in clusters by using City Clustering Algorithm (CCA). We evaluate the area distribution of the clusters, the population distribution on the clusters, and their growth rate distribution. Furthermore, we obtain various data from other database, and evaluate the correlation of population growth and the other data. From these results, the external factors which are important to population growth are determined. And these factors are useful to construct a population model. Finally, we extract inhabitable ground from land use data and simulate population models at there.

**Text Structure Analysis in the Framework of Complex Networks**

S. Furuhashi*, Y. Hayakawa

*Tohoku University, Japan*

Constituents of text such as words, phrases and sentences have certain structural relations. Grammatical relationship, semantic similarity and co-occurrence in sentence are the examples for relations of words. Recently, studies on those structures in the aspects of complex networks have been paid attention. In this paper, we focus on the relationships among sentences in texts in order to characterize human writing. In discourse analysis, contextual relationship of sentence is often studied. To the contrary, we analyzed structures of the network which was constructed from co-occurrence among sentence patterns of texts in public domain. Both in Japanese and English texts, we found that these networks showed scale-free properties. Moreover, after a preprocessing, networks constructed from Japanese texts exhibit some characteristic features such as significant degree correlation.

**Quantifying Complexity by Means of Multi-scale Variety with Application to a Robot Tasking Problem**

D. Galway*, G. Fusina, G. Pieris

*Calian, Inc., Kanata, Canada*

One of the foundations of complex systems science is the quantification of the complexity of a given system in a meaningful way. Bar-Yam [1] developed equations to calculate the multi-scale information entropy of a system by a state-space representation with a probability distribution over states. This multi-scale entropy is interpreted as characterizing the complexity at every scale, yielding a profile of complexity versus scale. According to a modified version of Ashbys Law of Requisite Variety [1], which we term "Law of Multi-scale Requisite Variety", a tasking system designed to perform a task should have a complexity profile that matches the complexity profile of the task. Given a task and a tasking system, both with a probabilistic state-space representation, the complexity profile of the task and tasking system may each be calculated and compared; The Law of Requisite Multi-scale Variety is a criterion of necessity which states that task completion is not possible if the tasking system's profile is not everywhere greater than the task profile. The equations developed by Bar-Yam were used in conjunction with the Law of Requisite Multi-Scale Variety –we term this the "Complexity Profile Method (CPM)"–for a Robot Tasking Problem (RTP), where a number of robots are required to map a gridded area in a limited time. The task is formally defined as a list of desired joint robot moves and the tasking system is defined as a subset of the list of all achievable internal robot states, each of which can map to a joint robot move. Using an equilibrium probability distribution, task and tasking system profiles are calculated and compared for various RTP scenarios. Each scenario is designed to either disallow or not disallow task completion, and all are correctly predicted by the complexity profiles. For systems modeled in a non-probabilistic manner, such as the RTP problem, an Alternate Multi-scale Method (AMM) is presented which uses the same state-space representation as for the complexity profile, except without the need for a probability distribution. The AMM provides more than a criterion of necessity; it is designed to answer definitively whether or not task completion is possible. When a task and tasking system have been designed such that task completion is possible, algorithmic speed tests show that the run-time for the AMM is generally faster than the CPM.

[1] Bar-Yam, "Multiscale Complexity/Entropy", Advances in Complex Systems, vol. 7, 2004.

**Nonlinear forecast of complex totaly discrete systems**

J. H. García*, P. García

*Universidad Central de Venezuela, Venezuela*

Finding the evolution operator it's one of the fundamental goals when studying any dynamical system. In the case of cellular automata, though it have proven to be an effective modeling tool for many systems, it's

dynamics is usually obtained either from an existing continuous model which is discretized or by setting an arbitrary rule of evolution derived by intuition which reproduce qualitatively the behavior of the system. Using the hodgepodge model as example, in this work we introduce a new approach to find the evolution operator, by representing the local dynamical rule in the Haar basis. Using this strategy, we are able to obtain good predictions with a relatively small history.

### Underlying patterns and morphogenesis of kinship networks

F. Gargiulo*, C. Roth, K. Hamberger, A. Bringe

*INED, Paris, France*

Empirical kinship networks are complex network structures emerging from the interaction of demographic constraints, marriage practices, and genealogical memory. Contextual analyses of this kind of structures are based on the counting of the matrimonial circuits. We are today able to count all matrimonial circuits in a given kinship network and to enumerate all their theoretically possible types. The aim of our study is to understand if the analyzed kinship structures are produced by precise matrimonial practices, or are simply random artifacts due to the network topology. Our analysis is based on a large basin of anthropologic and historic genealogic datasets. On these datasets, a comparison with a multinomial gravity-based model is performed. The aim of this comparison is to understand which are the characteristic features of a kinship network that a general statistical reconstruction cannot catch. In other words, we aim to understand which part of phenomenology, intrinsically based on the culture-tradition of a society (exogamy, asymmetry, sidedness..), could explain the diversity in the morphogenesis of different kinship structures.

### Modeling urban housing market dynamics: can the socio-spatial segregation preserve some social diversity?

L. Gauvin*, A. Vignes, J. P. Nadal

*Ecole Normale Supérieure, Paris, France*

"Don't buy the house, buy the neighborhood" (Russian proverb). This paper is concerned with issues related to social segregation in urban environments. Going beyond the simplest models such as the one introduced by T. C. Schelling in the 70's, we introduce a spatial model of real estate transactions between agents that are heterogeneous in their income and thus in their willingness to pay. The goal of the model is to see how the spatial income segregation depends on both economic constraints and social interactions. The housing market consists of assets differentiated by their location in the city and the agents choose according to these locations. A key feature of the model is the assumption that agents preferences for a location depend both on an intrinsic attractiveness of the location, and on the social characteristics of its neighborhood. The demand for an asset thus depends on the local attractiveness. An hypothesis of the model is that the price of an asset also depends on the local attractiveness. Non-trivial buying/settling patterns emerge from the resulting dynamics. We first focus on the case of a monocentric city, i.e. with a highly attractive center. The stationary state of the market dynamics is analytically characterized and yields the distribution of income over space. We then show how these results extend to more complex non-monocentric cities. The model is also studied through numerical agent-based simulations. The joint analytical and numerical analysis reveal that, even if socio-spatial segregation occurs, some social diversity is preserved at most locations. The analytical resolution of the model highlights the existence of a critical endogeneous income threshold: agents with willingness to pay above this threshold can buy an asset wherever they demand. On the contrary, agents with a willingness to pay below the threshold can buy only in a restricted area. We then empirically verify the pertinence of these results through the analysis of a database of real-estate transactions in Paris. Some general trends are reproduced by the housing market model: the distribution of agents by income inside the city is characterized by a dissimilarity index that shows variations in the space comparable to those observed through the arrondissements of Paris. We distinguish arrondissements with a low level of social mix, both with a high average price and a low average price and less segregated arrondissements.

Laetitia Gauvin, Annick Vignes and Jean-Pierre Nadal, Modeling urban housing market dynamics: can the socio-spatial segregation preserve some social diversity? arXiv:1012.2606, December 2010.

### Emergent bipartiteness in a society of knights and knaves

C. I. Del Genio*, T. Gross

*Max-Planck-Institut für Physik komplexer Systeme, Germany*

We present a toy model of a social network, inspired by Knights-and-Knaves puzzles. In the model the nodes

belong to two different classes, the "knights" and the "knaves". The network evolves dynamically, with links between an agent node and one of its next-nearest neighbours being placed or deleted according to the classes of the target node and the common neighbour. We show that if the fractions of knights and knaves are within a certain range, the network self organizes in a perfectly bipartite graph. On the other hand, if the excess of one of the two classes is greater than a threshold value, bipartiteness is not observed. We offer a detailed theoretical analysis of the model, investigate its behaviour in the thermodynamic limit, and argue that it provides one of the simplest examples of a topology-driven model featuring a first-order phase transitions far from equilibrium.

**Evolution of a barchan dunes field**

M. Génois*

*MSC Laboratory, Paris, France*

If single-dune dynamics of a barchan are henceforth well known, we have to admit that they are not sufficient to understand the behaviour of a barchan field. Indeed, balance between sand influx and outflux for a single barchan leads systematically to an unstable state, either the death of the dune or an infinite growth, whereas the observation of a barchan field shows a stable distribution of widths, and what seems to be stationary dynamics. The hypothesis we make is that dune interactions, such as sand exchange and collisions, disturb the single barchan dynamics by redistributing sand in a non trivial way, and therefore contribute to stabilize the field. Therefore we have built a simple agent-based model that reproduces the phenomenology of the field, including the collision patterns. Its study has led us to discover a very robust stationary, out of equilibrium state, both in dune density and width distribution. Depending on a dimensionless number xi, which compares the sand loss for each dune and the global sand income in the field, we have shown that there are two very different kinds of them : one for low xi where dunes don't interact, called diluted dynamics, and the other for higher xi where lots of collisions occur, called dense dynamics. According to the behaviour of the order parameter for the field, there seems to be a phase transition between them.

**Phase diagram of a cyclic predator-prey model by the gradient method**

M. Girardi*, N. Guisoni

*Universidade Federal de Santa Catarina, Italy*

In this work we study a cyclic predator-prey model in a square lattice by Monte Carlo simulations with the recently introduced gradient method [E. S. Loscar et al. PRE, 80, 051123 (2009)]. Here each site is empty or occupied by a single specie labeled as $1, \ldots, n$, and the system evolves through the invasion of preys sites by neighboring predators with the cyclic rule $1 \to 2 \to 3 \ldots \to 1$, and by the site exchange of neutral pairs. Due to the exchange and invasion rules, the number of entities are conserved. This model presents irreversible phase transitions from active to absorbing phases were only odd or even species survive depending on the system parameters. The control parameters are the invasion and the exchange rates which, in our case, are considered as a gradient in the horizontal axis of the lattice. This gradient allows the presence of both active and absorbing phases separated by an interface which we used to determine the loci of phase transitions. By the characterization of these interfaces, one can determine the universality class and the order of the active-absorbing transition. We can also define an interface between percolating and no-percolating phases. For the case of four species and no empty site, we constructed the system's phase diagram and obtained the critical exponents of the transitions. We studied $n > 4$ and the presence of empty sites, that also induces to phase transition by increasing the rate of neutral pairs exchange.

**Robustness of limit cycle attractors in Boolean networks under update schedule perturbations**

E. Goles*, G. A. Ruz

*Universidad Adolfo Ibañez, Chile*

Boolean networks were introduced more than forty years ago by Stuart Kauffman as a mathematical model for gene regulatory networks. Today, experimental and theoretical results for this model are still been discovered. The dynamics is defined by the way sites are updated. For instance, in Kauffman's paper the update is

parallel (every site at the same time); other authors consider sequential ones, i.e. each site is updated one by one in a prescribed order, another scheme is the general block sequential update where groups of sites are updated in parallel with groups following each other sequentially. In this work, we study the behavior of limit cycle attractors in Boolean networks under update perturbations; i.e. whether a cycle remains or not under update schedule changes. We first analyze a well-known model, the Arabidopsis thaliana network and show how changes in the updating scheme affect the attractors. Simulations using artificial data are conducted as well. In the first simulation we construct Boolean networks with predefined limit cycles using a swarm intelligence technique, similar to [1], then we change the updating scheme and record which cases the limit cycles are preserved. In the second simulation, we consider the limit cycle as a set of attractor vectors, then we analyze what happens with each vector when the updating scheme is changed, for this case the outcome can be that the vector remains part of the original limit cycle, it can become a vector of another limit cycle, or not belong to any limit cycle. The results show under what conditions, network wiring (indegree of each node) and limit cycle, the Boolean network can preserve a limit cycle when perturbation is applied. A theoretical result is obtain which states that, under certain conditions, a Boolean network with indegree less or equal to two can not preserve a limit cycle when changing from parallel to block sequential update. Results from the simulations show that robustness is increased when sets of attractor vectors are considered instead of exact limit cycles, but in general we find that Boolean networks are not very robust when this type of perturbation is considered, since most of the time the limit cycles are not preserved. It is important to point out that attractors in the Boolean network model are considered to represent different cell types, in some cases cancer cells, therefore, how attractors behave under external changing conditions is of interest.

[1] G. A. Ruz and E. Goles, Learning gene regulatory networks with predefined attractors for sequential updating schemes using simulated annealing, in proc. of IEEE the Ninth International Conference on Machine Learning and Applications (ICMLA 2010), Washington DC, USA, Dec. 12-14, 2010, 889-894.

### A Stochastic Rubber Landscape Model for Cell Differentiation

I. Gomez-Castano*, J. Zhou, S. Kauffman, S. Huang

*University of Calgary, Canada*

Cell differentiation is a dynamic process that generates all different cell types in a multi-cellular organism. The observed phenomenon is usually defined as a gene-centered and cell autonomous program. Such process is represented as the multistep branching trajectories in a high-dimensional genetic landscape, reflecting the behavior of a Gene Regulatory Network. This landscape is usually considered to have a rigid shape which is predetermined by intra-cellular gene interactions and doesn't take into account other biological processes which are also relevant for the developmental process. Our recent experiments show that inhibition of physical cell-to-cell interactions during the hematopoietic stem cell differentiation delays myeloid cells development, which show that differentiation in the hematopoietic system is a cell non-autonomous process in which mutual cell communication and physical interactions are crucial factors for development. Our stochastic dynamic modeling of gene network for hematopoietic cell differentiation reveals that cell-to-cell interactions reshape the genetic landscape and change HSCs cell's stability. They together offer strong theoretic and experimental support for the flexible (rubber) landscape hypothesis. i.e., Instead of a static 'genetic blue-print', cell differentiation is strongly influenced by population heterogeneity and their dynamical behavior in a complex gene network.

### The relationship between human behavior and the process of epidemic spreading in a real social network

A. Grabowski*, M. Rosińska

*Central Institute for Labour Protection, National Research Institute, Poland*

On the basis of the experimental data concerning interactions between humans we have investigated the process of epidemic spreading in a social network. We have found that the distribution of the numbers of contacts maintained in one day has exponential form. The data concerning frequency and duration time of interpersonal interactions are presented. The influence of distribution of frequency and duration time of those contacts on the process of epidemic spreading and effectiveness of control measures like mass immunizations campaigns was investigated. It occurs that a large increase in magnitude of epidemic is visible if and only if

both are taken into account.

**Interlocking directorates in Italy: network dynamic and centrality evolution**

R. Grassi*

*University of Milan Bicocca, Italy*

The aim of this work is to examine interlocking directorates and their economic effects in Italy by using network theory. Interlocking directorates is defined by Mirzuchi as the situation when a person affiliated with one organization sits on the board of directors of another organization (Mirzuchi,1996). A large part of scientific literature concerns interlocking directorates (see for instance Ferris et al 2003, Non and Franses 2007); part of this proposes an approach based on the network theory, as the ties between firms and directors can be well represented by a network in a rather natural way (see Caldarelli and Catanzaro 2004; Piccardi et al, 2010). Vertex centrality measures have been widely employed to investigate the network structural properties (see Battiston and Catanzaro 2004; Alfarano et al. 2010, Grassi 2010). Centrality measures are extensively used in the analysis of social networks to explain various phenomena. Centrality indices allow to quantify the role/position that nodes or edges play in the overall structure of the network. Moreover, as a great number of real-world situations can be represented by a network structure, the application of these measures has been extended to several fields, such as physics (see Barabasi Albert, 2002); biology (Barabasi and Zoltan 2004, Wutchy Stadler 1994, Estrada 2010); and more recently, economics and finance (see DErrico et al.2008,Santella et al. 2009). Centrality can be associated to power, i.e. the influence of a node on the others, or it can quantifies the intermediary position of a node in the network, so each of these measures may capture different, but not less important, features of the vertex centrality in the board network. Referring to a wide database, ranging from 1998 to 2009, we extend the approach followed in Grassi 2010; we intend using the most known vertex centrality measures in order to analyze how the structural position of a firm changes in time in the board network. At the same time we intend to measure the position of the directors in the director network; in fact we argue the strategic role of one, or a group, of directors can emerge only by a complete study of the two one-mode board and director networks. Among the several measures of vertex centrality which have been proposed in the literature (Bonacich 1987, Freeman, 1977) we focus on the degree, eigenvector centrality, betweenness, and closeness. Looking at network structure, the one-year analysis (Grassi 2010) reveals a typical topological shape: almost all companies tend to be connected in a "giant" component, stressing the importance of the relationship between different boards. What emerges by the analysis of the giant component and by applying the degree centrality is a structure with a large number of connections but not particularly dense, where the presence of a small number of highly connected nodes (hubs) is evident. The same characteristic can be found in similar works concerning the interlocking directorates (Alfarano et al. 2010, Caldarelli and Catanzaro, 2004 , Battiston and Catanzaro, 2004). We pay attention to the dynamic aspects of the network, this could be useful to establish how the structure evolves, and hence to document the existence of a ranking among Italian firms, with a few family firms and financial firms that always occupy the network's central positions.

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### Embodied simulation of social interaction

F. Griffiths*, J. Bown, R. Durie, A. Sutcliffe, J. T. Jackson, A. Winfield

*Warwick Medical School, UK*

Social scientists observe behavioural phenomena that manifest themselves at the level of social groups or populations, but how and why do these phenomena come about? If we assume these phenomena are caused by interactions between individuals, how might we capture all of the relevant data pertaining to all of the relevant interactions that might be hypothesised to cause these behavioural phenomena? If we were to be able to collect such data we then face the problem of how we might analyse and interpret this data. In response to these questions, we report a research project that aims to model the process of social learning and the evolution of genetic disposition using swarm robotics. In this interdisciplinary project, experiments are designed to address deep problems in the arts, humanities and social sciences. The project parallels work with virtual simulation, allowing developments, which occur in real-time, to be run through generational iterations. We report the design of an embodied simulation laboratory, where we assume imitation to be a fundamental human behaviour, and report our initial methods of interpretation. The laboratory consists of mobile robots with technical ability to observe using their camera, copy, store, choose and enact movement behaviours. We report initial experiments testing the hypothesis that repeated imperfect embodied imitation will result in the emergence of new behaviours. Robots were programmed with one preset movement sequence (circumscribing an equilateral triangle). Enacted movement was chosen at random from their memory. Observation by the research team of recordings made from video and tracking data revealed variation in pattern of movement. We showed the recordings to schoolchildren. They interpreted the movements as playing a game. We have complete datasets for every micro-level linkage and event that occurs during each experiment. We are developing analysis methods for relating the micro-level interaction with the observed emergent behaviours.

### Properties of Elementary Random and Preferential Dynamic Networks

L. Gulyás*, G. Kampis, R. O. Legendi

*Collegium Budapest and AITIA International, Inc., Hungary*

Inspecting the dynamics of networks opens a new dimension in understanding the interactions among the components of complex systems. Our goal is to understand the baseline properties to be expected from elementary random changes over time, in order to be able to assess the effects found in longitudinal data. We created elementary dynamic models from classic random and preferential networks. Focusing on edge dynamics, we defined several processes changing networks of fixed size. We applied simple rules, including random, preferential or assortative modification of existing edges - or a combination of these. Starting from initial Erdos-Renyi or Barabasi-Albert networks, we examined various basic network properties (e.g., density, clustering, average path length, number of components, degree distribution, etc.) of both snapshot and cumulative networks (of various lengths of aggregation time windows). Our results provide a baseline for changes to be expected in dynamic networks. Also, they suggest that certain network properties have a strong, non-trivial dependence on the length of the sampling window.

### A realistic cellular automata model for heterogeneous traffic flow

H. Guzman*

*UNAM, Mexico City, Mexico*

This paper presents a new two-lane cellular automaton for traffic flow model that extends another single-lane model, which takes into account the conflict between human behaviors, normal drivers spacing policies, and limited acceleration and deceleration capabilities of vehicles as the origin of congested traffic states. A new set of lane changing rules that incorporate implicit anticipation effects, mechanical restrictions of vehicles and safe driving practices with respect to its neighbors, is introduced. As a result, microscopic vehicle behavior follows capabilities of real ones. The model emphasizes the realistic behavior of a traffic

flow system that includes different kinds of vehicles, which could have different lengths, maximum velocities and acceleration/deceleration capabilities, as occurs in real highways. Simulation results were obtained for a system with periodic boundary conditions. Moreover, the improved model preserves the simplicity of cellular automata models.

**Cascades on a class of clustered random networks**

A. Hackett*, S. Melnik, J. P. Gleeson

*University of Limerick, Ireland*

We present an analytical approach to determining the expected cascade size in a broad range of dynamical models on the class of random networks with arbitrary degree distribution and nonzero clustering introduced in [M.E.J. Newman, Phys. Rev. Lett. 103, 058701 (2009)]. A condition for the existence of global cascades is derived as well as a general criterion which determines whether increasing the level of clustering will increase, or decrease, the expected cascade size. Applications, examples of which are provided, include site percolation, bond percolation, and Watts' threshold model; in all cases analytical results give excellent agreement with numerical simulations.

**Information sharing in a population of territorial individuals**

K. Halupka*

*University of Wroclaw, Poland*

Biological populations maintain integrity because individuals, even if they are sparsely distributed, share some information. This may be achieved when the majority of individuals synchronously react to the same global external stimuli, e.g. light ("dawn chorus effect"), or/and when a few individuals react to a local stimulus and then the information is transferred through a chain of neighbors which observe each other activity ("village dogs effect"). In a series of computer simulations I modeled both effects. I assumed that individuals create a regular network in which each node can communicate with its 8 nearest neighbors. An individual can react to stimuli delivered by the environment and/or produced by its neighbors. After receiving a stimulus (either social or nonsocial) the individual, for a while, produces signals which can activate its neighbors. I found that, depending on whether the "village dogs effect" or "dawn chorus effect" prevailed, the patterns of active nodes in the network, described in terms of number and size of clusters, were different. This creates a possibility of implementing the model in research of information transfer in real biological populations.

**Evolving Systems : A complexity management perspective**

B. Heydari*, J. Wade, A. Mostashari

*Stevens Institute of Technology, Hoboken, USA*

In this work, evolving systems are defined as systems who can autonomously manage complexity through a combination of giving rise to new structural forms and modifying the state vectors of the agents and subsystems. A conceptual and mathematical framework will be presented that connects the interaction with the environment, emergence of structural forms and change of state vectors. The view toward evolving systems in this work goes well beyond computational evolutionary methods in which mutation, reproduction and recombination are the key mechanisms. Instead, the evolution of complex systems are looked at from a network perspective by relating the dynamic of the system to the heterogeneity level of agents, aggregate characteristics of the system such as stability and flexibility and diversity of network connections.Besides the theoretical framework, the implications and applications of the research will be discussed for two cases of social and socio-technical networks.

**Gephi: An Open Source Software for Exploring Complex Networks in real-time**

S. Heymann*, J. Bilcke

*Université Pierre et Marie Curie, Paris 6, France*

Gephi is a new open-source network visualization platform for all kinds of networks and relational data: internet topology (machines to machines), peer-to-peer file-sharing networks, biological networks, online social

networks, communication and financial networks, but also semantic networks, inter-organizational networks and more. It aims at creating a sustainable software and technical ecosystem, driven by a large international open-source community, who shares common interests in networks and complex systems. Designed to make data navigation and manipulation easy, it covers the entire process from data importing to aesthetics refinements and interaction. Users interact with the visualization and manipulate structures, shapes and colors to reveal hidden properties. The goal is to help data analysts to make hypotheses and to intuitively discover patterns or errors in large data collections. Created with the idea to be the Photoshop of network visualization, Gephi combines a rich set of built-in functionalities and a friendly user interface aggregated around the visualization window. Our approach is to provide a visual tool with a smooth learning curve and an active open-source community supporting the project. The rendering engine can handle networks larger than 100K elements and therefore guarantees responsiveness. In addition of interactive exploration, Gephi embed most critical metrics used in Social Network Analysis, including Betweenness Centrality, Clustering Coefficient, PageRank or Modularity (community detection). More metrics can be added thanks to the extensible software architecture and the open-source code. The modular architecture allows any researcher or developer to extend, reuse and mashup Gephi features in different forms. Efforts are made to facilitate the community growth, by providing plug-ins development documentation, support and student projects. Focus is also made on interoperability, as Gephi can open major file formats, including GraphML, UCINet DL or Pajek. Network results can be exported as PNG, SVG and PDF. Current developments include Dynamic Network Analysis (DNA) and improvements on visualization capabilities on desktop using shader techniques on GPU, WebGL for the Web and customizable renders for information visualization research. The software demonstration will illustrate major use cases covered by Gephi. The entire process of representation, manipulation, layout, analysis and aesthetics refinements will be presented step-by-step on complex networks examples. Particular focus will be made on filtering, metrics and dynamic networks.

### Periodic three-dimensional assemblies of polyhedral lipid vesicles

A. Hocevar*, P. Ziherl

*Jozef Stefan Institute, Ljubljana, Slovenia*

We study the structure of bulk assemblies of identical lipid vesicles. In our model, each vesicle is represented as a convex polyhedron with flat faces, rounded edges, and rounded vertices. Each vesicle carries an elastic and an adhesion energy and in the limit of strong adhesion, the minimal-energy shape of cells minimizes the weighted total edge length. We calculate exactly the shape of the rounded edge and show that it can be well described by a cylindrical surface. By comparing several candidate space-filling polyhedra, we find that the oblate shapes are preferred over prolate shapes for all volume-to-surface ratios. We also study aggregates of vesicles whose adhesion strength on lateral faces is different from that on basal/apical faces. The anisotropy needed to stabilize prolate shapes is determined and it is shown that at any volume-to-surface ratio, the transition between the oblate and the prolate shapes is very sharp. The geometry of the model vesicle aggregates reproduces the shapes of cells in certain simple animal tissues.

### Dynamic Networks of Growing Density

G. Horváth*, G. Kampis, L. Gulyas

*Collegium Budapest, Hungary*

Recent years have shown how the interaction topology of complex systems can help understanding and classify the behavior of systems as diverse as telecommunications networks, food webs, metabolic pathways, social interactions and so on. The analysis of complex networks showed that the interaction structure of many of these systems have a lot in common and that in many cases structural properties determine or heavily influence system behavior. Initially, interaction structure was studied as a time-independent, static network, building on the assumption that changes in the topology operate on a larger time scale than the dynamics of interest. Recently, interest has turned to the study of dynamic networks, where the time scale of topological change is comparable to that of the dynamic processes unfolding on the network. Results in the area of dynamic networks include the analysis of longitudinal data samples, the modeling of growing networks or studies of the robustness of networks against various edge or node removal schemes. In this paper, we turn our attention towards network dynamics that results in _increasing_densities_. Such processes occur when a (more or less) fixed set of nodes co-exist over a longer period of time and their activity involves interaction (i.e., the creation of links). We introduce a variety of interaction models that result in densifying networks (including random

and preferential interaction, assortative mixing, double preferential and inverse preferential attachments, for example). We study a number of structural properties of the emerging networks, from elementary ones (density, connectivity, average path length, etc.) to the distribution of various centrality measures (degree, closeness, betweennness, eigen vector centralities, etc.). Our results show that many of the generating processes yield structurally similar networks with regard to most of the measures. Yet, the same time, the resulting networks can be classified according to certain structural properties.

### Self-organized critical model on fractal lattices of dimension between 1 and 2

N. Huynh*, G. Pruessner, Y. Chew

*Nanyang Technological University, Singapore*

Since being introduced by Bak, Tang and Wiesenfeld, Self Organized Criticality (SOC) has been the most popular subject within Complexity. Fractal, on the other hand, is a paradigmatic example of generating complicated structures by iterating simple rules. In this talk, I will introduce a universal procedure of generating fractals and lattices using geometric arcs. The lattices possess different neighboring structures and their fractal dimension is between 1 and 2. SOC models, especially sandpile models, are then studied on these lattices. Several interesting results on scaling laws, which are different from those in regular lattices, are reported.

Huynh et al., Physical Review E 82, 042103 (2010). http://pre.aps.org/abstract/PRE/v82/i4/e042103.

### On triadic models of Consensus Formation

G. Istrate*

*Babes-Bolyai University, Romania*

We study (using rigorous mathematical techniques) two discrete dynamical systems that fall under the category of opinion formation models (Castellano 2009) and work on triads (signed triangles).

The particular systems we investigate relate to earlier research on the Prisoners' Dilemma game with Pavlov dynamics on graphs (Dyer et al. 2002, Mossel and Roch 2009, Dyer and Velumailum 2011) and the Statistical Physics of Social Balance (Antal, Krapivsky and Redner) respectively. We view the systems as discrete Markov chains, and settle issues such as reachability and recurrence. We then investigate the dependence of the convergence time of these systems in terms of the network topology. Our first result points out that the correct object that is determining for convergence speed is not network topology but an associated topological object we call "triadic dual". Next, we show that for the first system mixing is fast on one-dimensional graphs (so-called "triadic cycles"), but exponential on complete graphs and graphs with a certain "high expansion property". For the second dynamics we show that in the particular case the triadic dual is a graph, a certain "Cheeger constant" associated to this graph determines the speed of convergence. We compare this rigorous result (in the case of the triangular lattice) with existing experimental findings from the statistical physics literature (Raddichi et al. PRE 2007). We further highlight the connections of the two dynamics with existing models in the literature: combinatorial so-called "lights-out" games in the case of the first system, an extension of interacting particle systems to hypergraphs in the second case.

### Simulation of land use changes in Warsaw Metropolitan Area (Poland). Application of Cellular Automata (CA) with Neighborhood Coefficients (NBCs)

B. Iwanczak*, P. Werner, E. Kozubek

*University of Warsaw, Poland*

Analyses and cartographical visualizations of the changes of land use have their roots from comparison of consecutive time-series of maps of land use. Map overlays and cross-tabulations usually allow for spatial analyses, statistical procedures and estimations, which areas change the most. The set of basic models of land use changes (described by W. Tobler, 1979) involves: independent model, dependent model, historical model, multivariate model, geographical model and future geographical model, but there are possible some mixed types based on the above mentioned. The majority of land use models come from geography. The research field of land use changes is interdisciplinary and forces the application of integrated tools based on simulations; GIS software has obviously become the tool of simulations and geovisualizations of the models'

results. The aim of the research is to verify the hypothesis stating that existing spatial pattern and the range of area with different classes of land use show defined tendencies for further spatial development according to the geographical model (Hagoort, 2006, Tobler 1979). The application of the neighborhood indicator in analysis of land use changes is the idea of combining the method of map algebra and two-dimensional cellular automata. The neighborhood indicator is reversible and calculated as the result of the expression of the ordered, numbered, nominal classes in the surrounding. The base for verification of the method were the CORINE Land Use maps of the Warsaw Metropolitan Area (WMA) for 1990, 2000 and 2006. On the basis of a statistical analysis of the neighborhood coefficients, the transition rules for cellular automata were formulated. The transition rules can be used to simulate the state of these areas in the future. The Cellular Automata using neighborhood coefficients allow to formulate the transition rules and simulate the spatial succession of land use changes. The results of simulations of land use changes using geographical model with CA and NBCs will be verified by comparing them with the results of the multivariate model (METRONAMICA, RIKS BV, FP7 PLUREL project, Korcelli, Grochowski, Kozubek, Werner, 2010).

### Making social structures that last from non lasting individuals

P. Jensen*, S. Grauwin

*ENS Lyon, France*

One of the fundamental questions of sociology is the durability of social structures, well beyond that of the individuals that compose it (see for example Georg Simmel, The Persistence of Social Groups, The American Journal of Sociology, Vol. 3, No. 5 (Mar., 1898), pp. 662-698). Of course, this is a complex question that should be investigated using many approaches to be understood. Here, we test the interest of simple computational models. The idea is to build on Kozma and Barrat opinion model (Kozma B. and Barrat A., Consensus formation on adaptive networks, Phys. Rev. E 77 016102, 2008) to create social dynamics, i.e. groups that are not completely stable as in their model yet keep their identity for a long time. In order to build such a model, we introduce two main ingredients: (1) a noise that allows agents having distant opinions to converge and close agents to break their link (2) death and birth of agents at a given rate, which sets the life time scale. We show how this model creates durable opinion groups with interesting dynamics in opinion space. We also discuss the interest of this dynamics as inspiration for sociologists.

### Spreading patterns of the influenza A (H1N1) pandemic

S. D. P. Junior*, J. J. V. Teixeira, H. V. Ribeiro, L. C. Malacarne, R. P. B. Santos, R. D. S. Mendes

*Universidade Estadual de Maringá, Brazil*

We investigate the dynamics of the 2009 influenza A (H1N1/S-OIV) pandemic by analyzing data obtained from World Health Organization containing the total number of laboratory-confirmed cases of infections - by country - in a period of 69 days, from 26 April to 3 July, 2009. Specifically, we find evidence of exponential growth in the total number of confirmed cases and linear growth in the number of countries with confirmed cases. We also find that, i) at early stages, the cumulative distribution of cases among countries exhibits linear behavior on log-log scale, being well approximated by a power law decay; ii) for larger times, the cumulative distribution presents a systematic curvature on log-log scale, indicating a gradual change to lognormal behavior. Finally, we compare these empirical findings with the predictions of a simple stochastic model. Our results could help to select more realistic models of the dynamics of influenza-type pandemics.

### Status-seeking and exhaustible resource under uncertainty

S. Katayama*, H. Ohta

*Aichi Gakuin University, Japan*

This paper is to extend Katayama and Long (2010) to examine the effect of uncertainty on the optimal consumption and resource extraction process when economic agents are status-seeking. We consider an economy endowed with a natural resource, which is exhaustible, and a public capital, which is accessible by each agent and augmentable by investments. The utility of an agent is derived not only from his/her own consumption level but his/her relative position in consumption among the agents in the economy. The resource is subject

to uncertainty in its stock level. It may increase by newly discovered reservoir or may decrease by water immersion. Two types of uncertainty are modeled: continuous change in stock level over time and jumps in discrete interval of time. The introduction of uncertainty may counteract the property under Markov-perfect Nash equilibrium, established by Katayama and Long (2010), that a higher degree of status-seeking leads to greater consumption than social optimum.

### Size distribution of barchan dunes with a cellular model

A. Katsuki*

*Nihon University, Japan*

Sand dunes are found in many places such as deserts, the sea bottom and the surface of Mars. They are formed through interplay between sand and air flow or water flow. When a strong flow blows, sand grains are dislodged from the sand surface. The entrained sand grains collide with the ground and are sometimes deposited. This process takes place repeatedly, resulting in the formation of a dune. The profile of the wind flow is modified by dune topography. Most fascinated dune is barchan, which is crescent dune. We reproduced many barchans in numerical simulations and investigate the dynamics. The motion of sand grains is realized by two processes: saltation and avalanche. Saltation is the transportation process of sand grains by flow. The saltation length and saltation mass are denoted L and q, respectively. Saltation occurs only for cells on the upwind face of dunes. The saltation length L and the amount of transported sand q are modeled by the following rules,L = a+bh(x,y,t)-ch^2(x,y,t), where a=1.0, b=1.0, and c=0.01 are phenomenological parameters. The last term is introduced for L not to become too large. Note that L is used only in the range where L increases as a function of h(x,y,t). The saltation mass is fixed at 0.1 for simplicity. In the avalanche process the sand grains slide down along the locally steepest slope until the slope relaxes to be (or be lower than) the angle of repose which is set to be 34 degrees. We reproduced a few hundred of barchans in numerical field by above model. Barchan releases sand from tips of two horns. The downwind barchan can capture the sand stream. Also, barchans sometimes collide each other. These direct and indirect interaction forms complex barchan fields. The size distribution of a few thousand of barchans is fitted by lognormal distribution well. This indicated that the small barchans exist around the large ones and the large barchans are around small barchans. The average size of barchans increase as the amount of supplied sand do. Next, when two barchan corridors collide, the size of barchan in the boundary between corridors has three type. Type (I) is not decoupling distribution, which shows superposition of each distribution. Type (II) is a distribution of uniform size. Through collision and inter-dune sand stream, the size of each barchan become uniform. Type (III) shows a enhanced distribution of the barchan's size. The size in boundary region between barchan corridors is lager locally. These results show that different distribution of barchans can be coexistence.

### Clustering of events and bursts generated by the nonlinear stochastic differential equations

B. Kaulakys*, V. Gontis, M. Alaburda, J. Ruseckas

*Vilnius University, Lithuania*

Starting from the point process model of 1/f noise [1] we present and analyze nonlinear stochastic differential equations [2] generating scaled signals with the power-law statistics. The behavior of the power spectral density may be obtained directly from the equations [3], without using the point process model. The special nonlinear stochastic difference and differential equations, due to the appropriate restriction of the diffusion-like motion of the stochastic variable, may result in q-exponential or q-Gaussian distributions of the variable [4, 5], preserving demonstration of 1/f noise. Numerical analysis reveals that the process exhibits some peaks, bursts or extreme events, characterized by power-law distributions of the burst statistics, similar to the crackling processes and observable long-term memory in time series. Therefore, the stochastic models may simulate self-organized critical and other systems exhibiting avalanches, bursts or clustering of events.

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### Success is Earned, or Not Really Accidental Influentials

A. Khrabrov*, G. Cybenko

*Dartmouth College, Hanover, USA*

In this talk, we build on the Reciprocal Social Capital, presented at ECCS '10, and apply it to rank all communicators on Twitter. Having analyzed billions of tweets across months dynamically, we present a framework for answering questions such as "are these influentials accidental,"by performing multiple simulations, with various starting conditions from reality, and seeing how various rules lead to new worlds where the new winners might, or might not, overlap with the real ones, segmenting the factors contributing to success and their randomness or stability. Our framework contributes: (i) an infrastructure and methodology for understanding communication on graphs; (ii) identification and exploration of sub-communities; (iii) metrics for identifying effective communicators in dynamic graphs; (iv) a new definition of dynamic, reciprocal social capital and its iterative computation (v) a methodology to study influence in social networks in detail, using a class hierarchy established by social capital, simulations mixed with reality across time and capital classes, and various attachment strategies, e.g. via friends-of-friends or full utility optimization. (vi) new ways to rank communicators, e.g. star-rank by replies or mentions, volumes per class, inter- and intra- class communication, or alignment of rankings when behavior is modified en masse or per class. We show that the middle class we discovered in social networks has a measurable reason to wield the key influence it holds over the poor and the elites, being the most efficient and reproducible set of communicators. While the elites may be accidental, in some worlds, and may be ours too, the middle class works hard to get and stay where it is.

### Multi-scale analysis of spatially extended population genetics models with heavy-tailed reproduction mechanisms

A. Klimovsky*

*Eindhoven University of Technology, The Netherlands*

We introduce and study a class of dynamical stochastic models for genetics of spatially extended populations related to the Cannings model from the population genetics literature. This class takes into account the effects of migration, local reproduction, and occasional global extinction-colonisation events that affect the whole patches of the geographical space. The considered heavy-tailed reproduction mechanisms allow for strong fluctuations in the effective population size. These fluctuations are tailored to reflect abrupt changes in the environment and occasional strong colonisation events due to beneficial mutations. We employ the multi-scale analysis and the renormalisation group type arguments to analyse the large space-time scale behaviour of the models. We show that, depending on the migration and the resampling rates, the ergodic behaviour of the process displays either coexistence of several allelic types within colonies, or clustering – emergence of mono-type colonies. Based on joint work with Andreas Greven (Erlangen), Frank den Hollander (Leiden/Eindhoven), and Sandra Kliem (Eindhoven).

### Linking in vivo immunogenicity with molecular dynamics simulations: A study on MHC class II

B. Knapp*, U. Omasits, W. Schreiner, M. Epstein

*Medical University of Vienna, Austria*

T lymphocytes recognize peptides in the context of the major histocompatibility complex (MHC) by their T cell receptor (TCR). This interaction process is one of the most critical steps in the initiation of an adaptive immune response. However, the molecular nature of the interaction between peptide and MHC and the influence on T cell activation is not fully understood. We analyzed the immunological consequences of the interaction of MHC class II molecule (I-Au) restricted 11-mer peptides of myelin basic protein (MBP) with amino acid substitutions at position 4. These mutant peptides differ in MHC binding affinity, CD4+ T cell priming, and alter the severity of peptide-induced experimental allergic encephalomyelitis (EAE). Employing molecular dynamics (MD), a computational method of quantifying intrinsic movements of proteins at atomic

resolution, we correlated the magnitude of the conformational changes in MHC upon peptide binding with in vivo immunogenicity. We found that irrespective of peptide binding affinity, MHC deformation influences immunogenicity, which then may lead to effective T cell priming and disease induction. Our findings (Knapp et al., PLoS ONE, 2010) lend support to the notion that spatial rearrangement of peptide-MHC complexes may be an additional level of T cell regulation.

### Evacuations Processes Modeling with Langevin Equations and Social Force Term

R. A. Kosinski*, A. Grabowski

*Warsaw University of technology and Central Institute for labour Protection - National Research Institute, Poland*

The processes of evacuating buildings of different types are modeled using Langevin equations. The mental component present in the motion of each pedestrian is taken into account in the model as an additional term in the equations - Social Force, where also the terms describing interactions of pedestrian with surroundings are included [1]. The level of panic in the evacuation is connected with the value of desired velocity vD –a parameter in the social force term. Additional vertical force, introduced in the model and exerting on pedestrians on the staircases, makes it possible to extend applications of the model to the cases of multi-floor buildings. Boundary and initial conditions correspond to the geometry of investigated inside spaces (e.g. rooms, halls) and initial locations of N pedestrians, respectively. In the numerical simulations the trajectories of each pedestrian, their average velocities and the time of evacuation of all pedestrians from the building under consideration, are calculated. In the model an influence of critical phenomena (like pedestrians falling down) on the effectiveness of evacuation can be taken into account. Numerical simulations were performed for a typical three-floor office building; trajectories of pedestrians during evacuation and the times of evacuation for different levels of panic were obtained. The factors influencing the effectiveness of evacuation were discussed.

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### How symmetry reduces the size of state space

M. J. Krawczyk*, K. Kulakowski

*AGH University of Science and Technology, Krakow, Poland*

States of a discrete system can be described as nodes of a graph, where edges correspond to possible transitions between those nodes. The concept is known as Kripke structures [1]. If we have to deal with large systems, an exhaustive analysis is time consuming. Here we show how this difficulty can be partially eased if the system reveals some symmetry. The approach will be discussed here for three entirely different example systems. For two of them we will show that it is possible to reduce the size of the system by grouping states by their similar properties. The last example shows that such compression for some systems is not efficient if the advantage of symmetry is utilised at previous steps of research. The first presented system is a set of antiferromagnetic Ising or Potts spins located in nodes of a piece of some regular lattice [2]. In this case the number of possible ground states of the system, expressed as nodes of the graph, strongly depends on the applied model and the size of the lattice. In this graph of the states, edges between any two nodes appear if one-spin flip allows for a transition between the states. The second analysed system is a roundabout, with three access and three exit roads [3]. On each of them, no more than two vehicles are allowed at the same time. In this case, edge between nodes exists if two states differ by the location or presence of one car which appears on an access rode, disappears on an exit rode, or shifts from an access to an exit road. Even for this small system the number of possible states, i.e. nodes on the graph formed, is 729. The last presented system is a circular molecule, such as e.g. plasmid. Such molecules can be modelled as rigid reptons connected by flexible ties, all of the equal length [4]. Because of that, possible conformations of the molecule can be analysed by placing reptons in the nodes of a regular square lattice. In order to transform one state to another, at least two neighbouring reptons have to be placed at the same node of the lattice. Transition is also possible if, for three subsequent reptons the two exterior reptons are placed at the same node of the lattice and the one interior is located in one of the next neighbouring nodes. As reptons are indistinguishable, the number of states which form the state space of the system is significantly reduced. The compression is performed as follows. What differentiates nodes in the states graph is their degree, i.e. the number of states they are connected to. This property establishes a class of state. But even if the degree of two nodes of the graph (two states of the system) is the same, and they are of the same class, the set of neighbouring nodes may be different, i.e. they belong to different classes.

In such a situation, subclasses are introduced to make classification of states unique. This procedure leads to a compressed states space, which again can be represented as a graph. In this case, each node represents a group of states which belong to the same subclass. The existence of classes is a consequence of the symmetry which occurs in a system. It allows for a significant reduction of the size of the system. In particular, in our second example, the compression reduces the graph of states from 729 to 55 nodes. On the other hand, in the case of analysed molecules the applied procedure does not allow for compression of the system size. The advantage of the compressed set of states is best visible when we calculate the stationary probability of particular states. The probability fulfils the conditions of detailed balance for each pair of connected states. The links can be weighted, which reflects different probabilities of elementary processes from one state to another. These weights influence the symmetry of the system. Still, in each case the stationary probability distribution can be obtained for the initial graph and for the compressed graph of states. In the latter case the system is smaller, which makes the calculations simpler. The goal is that the probability of states can be obtained easily from the probability of subclasses, represented by nodes in the compressed graph.

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### Notion of Hierarchical System and Structural Properties of Guaranteed Control-estimation Problems

S. V. Kruglikov*

*Ural Branch of the Russian Academy of Sciences, Russia*

Recently, the problems of control and decision-making in organizational systems are of great significance and value. Wide range of problems includes a real-time modeling of team interaction. Analysis shows that various interactions may be considered as a sequence of individual or common actions with restricted resources under hierarchically organized control. The motion of participants may be treated in terms of system trajectories reflecting state, conceptual and organizational structures, results of observation and control. Participants may change their positions in accordance with consequent decisions step-wise formed in accordance with positions on discrete grid. Hence a common interaction may be split into multiple layers of relatively independent processes for pairs of symmetrical systems. To describe adequately features of such problems mathematical notions have to satisfy a number of key assumptions. 1) Situational scheme describing the interaction of open systems with relatively constant environment and participation. 2) Description of systems interaction in discrete time, that implies concerted shifts of an action of the participants. 3) Hierarchy in description of the participation, structure and behavior of the systems leads to the absorption of the description of lower layer subsystems that are out the observabillity boundaries. 4) Internal information model, describing data available, is constructed via inverse scheme and reflects shifts of perception with the center on the image of system. Our discussion is based on the approach of the theory of guaranteed control and estimation for systems with uncertainty in cases where uncertainties in dynamics and location of object are possible to imbed in description of space state. The paper deals with axiomatic description of hierarchical systems, the choice of adequate statements of optimization problems under uncertainty for such systems, the study of analogues of the basic structural properties (duality, separation) that are obtained earlier for the control and estimation problems in the operator form. The mathematical formalism is motivated by applied research, including the simulation of control of objects team motion and processes of decision making in modernization of high-tech engineering enterprises.

### Towards an Mathematical Information Formalism in Complex Behavioral Systems

R. Kumar*, H. J. Jensen

*Imperial College, London, UK*

We want to expand the description of a system to define an object not only by its physical properties, e.g. position and mass, but also by the information the object, an agent for example, has about the state of the system including perhaps its own physical properties. This would be very useful to describe behavioural systems, where information storage is a defining characteristic of the objects (e.g. memory, higher order

reasoning, foresight etc). Despite that the concept of information has found place in almost all areas of scientific research, a unified formalism that encompasses even the most fundamental of concepts has yet to be discovered. In this project, we explore three different concepts relating to information - Shannon entropy, physical observables and the so-called interactive epistemology - and use it in a single underlying framework. Throughout the exposition, we consider a set of possible states and define a atom of information to be a subset of the states space and an information set to be a partition of it. In keeping with canonical information theory, the amount of information contained in the atom and the set is a non-negative real number relating to Shannon entropy. One of the main thrusts is to define how the information atoms arise from observation and their relation to knowledge. To do this, the formalism from Robert Aumanns interactive epistemology is extended to include observables, which are mappings from an abstract state space to an observable space. The relation between observation, information and Shannon entropy as a means of quantification is explored analytically.

### Limit theorem leading to Bose-Einstein, Boltzmann, Zipf Law and application to Complexity Science

T. Lapinski*, V. Kolokoltsov

*University of Warwick, UK*

A new limit theorem which originated from work of Prof. Maslov will be presented. The theorem yields three limiting distribution: Zipf Law, Bose-Einstein statistics and Boltzmann distribution, depending on three asymptotic behaviour of system (i.e. in the thermodynamic limit). It is important to that the presented result emerge from few simple assumptions, formulated independent of context of application (i.e. physics, economics, linguistics, etc.). These assumptions are (in bracket for ideal gas system in statistical mechanics): 1) Sufficiently large number of elements in system (i.e. particles) 2) Fixed total amount of considered 'feature' (i.e. total energy) 3) If the value of 'feature' (i.e. particle energy) for two elements is the same then they are indistinguishable (i.e. the particles on the same energy level are indistinguishable) 4) Asymptotic dependence of number of possible values of 'feature' on the number of elements in the system (i.e. number of energy level degenerations depend on the number of particles in system). The three distributions appear in the limit when we consider following asymptotic dependencies i.e. a)We get the first case, Zipf Law, if the number of energy level degenerations increases much faster than number of particles in the system. b)The Bose-Einstein statistics is when the rate of increase is similar for degenerations and particles. c)The third case, Boltzmann distribution is when the number of levels degenerations increase much slower. We will focus mostly on the Zipf Law which was first noticed in linguistics. It is of particular interest as it is a power law. The power laws are proven to be very useful in various fields. For instance in geology, Horton's law for river system, Gutenberg-Richter law for earthquakes as well as Pareto law in economics. Moreover, many empirically observed networks, such as WWW or some social networks seem to be scale-free networks, characterized by power laws, too. In the Complexity Science the Self Organized Critical Systems (SOC) phenomena manifests as various power laws. In addition, there are few mathematical results associated with main theorem. They are important in the practical applications. The Central Limit theorem describes the possible deviation of mean for certain system size. The theorem for large deviation theorem provides estimates for the tail of the deviation from mean.

### Random Complex Process Analysis through Cross-impact second Moment Probabilistic Approach

F. Lara-Rosano*

*Universidad Nacional Autonoma de Mexico, Mexico City, Mexico*

A random complex process is characterized by a set of uncertain interrelated events in such a way that the change in the probability occurrence of one of the interrelated events modifies the ocurrence probabilities of the rest. This is a common situation in complex system dynamics where environmental events modify the occurrence probabilities of certain attractors, critical points and bifurcation points. The aim of the cross-impact analysis (Helmer & Gordon 1965) of random complex processes is to reduce the uncertainty about the process dynamics, when occurrence probabilities of some of the process interrelated events change. In the classic probabilistic approach to estimate this change requires know the full joint probability distributions of all random variables involved. This represents a huge amount of information very costly or impossible to obtain. The second moment probabilistic approach reduces this required amount of information by truncating the moment sequence corresponding to the full probabilistic distribution and taking into account only the

first two moments. This gives a good sufficient approximation in many application fields like engineering and social sciences. A second moment random variable is defined as a random variable whose sequence of moments consists only of its mean value and its variance. In a similar way a second moment random vector is defined as a random vector with only two moments defined: the mean vector and the covariance matrix. In this paper a cross-impact analysis method is proposed to estimate the a posteriori occurrence probabilities of a random complex process interrelated events, based on the second moment probabilistic approach. The method is illustrated with a brief example.

**Contribution of complex systems approaches to the development of a research capacity for the fishery sector in Guinea (West Africa)**

J. L. Fur*

*Institut de Recherche pour le Développement, France*

Fishery sectors are complex organized sets of diverse items, ranging from the nutritive plankton to the contents of the consumers plate. In the management of these systems, complexity is generally considered as a source of variability or uncertainty that must be overcome, rather than an essential property. We present here a project for the building of a research and information capacity for the fishery sector in Guinea (West Africa) designed according to principles inspired from the complex systems approach. The project and Guinean fishery sector were considered to be hierarchically embedded complex adaptive systems. A research system was designed as a set of adaptive research operations, each considered as a semiautonomous agent shedding light on a given aspect of the fishery sector. The project was considered as a construction enclosed in its own history (ontogeny) and we deliberately distributed operations so as to provoke the emergence of a final global outcome. Emphasis was placed on the environment of the research system more than on the realization of each operation. The aim was to make it possible to generate opportunistic contexts, which could be captured through the adaptive nature of the operations. Inspired by the fractal structure of some systems, we applied the same set of principles at all levels, from individual research actions to the whole system project and the entire fishery sector. The system of operations led to a better understanding of the integrated dependencies of the fishery sector, a significant increase in the reactivity of research to new problems and challenges, the sugges-tion of integrated groups of actions, a wider audience for the dissemination of results and a common platform for discussions between the various stakeholders. Methodological questions are linked to this approach such as the necessary gamble on the production of unexpected emergent outcomes or the possible means to develop opportunistic contingencies.

**Network Analysis in Media Framing Research**

E. F. Legara*, C. Monterola, C. David, J. M. Atun

*National Institute of Physics, Philippines*

The theoretical literature on framing can be found in various disciplines of the social sciences, most notably in political science, psychology, and communication. Framing, in its specific application to media research, is defined by Entman (1993) as the "central organizing idea for making sense of an issue or conflict and suggesting what is at stake". In our work, framing analysis in the context of network theory is performed to a corpus of news articles. The research is significant on at least two levels: social and methodological. Contentious political debates regarding the population and family planning issues have been perennial over the past decades especially in developing countries like the Philippines. This work aims to gain perspective for reasons on the lack of progress in discussions about suitable population policies. On the methodological significance, detecting media frames has generated various array of methods in communication research; however, very little has been done to investigate whether these methods provide comparable results since most of the works examining a particular issue only use a single method of frame analysis. Consequently, this work improves upon existing framing analysis protocols by using tools in complex networks applied to a singular issue. Specifically, three protocols are investigated: (1) singular holistic approach to framing, (2) framing analysis using co-occurrence networks; and (3) framing analysis using content-analytic variable (CAV) networks.

**Taking Bioinformatics to Bedside**

F. Lenz*, M. Cibena, P. Anner, W. Schreiner

*Medical University of Vienna, Austria*

Genome data from various sources shall be integrated with clinical patient records. Clinical departments of the Medical University at the AKH conduct clinical studies on numerous cohorts of patients, which are of research

interest. Specific study data is stored in the Research- Documentation and Analysis (RDA) system, which also integrates data on routine treatment via permanent interfaces. Apart from this an increasing amount of genome data are measured for these patients. Up to now the integration of genome- and clinical data is done manually, by separately importing lists and spreadsheets from one desktop application into another. Drawbacks of these procedures are evident: frequent errors, tedious procedures and the necessity to repeat the whole process if any of the original data has changed or additional data are to be included. In the project AKIM-Bio we aim at full integration of multi-modal genomic data (DNA-sequence, RNA-expression, proteomics) with clinical patient registers, allowing comprehensive statistical evaluations. In particular, data integration shall be easily repeatable, and complicated procedures may be stored as a whole via scripting facilities. The project aims at fostering cooperation between basic biomedical research and clinical patient treatment: taking -omics to bedside.

**Reinforcement Learning in Complementarity Game and Population Dynamics**

W. Li*, J. Jost

*Max-Planck-Institut für Mathematik in den Naturwissenschaften, Germany*

We find a new version of Roth-Erev (NRE) reinforcement learning within the framework of our complementarity game (Physica A 345, 245-266 (2005)). In this NRE scheme, the probability of choosing a certain action k for any player n at time t is proportional to the accumulated rescaled reward by playing k during the time steps prior to t. The formula of the rescaled reward is a power law of payoff, with the optimal value of the power exponent being 1.5. NRE reinforcement learning outperforms the original Roth-Erev-, Bush-Mosteller-, and SoftMax reinforcement learning when all of them choose optimal parameters. NRE reinforcement learning also gains advantage over most evolutionary strategies, no matter whether information is processed directly from players' opponents or indirectly from their friends. However, most simpler and more flexible versions, without look-up tables, of the evolutionary strategies can have very significant advantage over NRE reinforcement learning. The reason is that the former converge more quickly than the time-costly reinforcement learning, and can settle more quickly at some values which are more favorable to themselves.

**Molecular Motor-Cargo systems: Modeling energetics of the kinesin with different approaches**

B. Lisowski*, M. Świątek, M. Żabicki, E. Gudowska-Nowak

*Jagiellonian University , Kraków, Poland*

Motor proteins, sometimes referred to as mechanoenzymes, are a group of proteins that maintain a large part of intracellular motion. Being enzymes, they overgo chemical reactions leading to energy convertion and changes of their conformation. Being mechano, they use the (chemical) energy to perform mechanical work, leading to the phenomena of motion. Series of novel experiments, e.g. single molecule observations, were performed to gain the knowledge about the performance of chemical states of the molecular motors as well as their dynamics in presence orabsence of an external force. At the same time, many theoretical models were proposed, offering deeper insight into the small-world (nanoworld) dynamics. They can be divided into three main categories: chemical models, ratchet models and molecular dynamics models. Chemical models focus on the Markov-chain, kinetic description of the reaction cycles responsible for the mechanical transitions. Ratchet models are mostly based on sets of Langevin equations and treat the kinesin dimer as two linked Brownian particles moving in a periodic potential. Molecular dynamics models approach the problem from the low level dynamics of single or grouped molecules, based on information obtained from crystallographical data. We show that by combining those complementary approaches one can gain deeper understanding of the dynamics and chemistry of the motor proteins. As a working example, we choose kinesin and dynein - motor proteins responsible for bidirectional transport of organelles and vesicles using microtubular tracts.

**Modelling the focus formation after double-strand breaks caused by ionizing radiation**

D. Löb*, B. Drossel

*TU Darmstadt, Germany*

When DNA damage is induced by ionizing radiation, proteins for repair and signaling are recruited to the damaged region and within a few minutes form foci that extend over millions of base pairs in the adjacent

DNA. Within these foci a number of mutually dependent processes take place. For double strand breaks, these processes are the recruitment of the MRN complex, MDC1 and additional proteins, as well as the phosphorylation of histone H2AX and the activation of ATM. Spatially and temporally resolved recruitment measurements of proteins such as NBS1 show that after irradiation with a low linear energy transfer (LET) the formation of the focus takes about 10 minutes, whereas after irradiation with a higher LET it takes only 3 minutes. We will present a model for the recruitment of the mentioned proteins. This model includes rate equations for protein binding, dissociation and phosphorylation. The density of double-strand breaks, which is proportional to the LET, is an important parameter of the model. Furthermore, the effects of positive feedback loops in the phosphorylation kinetics are taken into account. We present numerical results of this model for different LET values.

### Fussy rationality and mathematical formalism of social systems

I. Lubashevsky*

*The University of Aizu, Japan*

Complex cooperative phenomena like nonequilibrium phase transitions including ones giving rise to metastable state multitudes, self-formation of multiscale spatio-temporal patterns, etc. have been observed in a wide variety of many-element systems, where humans or, more generally, living beings play a crucial role. Traffic flow, ensembles of pedestrians in crowded places, trading agents in a certain market as well as flocks of birds, schools of fish are typical examples of such "statistical"social systems. In contrast to objects of the inanimate world complex behavior of statistical social systems can be also due to the individual complexity of their elements in addition to interaction of the elements between one another. Living beings possess many unique properties that, on one hand, affect substantially their behavior and, on the other hand, cannot be found in the inanimate world. In particular, these are memory, learning, prediction, cognition, motives, wiliness, and so on. It poses a question about the necessity of developing individual physical notions and mathematical formalism for modeling such social systems. In the present work we, first, discuss what mathematical formalism can take into account the bounded capacity of human cognition, which has attracted much attention during the last decades with respect to various aspects of decision-making. The main attention is focused on the fact that humans just cannot order events according to their preference when these events are close to one another in value. As a result, if the current state of a system at hand is in close proximity to the optimal one, then an operator (individual) governing the dynamics of a given unit will consider it optimal with a certain probability. Exactly this feature is referred to as the fussy rationality in the present work. The neighborhood of the optimal state in the system phase states, where the given probability is high, will be called the region of dynamical traps. This term is reasoned by the fact that if a system state is located inside the region of dynamical traps then the operator will consider the correction of the unit dynamics unnecessary with a high probability. As a result, human behavior in the region of dynamical traps becomes inactive and the human control over the system dynamics is depressed. Mathematically it is described in terms of singularities in the corresponding kinetic coefficients. When the system goes out of the dynamical trap region the necessity of governing the system dynamics becomes perceptible and the operator behavior is active again. This phenomena is regarded as a collection of action points and the system dynamics looks like a collection of alternative fragments controlled by or being out of control of the operators. Second, it is demonstrated that the dynamical traps can induce complex cooperative phenomena, in particular, nonequilibrium phase transitions of a new type. Their origin is the singularities of kinetic coefficients rather then a change of the form of regular forces. It should be noted that the latter factor is the main mechanism of various phase transitions in physical media. Several illustrative examples and particular models are presented to elucidate the key points of the introduced notions.

### An Autonomous Evolving Neural Comparator

G. Ludueña*

*Universität Frankfurt, Germany*

In order to develop a complex targeted behavior, an autonomous agent must be able to relate and compare the information received from the environment and its internals by its different modalities (e.g. deciding if the visual image currently being perceived is similar an image previously stored in the memory). For artificial agents, such basic comparison capabilities are typically either hard-coded or taught (e.g. by reinforcement learning), both processes involving the intervention of a Master. However, living organisms must have acquired

this capability only by interaction with the environment and evolution. We can therefore assume the presence of neural circuitry in these organisms, which is capable of comparing the information content provided by different populations of neurons. Moreover, these populations should not need to be physically similar, hold the information in the same encoding or even manage the same type of information (the case of different sensory modalities). In the present work, we develop a neural circuit which is capable of autonomously evolve from the correlations found in the information received. This "comparator" circuit can autonomously acquire the capability of comparing the information received from different neural populations, which may differ in size and encoding used.

### A first principles derivation of animal group size distributions

Q. Ma*, A. Johansson, D. J. T. Sumpter

*Uppsala University, Sweden*

Several empirical studies have shown that the animal group size distribution of many species can be well fit by power laws with exponential truncation. A striking empirical result due to H-S Niwa is that the exponent in these power laws is one and the truncation is determined by the average group size experienced by an individual. This distribution is also known as logarithmic distribution. In this paper we provide first principles derivations of such truncated power laws using a site-based merge and split framework. In particular, we investigate two such models. Firstly, we look at a model in which groups merge whenever they meet but split with a constant probability per time step. This generates a distribution similar, but not identical to that proposed by Niwa. Secondly, we propose a model, based on preferential attachment, that produces the logarithmic distribution exactly. Given the wide variety of merge and split mechanisms which generate logarithmic distribution, our derivation helps explain why such distributions are so widely observed in nature. Our derivation also allows us to link splitting and joining behavior to the exponent and truncation parameters in power laws.

### Aggregation Procedures for Complex Systems

R. S. MacKay*

*University of Warwick, UK*

A complex system has many interdependent components. An aggregation procedure consists in amalgamating selected groups of components into super-components with derived interactions between the super-components. No information is lost at the higher level and that at the lower level can be derived from the higher level by disaggregation. Aggregation can often be iterated, producing hierarchical aggregation. Aggregation can be useful for computation, by breaking down the problem into pieces and combining them later. It can be useful for planning, since the effects of localised changes can be examined without recomputing the rest of the system. In systems with iterated aggregation, asymptotic trends to higher scales may emerge. Illustrations will be given from statistical physics, Markov processes, selfish traffic flow, synchronisation in oscillator networks, and multi-agent games.

### On reading multifractal spectra: healthy aging by multifractal analysis of heart interbeat intervals

D. Makowiec*, A. Rynkiewicz, M. Zarczynska-Buchowiecka, J. Wdowczyk-Szulc

*Gdansk University, Poland*

The method of effective reading of multifractal properties is proposed. The method consists of analysis of a given signal together with analysis of integrated signal. A practical way to separate monofractal type signals from other signals is described. Then, the method is used to 24-hour ECG recordings of heart interbeat intervals to assess the effect of aging on autonomic regulation of the heart in healthy adults. Heart rate variability is evaluated by Wavelet Transform Modulus Maxima multifractal estimator. The nocturnal and diurnal multifractality is considered separately. The method offers insights into dynamical differences in the autonomic regulation caused by circadian cycle and aging. A switch from mono- to multifractality is observed between diurnal and nocturnal parts of series in the group of young adults. With aging the multifractal structure of nocturnal signals declines. Observed changes can be related to the circadian alternation in

the central mechanisms controlling the cardiovascular system which becomes impaired with age advance of a human. Assuming that vagal tone - one of the two parts of autonomic nervous system, dominates during nocturnal rest our observation supports the hypothesis that imbalance in the autonomic control due to healthy aging could be related to changes emerging from the vagal system.

**Scaling laws and universality in the choice of election candidates**

M. C. Mantovani*, H. V. Ribeiro, M. V. Moro, R. D. S. Mendes

*Universidade Estadual de Maringa, Brazil*

Nowadays there is an increasing interest of physicists in finding regularities related to social phenomena. This interest is clearly motivated by potential applications that a mechanical statistical description of the human behavior may have in our society. We address this work to cover an open question related elections: the choice of candidates. Specifically, we investigate the relation between the number of candidates and the size of the electorate (number of voters). We found a non-linear (power law) mean correspondence among these two variables and also evidences that this choice has a multiplicative underlying process. The universality of our findings is supported by data from 15 elections from 5 countries. In addition, we show that network scale-free models are able to reproduces this universal behavior.

**FoodSys - An integrated model to assess vulonerabilities of the global trade food system and global environmental change.**

R. Margarido*

*ISCTE, FCUL, CENSE, Portugal*

We face several challenges in the near future: climate changes, water scarcity, the rise of oil prices, loss of biodiversity and soils degradation are unequivocally connected to our ability to produce food. Globalization showed us a new world with apparently no limits, of which our food system structure is a good example. The beginning of human history will always be linked to times of scarcity and great effort to get enough food. In the twentieth century a new hope arrived, we managed to create a food system where abundance and massive production ruled, the so called Green Revolution. This success of the modern food sector relies in the ability to treat food like any other consumer product. As we explore the global food trade, the persistence of world hunger, the rising threat of food-borne disease, and the accelerated decline in irreplaceable natural systems, we conclude that the high-volume model is now disrupting the equilibrium not only of our internal systems but of larger global systems, with severe consequences. More than this, global developments such as the increasing world population, changing diets and the growing demand for energy crops, have raised awareness about the global availability of food. Today, a simple commodity is embedded in a complex dynamic network of trade relationships among nations. Each country no more produces all its food; with trade liberalization a new system emerged and today most of world countries have high trade rates and food became a true global commodity. Furthermore, globalization may lead to more regional specialization and the concentration of production areas can increase the vulnerability to risks. In the future the combination of rising temperatures and shifting patterns in rainfall and storm frequency will push down total global food output, while demand is rising. These developments lead to the fact that food security has become an issue of growing concern. Also variability and volatility often threaten food security. Analyses of global food systems to date have concentrated on food availability and access and less on the trade system network: the methods used fail to account for variability in prices and climate, and the effects of these variables in the global food trade system dynamics. In this research we suggest a new approach to the study of the global food system. We propose to use network theory and multi agent simulation to understand changes in the global food trade system due to environmental change. The aim is to create a model that helps to give a new understanding of global trade dynamics and food prices volatility in scenarios of global environmental change. Specifically we propose to create a model of the global trade food system that has its foundations in Dynamical Network Analysis (DNA). The focus is to understand persistent emergent phenomena in the global food system when facing global environmental changes. The first step of the research was to model the trade network of one commodity in Mediterranean countries, maize, to validate the research approach. The exercise was useful enough to understand some trade dynamics between countries and how the network may have the capacity to adapt in a scenario of disruption. Here transitivity and low node in degree (weak nodes) seem to have an

important role. Ongoing research aims to couple the network model with the dynamic behavior of a multi-agent simulation.

### Selecting Players for a Combination of Partners

P. Mariano*, L. Correia

*University of Lisbon, Portugal*

In social interactions one of the main sources of distress is the proliferation of non-cooperative elements. A small percentage of free-riders is well accepted or even beneficial. However, an unlimited growth of the percentage of free-riders is detrimental to cooperation and therefore to the maintenance of a society as a whole. Using games to model social interactions, several approaches have been de- veloped in order to limit proliferation of free-riders. Some of them use game specific strategies while others fall into mechanism design. In the former cate- gory, we have tit-for-tat as an example of a strategy to play Iterated Prisoners Dilemma (IPD) that in a variety of conditions is able to resist non-cooperative players. In the latter we have partner selection (Izquierdo et al., 2010; Santos et al., 2006; Aktipis, 2004). Mariano and Correia (2010) have proposed a model of partner selection for any n-player game. A player using that model is capable in the long run to only select partners that he considers cooperative. The player has a pool of combinations of partners. Each combination has a probability. Whenever a combination is considered unappealing, meaning the utility the player gets is lower than some threshold, it is replaced by a random combination of partners. In this work we improve the method of calculating the replacing combina- tion. Instead of random selection, a partner has a weight that is a function of the utility obtained and of the probabilities of all the combinations where he appears. Formalising, a player has a combination vector c that contains combi- nations of partners drawn from a set of potential partners, V. Each combination has a probability stored in vector p. All partners in V have a weight stored in vector w. Possible values for elements in vector w range from the lowest utility to the highest utility a player may get. After a player plays the tth game with combination of partners p and before updating vectors c and p, he updates vector w. In the following rules, k represents a partner belonging to ct . Weight of partner k changes according to: $w = w(1b) + bt$ where u is the utility he obtained in the tth game and b is calculated as follows: we first take the probabilities of the combinations where player k appears, then we calculate the average of these probabilities to obtain b. The rationale of this policy is that a partner gets a weight that reflects his utility towards each player. By evaluating a partner according to the utility provided by each game where he enters, a player may progressively find the best partner combinations. If a partner combination is below some threshold, a player may generate a new combination by picking n 1 partners taking into account their weights in local vector w. Different strategies to select partners considering their weights may be used, up to the extreme case of greedy selection. Like the original model this one is capable of handling a dynamical set of partners. That is to say, partners may enter and leave set V, in runtime. Results are currently being collected. We expect to show that this approach converges quicker than the original to favorable partner combinations. We are also studying strategies to make the new model avoid getting stuck local minima.

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### Evaluation of Robustness and Performance of Environmental Influences on Evolutionary Algorithms compared to Ant Colony Systems

O. Maurhart*, W. Elmenreich, I. Fehérvári, A. Bouchachia

*Austrian Institute of Technology, Austria*

In this work we examine the impact of dynamical environments on evolutionary algorithms and ant colony optimization. In particular we evaluate these algorithms for a shortest path problem in a continuously changing network. The problem of establishing the shortest or cheapest path in a randomly changing network acts as

a representative for the class of situations to be solved. Also nodes are added and removed to this network being reminiscent of today's wireless networks consisting of a variety of mobile devices having changing signal quality between the participants and peers entering and leaving the networks. Within this problem definition lies the possibility of radical changes since former best paths may not exist any longer and may have collapsed after a series of such changes. Resilience to and recovering from such incidents correspond to the robustness quality whereas finding the best solution in the least number of steps indicate good performance values. We first simulate a radical Darwinistic approach; the genes of individuals of a population are recombined and mutated randomly, evaluated by a fitness function and, dependant on the fitness value, selected for the next generation in order to gradually create a better performing population over several generations. The results are compared to a set of different Ant Colony Systems best suited for this class of problems. Choosing different evaporation rates, greediness and visibility values constitute to a variety of ACS instances yielding candidates for the optimal problem solution with respect to the quality criteria objective. The goal of this work is to obtain a better understanding of these techniques when designing and building complex systems. The results derived from this work may give new insights when creating self organizational systems based on artificial neuron networks and evolutionary algorithms in mind.

### A MODEL OF URBAN EVOLUTION

F. Medda*, J. Kelsey, A. Wilson

*University College of London, UK*

The relationship between city development and urban investment is inherently complex: it can be influenced by many factors, from policy strategies to financial mechanisms, but also the evolution of the city is influenced by the many individual responses to these macro-actions. In this work we examine urban change through a framework of positive feedback. Our objective is to generalise the logistic-like model of Boltzmann, Lotka and Volterra with a more urban economic model of the city based on Turing reaction-diffusion model. We develop a dynamic two-dimensional model of the diffusion of economic information across urban space. We assume that economic information, such as urban investments,diffuse from contiguous zones through space and time. The model reaches different interesting conclusions in relation to economic agglomeration and the dynamics of urban morphologies.

### Earthquake-like patterns of acoustic emission in crumpled plastic sheets

R. D. S. Mendes*, L. C. Malacarne, R. P. B. Santos, H. V. Ribeiro, S. D. P. Junior

*Universidade Estadual de Maringa, Brazil*

We report remarkable similarities in the output signal of two distinct out-ofequilibrium physical systems —earthquakes and the intermittent acoustic noise emitted by crumpled plastic sheets, i.e. Biaxially Oriented Polypropylene (BOPP) films. We show that both signals share several statistical properties including the distribution of energy, distribution of energy increments for distinct time scales, distribution of return intervals and correlations in the magnitude and sign of energy increments. This analogy is consistent with the concept of universality in complex systems and could provide some insight on the mechanisms behind the complex behavior of earthquakes.

### A Process for Mapping Large Directed Networks to 2D Images and its Applications

T. Menezes*

*CNRS-EHESS, France*

We propose a process for mapping directed networks to 2D images. This work was motivated by two main difficulties when investigating large directed networks: how to measure the similarity between two networks and how to visually convey the main characteristics of a network. The process we propose consists of mapping each node into a two-dimensional space, and then the generating a density map of this space. The two dimensions represent the input and output centrality of a node in relation to the rest of the network. Current approaches to measuring network similarity fall into three main categories: graph edit distance, eigenspectra analysis and ad-hoc metrics. We discuss the limitations of the existing approaches in the context of large,

dynamic and directed networks. We argue that our process is a better approach in this case. We show how the images we generate can be used to convey the main characteristics of a network at a glance, overcoming the limitations of conventional network visualization techniques, which tend to become unusable when the number of nodes or the connection density is too high. We provide some examples where we show how different networks with similar underlying phenomena map to similar images. We show how snapshots of dynamic network mappings tens to maintain their structure with small changes, and also how significant events in the lifespan of the network can be detected. We illustrate the diversity of images that our process generates when applied to different networks. We discuss how working in image space allows us to take advantage of algorithms from the field of computer vision, namely to define similarity metrics between directed networks. We show how these metrics can be used to cluster a set of real world networks according to their similarity, and describe other possible applications, for example in our own work of automatic network modeling. We finalize by presenting an open source tool (https://github.com/telmomenezes/synthetic) that includes an implementation of the mapping process. A few examples of 2D images generated with this process can be found at: http://telmomenezes.com/resources/netmaps.pdf.

### Similarity solution of the coagulation equation in an electrorheological system

Z. Mimouni*, J. Wattis

*Cadi Ayyad University, Morocco*

Aggregation phenomena are met in a wide variety of physical, chemical and biological processes; for example the formation of aerosols, micelles and vesicles, polymers, and even celestial bodies on astronomical scales. The irreversible aggregation of colloidal particles is of interest, both from a fundamental point of view, and because of its industrial applications. Electrorheological (ER) fluids are colloidal suspensions of conducting particles in an insulating fluid. The particles acquire an electric dipole under the action of an external electric field. We present the analysis of a model for the aggregation of colloidal particles which arises in an electrorheological system. Linear clusters grow upon the application of an AC electric field. We consider coagulation kernels involving as negative powers of cluster sizes. We investigate the reduction of the governing equations to a similarity solution in the large time limit. Comparison between the experimental results and the theory shows a good agreement.

### Complexity in the Dynamics of Web Users: Methodology for Quantitative Analysis of Empirical Data and Simulations

M. Mitrovic*, B. Tadic

*Jozef Stefan Institute, Ljubljana, Slovenia*

Data related with communications between Web users on Blogs and similar portals provide a valuable source of information for study the emergent social phenomena on the Web. These interactions are mediated by text-based messages, which suggests importance of their contents and the amount of emotion expressed in the text for user's behavior. We developed systematic methodology for quantitative analysis of user behaviors by mapping large datasets onto bipartite graphs and using the concepts of complex dynamical systems, supplemented with the machine-learning methods of text analysis. We will present details of the approach applied to study large datasets from diggs.com and bbcblogs.com, where we compute several complexity measures of users collective dynamics. Using the agent-based modeling with the emotional agents as bloggers, we further investigate the role of emotions for the emergent bipartite network and the collective behavior of the agents.

[1:M. Mitrović, G. Paltoglou and B. Tadić, JSTAT P2005 2011; M. Mitrović and B. Tadić, preprint, 2011].

### Relaxation of expectation values of macroscopic observables

T. Monnai*

*Osaka City University, Japan*

An isolated macroscopic system eventually approaches to equilibrium. But microscopic justification of the relaxation is a long standing fundamental issue of statistical mechanics. Recently it has been pointed out that quantum mechanics provides convincing perspective, i.e. majority of the pure states in the Hilbert space at a

specific energy give the expectation value close to the thermal average. Then the initial non-equilibrium state is expected to reach a more probable state of equilibrium. The relaxation dynamics has been explored for time-independent systems. In this presentation, we explain how the relaxation dynamics can be made quantitative for the unitary time evolution with non-negligible off-diagonal elements of the density matrix. Especially, the relaxation property is explored for the initial microcanonical state externally perturbed for a transient duration and then left untouched. We note that the off-diagonal elements between macroscopically different states are quite small, since such a matrix element expresses a transition amplitude between essentially different states. Indeed this is correct for observables, which polynomially depend on the system size, since the dimension of the Hilbert space exponentially depends on the system size. This assertion excludes conservative quantities such as projection operator to the energy eigenstates, and thus guarantees a kind of non-integrability. We give a quantitative expression for this statement. Numerical analysis for many body systems is compared with the theoretical evaluation of matrix elements. This perspective suggests that the superposition principle of quantum mechanics makes the relaxation phenomenon easy to understand.

### Two different types of scaling for analyzing financial markets crisis

R. Morales*, T. Di Matteo, T. Aste

*Kings College London, UK*

The aim of this work is to have deeper insights in how financial crisis can be studied and forecasted by using tools which look at the scaling behaviour of financial time series. There are two types of scaling behaviour studied in the finance literature: the behaviour of some forms of volatility measure as a function of the time interval on which the returns are measured and the behaviour of the tails of the distribution of returns as a function of the size of the movement by keeping the time interval of the returns constant [1,2]. The recent unfolding of the 2008-2009 'credit crunch' financial crisis has made all of us aware that in real markets very large fluctuations can happen with finite probability. By looking at the tails of the distributions of prices of 395 stocks traded in the US equity market in the time period between 1 January 1996 and 30 Aprl 2009 [3], we have studied how the inclusion of the crisis affects the tail index values. Reliability and robustness of the results have been tested by means of different statistical tests. We have then looked at the scaling behaviour by means of the generalized Hurst exponent (GHE) that has been proved to be relevant in characterizing the different degree of development of the market [2]. The dynamics of the GHE shows some interesting trends that cluster stocks in the market sectors they belong to. The dynamics is also conveying interesting information as far as the crisis is concerned. In particular, it is observed that stocks belonging to the financial sector exhibit a tendency in increasing their scaling exponent in correspondence to the unfolding of the crisis.

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### The Evolution of Cultural Resilience and Complexity

A. Morris*, W. Ross, M. Ulieru, J. Whitacre

*University of New Brunswick, Canada*

The study of memetics has thus far mostly applied a reductionist view of genetics to describe the pathogenic infectivity and transmission dynamics of ideas/memes. In this position paper, we take a fresh look at some of the distinctive attributes of cultural evolution through the lens of complexity science and theoretical biology. First, we describe some basic roles that self-organization and selective processes play in the integration of memes into personal worldviews and the consequences this has on the complexity of personal mental constructs (meme networks). Using the concept of an attractor landscape, we propose specific correlations between the fitness of an idea and its influence on attractor basin attributes for pre-existing mental constructs. Interestingly, these proposed relationships are very similar to recent in-silico findings reported on the evolution of attractor landscapes for biochemical networks [Aldana et al, JTB, 2007], suggesting the possible existence of universal principles. In applying the attractor landscape metaphor, we illustrate how good ideas can paradoxically both reinforce existing beliefs yet also construct the very conditions that make new sets of beliefs possible. The remainder of the article comments briefly on additional connections between memetics and complex biological systems. In an extension of recent evolution-theoretic concepts [Whitacre, EvoEco, 2011], we propose the

existence of both meme-induced and environment-induced origins for innovative cultural traits as well as the important role of degeneracy in facilitating both forms of cultural novelty. Similar to the invasiveness of non-native species in ecological field studies, the order that individuals are exposed to ideas will influence susceptibility. We propose that such sequence-dependence or historical contingency could play an important role in sustaining complex heterogeneous cultures beyond what would otherwise be expected within highly connected (small-world) societies. Finally, we predict particular properties will consistently be associated with highly resilient cultures. As seen in neural networks and gene regulatory networks, we predict that cultural resilience is positively associated with Tononi et al.s definition of hierarchical complexity - the extent that individuals are both functionally/culturally integrated and functionally/culturally segregated - and that such features require the presence of degeneracy [Tononi et al., PNAS, 1999].

### How smart is a crowd?

M. Moussaid*

*University of Toulouse*

Human crowds display a rich variety of collective behaviours that support an efficient motion under everyday life conditions. For example, when two flows of people are moving in opposite directions in a crowded street, pedestrians spontaneously share the available space by forming lanes of uniform walking directions, which enhances the traffic efficiency. Similarly, when opposite flows meet around a bottleneck, people self-organize to deal efficiently with congestion zones. In other situations, however, the collective coordination may suddenly break down giving rise to unadapted behaviours, such as stop-and-go waves that reduce the walking efficiency. More dramatically, crowds can display life-threatening under extreme conditions, such as crowd turbulence causing serious trampling accidents during mass events. In this poster, I will review various observed crowd collective behaviours, describe the related underlying mechanisms, and discuss the idea of wisdom of crowds.

### On the functions computed by Boolean networks

A. Mozeika*, D. Saad

*Aston University, UK*

In 1969 Kauffman [1] introduced a simple dynamical model of gene-regulatory networks. The state of each gene was modelled by a binary ON/OFF variable, interacting with other genes via a coupling Boolean function (or Boolean gate) which determines the state of a gene at the next time-step. There are N such genes (sites) in the network and each one is influenced by exactly k other genes from the same network. In Kauffman's approach, the network topology and Boolean functions are random but fixed for all subsequent time-steps. This model, also known as Random Boolean network, belongs to a larger class of Boolean networks (BN) which found its use in the modelling of genetic networks, neural networks, social networks and in other branches of science [2]. In a Boolean network a site i at time t is the root of a full k-ary tree of depth t growing from the network-state at time t=0 (S(0)). Each tree can be regarded as a random Boolean formula computing a Boolean function of inputs which are a subset of S(0). By employing analytic methods from non-equilibrium statistical physics we derive an equation for the evolution of density of Boolean functions computed by BN in the limit of large N. We show that this equation is exactly the same as in the Boolean formula growth process studied by Savický in [3]. In this process, for large formula depth (large t), the formulas converge to a single Boolean function or to the uniform distribution over some class of Boolean functions depending on the initial conditions and the (single) gate-type used.

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### Modularity in protein complex and drug interactions reveals new polypharmacological properties

J. Nacher*, J. Schwartz

*Future University-Hakodate, Hokkaido, Japan*

Recent studies have highlighted the importance of interconnectivity in a large range of molecular and human disease-related systems. Network medicine has emerged as a new paradigm to deal with complex diseases.

Connections between protein complexes and key diseases have been suggested for decades. However, it was not until recently that protein complexes were identified and classified in sufficient amounts to carry out a large-scale analysis of the human protein complex –disease system. We constructed the first systematic and comprehensive set of relationships between protein complexes and related diseases and analyzed their topological features. The network structure is characterized by a high modularity, both in the bipartite graph and in its projections, indicating that its topology is highly distinct from a random network and that it contains a rich and heterogeneous internal modular structure. To unravel the relationships between such modules and diseases, we investigated in depth the origins of this modular structure in examples of particular diseases. This analysis unveils new associations between diseases and protein complexes and highlights the potential role of polypharmacological drugs, which target multiple cellular functions to combat complex diseases.

### Competitive Dynamics in Percolation and Game Theory

J. Nagler*

*Max Planck Institute for Dynamics and Self-Organisation, Germany*

How a complex network is connected crucially impacts its dynamics and function. We review recent results on discontinuous phase transitions in percolation (Nagler, Levina, Timme, Nature Physics 7, 2011), and game theory (Boettcher, Nagler, in prep.). We show how competition in game theory implies group selection being distinct from other themes in game theory. In addition, we reveal the microscopic mechanisms responsible for discontinuous phase transitions in growing networks.

### Agent-based Modeling of Tumor Morphology Changes Introduced by Infiltrating Immune Cells

S. Y. Wong, V. Narang*, J. Abastado, A. Gouaillard

*Singapore Immunology Network, Singapore*

Tumor development involves a complex interplay between a growing population of cancer cells and their surrounding microenvironment (Rejniak & McCawley, 2010). The communication between the tumor cells and the neighbouring cells in the microenviroment helps to drive tumor progression (Polyak et al., 2009). Multiple factors influence the outcome of tumor growth, including nutrient competition, cancer cell proliferation and apoptosis rates, cancer cell motility and adhesion, and various chemokines, cytokines and growth factors secreted by other cells in the microenvironment. Immune cells are an important component of the tumor microenvironment which exerts various influences on the proliferation, apoptosis and motility of cancer cells (Pietras & Ostman, 2010). Usually immune cells such as T cells and NK cells are known to inhibit cancer cells in a tumor. However, recent reports (Qian & Pollard, 2010) show that during the initial avascular phase, immune cells in the tumor microenvironment favor tumor growth and metastasis by secreting growth factors and chemokines which increase the proliferation and motility of cancer cells. The dynamics of interaction between cancer cells and immune cells and its influence on early tumor growth is not well understood. It is very important to understand this dynamics as this can be used to devise therapeutic treatments to suppress tumor growth and metastatic dissemination in early stages of cancer. In silico models provide a reasoning framework for answering questions which are difficult to address in vitro and in vivo. Computational modeling allows us to incorporate information from different scales (from molecule, cells, tissues, organs, up to organisms) and address the questions systematically. One of the modeling techniques that has been applied to study complex system problems is agent-based modeling (Shalizi, 2006) (Jeon et al., 2010) (Zhang et al., 2009). Agent-based models can be used to study the complex behaviors of cells emerging from the interactions and simultaneous operations of individual cells in the system. We have developed an agent-based computational model to unravel the complex mechanism of interaction between immune cells and cancer cells. Our 2D computational model simulates in vivo avascular tumor growth in a microenvironment consisting of nutrients, growth factors, chemokines and immune cells. The basic concepts are adapted from the previous work of Drasdo and Hohme, (Drasdo & Hohme, 2005) and Jeon et al. (Jeon et al., 2010), whereas the microenvironment and immune system components are a novel addition. Instead of the usual mono-formalism approach where entities are either all discrete or all continuous, we have taken a complex systems approach where the model is a hybrid of continuous fields and discrete agents. In the model, nutrients, growth factors and chemokines are continuous fields on a regular lattice whereas cancer cells and immune cells are discrete off-lattice autonomous mobile agents. Off-lattice modeling of cells allows the simulation of experimentally observed superdiffusive behavior of mammalian cells and cell mobility is not restricted by a lattice and a limited set of possible directions.

In addition to that, unlike cellular automata model on square lattice which describes cell-cell and cell-ECM adhesion through heuristic stochastic terms, an off-lattice model addresses the adhesion forces in a more realistic mechanical aspect. Behaviors of individual cells in the model are determined by random motility and intercellular forces, which includes adhesion and repulsion force between cells, and friction force, which represents cell-ECM interactions. The immune cells are attracted into the microenvironment by chemokines secreted by the tumor cells. The immune cells also secrete chemokines which further attract more immune cells to the system, forming a feedback loop. The immune cells infiltrate the tumor and diffuse growth factors and chemokines which promote the proliferation and motility of cancer cells. Our agent-based model explains the interactions between cancer cells and immune cells that lead to different morphological growth patterns of tumors in the presence and absence of immune cells. Simulation results from the model demonstrate tumor morphologies that are similar to those observed in the experiments.

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### A framework for analyzing the reflexive relationship between stock prices and fundamentals

C. Necula*

*Bucharest Academy of Economic Studies, Romania*

In the aftermath of the financial crisis, the failure of the rational expectation hypothesis is generally admitted and a new paradigm based on behavioral economics is emerging. Behavioral macroeconomics investigates the importance of confidence and of other psychological factors in influencing the economy contrary to the cannons of neoclassical economic theory. Behavioral economics focus on the mispricing of asset prices due to the distortions of the underlying fundamentals by the perceptions of the economic agents. However, Soross theory of reflexivity implies that, instead of playing a purely passive role in reflecting an underlying reality, financial markets also have an active role, since they can influence the very fundamentals they are supposed to reflect, a feedback effect that behavioral economics is missing. The paper proposes a framework for capturing the insights of the theory of reflexivity about the influence of stock prices on fundamentals. This modeling framework will allow for a deeper investigation of the interconnections between the financial system, the confidence of economic agents and the real economy. In contrast to neo-classical economics we will not assume that firms maximize profit or that agents optimize the utility function, nor will we assume that agents have perfect information or know perfectly how the macroeconomic system behaves. In other words, there is no need for the representative agent or for the rational expectations hypothesis. Agents in our framework are heterogeneous, are interacting, and have bounded rationality. Therefore, the real economy and the financial markets are modeled as complex systems of interacting heterogeneous agents using tools drawn from statistical physics, mathematics, and biology. The transmission mechanism that we propose is as follows: the stock prices affect the mood (i.e. confidence) of the economic agents, the mood of economic agents affect the aggregate level of consumption and investment, the aggregate level of output and, therefore, the fundamentals. The stock price formation mechanism is subject to herding effect and distortions due to heterogeneous beliefs of traders.

### New City Landscape - Twitter Based Urban Social Networking Activity

F. Neuhaus*

*Centre for Advanced Spatial Analysis, UK*

Increasingly people use digital or online networks to communicate and interact. They leave messages, distribute news and respond to conversations. The data that for this paper is derived from the Twitter service, where

users can send information as 140 character message. The platform allows to maintain a pool of followers (friends) with whom one shares the tweets (messages). Technically it is possible to collect every tweet sent via the open API (application programming interface) gaining access to millions of location based messages. This changes the way we understand the socialscape of the urban area and with it how the interactive hot spots change and fluctuate throughout the city as individuals follow the narrative path of their everyday routines. People leave messages, distribute news and respond to conversations not only in traditional locations anymore but potentially anywhere in the city. This paper discusses the emerging potential of social media data used for urban area research and city planning. Working with crowd sourced data in a web 2.0 manner as described for example by Hudson-Smith et All. (2009). Specifically we look at the connections between the emerging social network, as for example described by Boccaletti et All (2006), and the local physical surrounding and conditions. Also aspects of visualisation as well as privacy and ethical implications are discussed. The information gathered from social media networks, is gathered directly of the platform used by the network participants as for example already employed by Eagle et all (2009) in their study of social networks using mobile phones. The twitter data however, usually can be associated with a physical location for example via the GPS of the smart phone. Research using this location based technology together with a temporal structure has been demonstrated for example by Reads et All (2009). For this virtual social network and infrastructure-mapping project, the data is derived from the Twitter micro blogging service directly via the API and aims to merge the previously listed approaches into a combined location based temporal network. These local activity are analysed and visualised based on networks of interaction. Who knows whom and get in touch with whom? However, of specific interest are these datasets in relation to place and how this location based network enable the individual to shape a distinct sense of place.

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### Aggregation of variables in time discrete metapopulations models

T. Nguyen-Huu*, P. Auger

*IRD, Paris, France*

Aggregation of variables methods allow to reduce the complexity of mathematical models involving different time scales, and they often permit to exhibit emergent properties. In population dynamics spatial models, demography is often considered as a slow time scale process, while dispersal is considered as fast time scale. It is clear that within the demographic processes reproduction should be actually described at a slow time scale, there are nevertheless some examples like survival that are treated or monitored at a fast time scale while they are actually slow time processes. We present here a class of models of metapopulations connected with dispersal based on a Leslie demographic model. The processes represented in the Leslie matrix must be separated in those occurring at slow time scale (reproduction) and those occurring fast time scale (survival). We introduce an aggregation method which allows reducing such a kind of spatial model into a global non-spatial one. We compare their dynamics and classical representative elements (eigen elements, net reproductive rate). We then describe an application of this Kind of model to the dynamics of a beetle called abax parallelepipedus living in Britany (France).

### A Mathematical Model of 6S RNA Regulation of Gene Expression

M. Nitzan*, O. Biham, H. Margalit

*The Hebrew University, Jerusalem, Israel*

E. coli's 6S RNA is a type of noncoding, small RNA that is ubiquitously expressed in the cell and is the key component in a unique global RNA polymerase (RNAP) - mediated regulation mechanism [1]. 6S RNA was shown to differentially inhibit $\sigma$-70 dependent promoters during stationary phase by binding and forming a stable complex with the housekeeping form of RNAP, blocking the ability of RNAP to bind to promoter DNA. Surprisingly, when stationary phase cells are exposed to high enough levels of nucleotide-triphosphate (NTP), they enter outgrowth phase at which time 6S RNA is used as a template for product RNA (pRNA)

synthesis. 6S RNA interactions with RNAP are destabilized during the pRNA synthesis reaction, leading to the dissociation of the 6S RNA-RNAP complexes. The released 6S RNA becomes highly unstable and the released RNAP enables increased transcription of genes. Many of the dynamic properties and the promoter specificity which characterize this regulation mechanism are still unclear. Using a mathematical model of this biological system we study the dynamics of the system components and specifically mRNAs transcribed by $\sigma$-70 dependent promoters (during exponential phase, stationary phase and outgrowth) [2]. We find that this global regulation mechanism exhibits unique properties; RNAP level returns to steady state subsequent to its inhibition, and stored inactive RNAPs bound by 6S RNA accumulate over late stationary phase and can return to their active form rapidly upon the introduction of newly available nutrients. We show that a gene's sensitivity to 6S RNA regulation varies according to its inherent effective promoter parameters- affinity to RNAP and clearance rate. We also compare 6S RNA regulation to other global RNAP-mediated regulation mechanisms and deduce several of its properties, including its energetic efficiency, its robustness to noise, and the competitive edge of cells carrying it at the transition to a new environment.

[1] Karen M. Wassarman and Ruth M. Saecker, "Synthesis-Mediated Release of a Small RNA Inhibitor of RNA Polymerase,"Science 314, 1601 (2006). [2] Mor Nitzan, Karen M. Wassarman, Ofer Biham, and Hanah Margalit, "Regulation of gene expression by 6S RNA: a quantitative view,"in preparation.

### Dynamics of Maximal Entropy Random Walk: Solvable Cases

J. Ochab*, Z. Burda

*Jagiellonian University, Krakow, Poland*

We consider the Maximal Entropy Random Walk (MERW) on graphs, which maximises entropy globally (which means all paths of a given length and endpoints are equally probable) in contrast to the Generic Random Walk (GRW), which maximises entropy locally (moves to neighbouring nodes are chosen with equal probabilities). The two random walks behave identically on regular graphs, but any impurities affect the two cases very differently. Most spectacularly, on weakly diluted lattices the localisation phenomenon arises, where a particle performing MERW eventually gets trapped in the largest nearly spherical region which is free of impurities. We obtain the stationary state probability distribution for the case of Cayley tree (Bethe lattice) with arbitrary number of generations and arbitrary branching parameter. We also generalise the results by varying the degree of the root independently of the branching parameter. While the probability distribution for GRW concentrates in the last but one generation of the tree, the stationary state for MERW is well described by the sine, cosine or exponent of the number of generations (depending on the parameters), with high occupation probability of the root. We also show that the second largest eigenvalue of the adjacency matrix does not suffice to describe relaxation process of the probability distribution to the stationary state. In fact, the associated notion of mean passage time between two given nodes strongly depends on the initial and final nodes. We also consider ladder graphs, which are divided in half by gaps (i.e. a number of rungs taken out of the ladder). We check the relaxation dynamics of the probability flowing from one of the halves to the other. In the case of GRW, the stationary probability is proportional to the degree of a node, and we observe the usual scaling relation of the relaxation time with respect to the size of the ladder with the exponent of two, independent of the gap size. In the case of MERW, however, where the stationary distribution is localised in the regions free of defects, we find that for a given size of the ladder the relaxation time grows exponentially with the gap size, and only then the size effects come in.

### Recurrence interval analysis of high-frequency returns on foreign exchange

T. Ohnishi*, H. Takayasu, T. Ito, Y. Hashimoto, T. Watanabe, M. Takayasu

*Canon Institute for Global Studies and University of Tokyo, Japan*

We investigate scaling and memory effects in the recurrence intervals between two consecutive price volatilities above a certain threshold value for the dollar-yen exchange market by using the tick-by-tick data with a recording frequency of every one second. We find that the distributions of recurrence intervals with different thresholds collapse onto a single scaling function that depends only on the ratio between the recurrence interval and its mean. The scaling curve can be fitted by a stretched exponential function, which is far different from the Poisson distribution expected for uncorrelated records. We also find memory effects such that a large (or small) interval is more likely to be followed by a large (or small) interval by investigating the conditional probability distribution P(T|t) which is defined as the probability of finding interval T conditioned on the preceding interval t. We further analyze the distribution of the cluster size of interval which is obtained by

calculating the successive intervals with similar size, and confirm the clustering phenomena.

### Understanding disease control: influence of epidemiological and economic factors

K. Oleś*, E. G. Nowak, A. Kleczkowski

*Jagiellonian University, Krakow, Poland and University of Stirling, UK*

The goal of our work is to find optimal control strategy of epidemics. We have considered an extended SIR model including pre- and symptomatic cases for a disease spreading on a regular and small-world network. The effective treatment strategies for a disease control are expected to minimize the total cost of an epidemic. However, in designing efficient control strategies, we have to consider both – epidemiology and economics. The most optimal control is determined by the relative costs of treatment and infection, as well as by the initial distribution of infectious cases and kinetics of its spread and transformation. We have shown that even if the knowledge of a pathogen is limited, or its origin is unknown, one is still able to make a valuable prediction about the evolution of the epidemics, based on the economic analysis only. Although economics determines control strategies, the range of applicability of chosen scenarios depends strongly on epidemiological factors such as infectiousness, detectability, recovery, removal and map of contacts in population. Some of those factors such as e.g. contagion or mortality are specific for a particular disease and hard to control. On the other hand, we can have an influence on some parameters affecting kinetics of the epidemics spread. For example, the quicker the symptoms occur or the higher is the recovery level, the smaller control radius can be applied. Additionally, we have analyzed the relationship between an efficient control and the size of an infected neighbourhood. Our studies allow to devise the most influential epidemiological parameters for such a control.

### Evolution of research regarding a particular scientific problem in academic community

M. Olesya*, H. Yurij

*National Academy of Science of Ukraine, Ukraine*

Science as an enterprise that builds and organizes knowledge can be considered as an object of study of its own. Such an idea gave rise to a separate branch of knowledge called Scientometrics (science of measuring and analysing science). Moreover, the complexity of this enterprise on different levels makes it an appropriate and important object for modern Complex Systems Science. Here, we present an attempt to analyse how does the research of a particular scientific problem evolve. We have chosen to examine a body of research strictly concerning the Chornobyl disaster that occurred on 26 April 1986 in Chornobyl (Chernobyl), Ukraine, at the nuclear power plant. The reaction of an academic community is evaluated on the base of data about papers that appeared in scientific journals since 1986 and strictly concern Chornobyl disaster. We analyse the publication activity, the corresponding multidisciplinary landscape and collaboration patterns. We use both the Scopus database (http://www.scopus.com) to present the picture on an international scale and the Ukrainian bibliographic database "Ukrainika naukova" (http://www.nbuv.gov.ua/db/ref_inf.html) to consider it on a national level.

### Game Theoretic Models of Crime Prevention

H. Passi*, V. Kolokoltsov

*University of Warwick, UK*

Many instances of crime can be formulated as a strategic interaction between would-be criminals and law enforcement agencies. As a result, non-cooperative game theory can be used to gain practical insights into effective deterrence strategies. We formulate a model of crime in which individuals from a large population can choose an amount of criminal activity, and authorities choose whether or not to inspect. We find that even the simplest versions of this model possess an interesting class of mixed-strategy equilibria whereby almost any distribution of crime may obtain in equilibrium, but there is a well-defined average level of crime which depends on the costs and accuracy of inspection and the severity of punishment. We investigate the dynamic properties of such equilibria by considering various means by which successful strategies can be transmitted through the population including deterministic and stochastic evolutionary dynamics. We also investigate

the properties of equilibria under different assumptions about the knowledge and foresight possessed by the authorities. Early results and intuition suggest that such equilibria are stable under a range of plausible assumptions. Separately, we are also developing models to gain theoretical insight into the most effective means of tackling organized crime. Specifically this includes situations where the gains to criminal activity are subject to competition (and possibly collusion), and engaging in criminal activity requires non-trivial investment costs which carry the risk of being sunk in the case of discovery by the authorities.

### Can complexity science explain role of physical environment in emerging form of encroachments.

A. Patil*, A. Dongre

*VNIT, Nagpur, India*

Our cities are growing rapidly, in spite of development control regulations enforced by the public authorities; considerable part of it is uncontrolled. Encroachments –physical manifestations of informal sector are the best examples of uncontrolled growth. The emergence of encroachments, even after uprooting them proves that the activities happening within the encroached areas have an important role to play in the functioning of the city. Our attitude towards resolving this burning issue needs to be reviewed. The overall characteristics of the encroachments are something similar to chaotic, beyond the scope of hard science and can be referred as complex system. The recent development in complexity science has immense potential to explore encroachments and can offer better ways of analyzing this issue. The paper is an attempt to draw inputs of complexity science to search for order in the chaotic form encroachments. Such study can lead to better analysis of existing form of encroachments in an urban environment. The paper highlights the importance of an urban environment which becomes the integral part of the system in analyzing the encroachments. To justify this, an urban core in the city of Nagpur, India was taken as a sample which satisfies the domain of interest and detailed mapping and analysis was done. The effort is to identify the determinants of the encroachments in an urban environment and how they lead to a hidden order. There is the need to filter the variables from the determinants set. As an urban designer one has potential of intervening into the physical aspects only - determinants are defined as the factors which determine the emergence of encroachments in an urban environment irrespective of our ability to alter it and they are namely –socio-economic determinants, area level determinants and cluster level determinants, Whereas, variables are defined as the those determinants which can be intervened in to make certain changes in the emerging form of encroachments in an urban environment and they are namely - area level determinants and cluster level determinants. These set of determinants and variables are applied for the study of encroachments in an urban environment. The quest is into the meaningful relations of the major variables assumed to be associated with the emerging form of encroachments. The exploration is about the determinants and variables, which determine the location of the encroachments in an urban environment. Further, similarities between encroachments in an urban environment and complex systems are explored based on the concepts of complexity science. The paper presents a series of justifications to assert that encroachments in an urban environment are complex system. The research can progress further with investigating the effect of rate of change of these determinants & variables and possibility of predicting the emerging form of encroachments in an urban environment.

### PROBABILITY DISTRIBUTION FUNCTION FOR FREQUENCY OF LIGHTNING

I. T. Pedron*, E. A. Leite, R. D. S. Mendes

*Universidade Estadual do Oeste do Paraná, Brazil*

Atmospheric electrical discharges, specifically lightning, are a natural phenomenon that can either contribute to environmental balance or cause harmful effects. The electrical discharges are the main source of shutdowns and damage to transmission systems and power distribution. Possibility to identify and map in advance the occurrence of atmospheric electrical discharges is essential for strategic actions that minimize the impact of the phenomenon. There are no much studies in an attempt to develop tools to forecast lightning. One possibility is to explore the empirical frequency of discharges and try to get a theoretical probability distribution function that fit the data. There is a correlation between lightning, rain and strong winds at different delays. Through data of meteorological radar is possible a good knowledge of the real distribution of lightning, which in turn could be useful as predictors of these other variables sometimes not always accessible. Atmospheric electrical discharges are events highly correlated, and such behavior should appear in the corresponding probability distributions. Thirteen years of lightning data in the south of Brazil are analyzed in hourly and daily data

series. Each record is characterized by time, longitude and latitude. Continuous distribution functions are used to fit the data. It is showed an excellent fit with non-Gaussian distributions like Lorentzian and q-Gaussian. However, these distributions have not finite variance (for appropriate q). An excellent alternative is to apply Weibull and q-Weibull distribution with very good results.

### Sensory bases of collective pattern formation: from the perception of pheromone in individual ants to the formation of efficient trail networks

A. Perna*, B. Granovskiy, S. Garnier, S. Nicolis, M. Labédan, G. Theraulaz, V. Fourcassié, D. J. T. Sumpter

*Uppsala University, Sweden*

Ant colonies achieve efficient transportation networks in the absence of centralized control and without global knowledge of the environment. In particular, the ability of an ant colony to find the shortest path to a food source has inspired more than twenty years of research in combinatorial optimization, and is at the origin of the research field of "ant colony optimization". Paradoxically, however, no experiment to date had tested how real ants achieve the particular configuration of their trail networks: how do they process and integrate pheromone concentrations when they walk on and off trail? What rules of motion followed by individual ants are responsible for the formation of the complex trail networks observed at the colony level? Here, by performing automated tracking of Argentine ants exploring an empty arena (more than 600,000 tracking events), we could extract a number of statistics on the behavior of individual ants. More precisely we showed: 1) That ant response to pheromone concentrations follows a logarithmic relation, which we can reconduct to the Weber-Fechner law of psychophysics. 2) That ants do not integrate information about pheromone quantities (i.e. they respond almost immediately to local concentrations only). 3) They do integrate, however, proprioceptive information about their own motion. When the above rules of behaviour are implemented in a multi-agent simulation, they are sufficient to lead to the formation of trails. Secondary differences between the real and simulated trails can be attributed to the direct exchange of information between ants through antennal contacts. To summarize: this is the first detailed experimental measure of the mechanisms of trail formation by ants. It is also, to our knowledge, the first time a large scale spatial pattern (the trails formed by one colony) is related to a perceptual mechanism (the logarithmic perception of pheromone quantities) at the individual level.

### Percolation theory in multiscale networks

E. Perrier*, N. Bird

*IRD and RNSC, France*

Standard percolation theory has been well-established in random networks by physicists, namely as regards the critical transitions emerging at a macroscopic scale from small differences in the connectivity at a microscopic scale. Applications to natural media are not straightforward due to embedded levels of organizations leading to spatial correlations modifying the assumptions of classical theory. Computer simulations show that percolation thresholds from textbook tables do not hold any more in correlated media. In simple fractal media used as case-studies, calculations can be carried out using appropriate renormalization functions, which confirm the strange behaviour of multiscale networks: one can demonstrate how porous media exhibiting an arbitrary high porosity can be impervious or how infinitely dense forests could be theoretically designed to prevent forest fire propagation! Numerical experiments on 2-D and 3-D prefractal media confirm the qualitative theory. More practically, these new findings lead to the re-analysis of straining and filtration processes in porous media. Quantifying the connectivity of pore networks is a key issue not only for modelling fluid flow and solute transport in porous media but also for assessing the ability of soil ecosystems to filter bacteria, viruses and any type of living microorganisms as well inert particles which pose a contamination risk. The range of sizes of entities which can be trapped inside soils can be associated with the large range of pore sizes involved in natural soil structures and we define a Critical Filtration Size (CFS) delimiting the transition between percolating and non percolating regimes in multiscale pore networks. The mass fractal dimensions which are classically used in soil science to quantify scaling laws in observed pore size distributions can also be used to build 3-D models explaining such a critical transition in natural media. These results open the way towards the conception of optimal filters based on appropriate network geometries.

E. Perrier, N. Bird, T. Rieutord, 2010, Percolation properties of 3-D multiscale pore networks: how connectivity controls soil filtration processes, Biogeosciences, 7(10), 3177-3186, available at www.biogeosciences-discuss.net/7/2997/2010/ N. Bird, E. Perrier, 2010. Multiscale percolation properties of a fractal pore network,

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**A novel Markov chain approach to community analysis in networks**

C. Piccardi*

*Politecnico di Milano, Italy*

Identifying communities, namely groups of nodes with strong internal connections, is a fundamental task for deeply understanding the structure of a network. We propose an approach which is based on the well-known correspondence between networks and Markov chains. First, a measure of similarity/distance between node pairs is introduced, based on the idea of following an arbitrarily large fleet of random walkers. Yet, the distance is obtained by direct computations on the Markov matrix, namely without the need of performing explicit random walks. Then, an aggregative, hierarchical cluster analysis is performed. Cutting the associated dendrogram at deeper and deeper levels, a family of network partitions is obtained, with increasing number of communities. A meta-Markov chain, which describes the transition from one community to another, is associated to each partition. The best partition is finally obtained by analyzing the diagonal terms of the meta-Markov matrices, as they provide information on the expected escape time from communities. By setting a probability threshold $\alpha$, a sharp definition of community is given, by introducing the notions of $\alpha$-community (a group of nodes with escape probability less than 1-$\alpha$) and $\alpha$-partition (a partition composed of $\alpha$-communities). The method has fair computational requirements, and can be applied to fully general networks (i.e., directed and weighted). Furthermore, it is able to isolate well-defined communities even in networks which, as a whole, do not possess a definite clusterized structure. The entire procedure is demonstrated on four different networks: two of them are synthetically generated benchmarks, whereas the others are obtained from real-world data.

**Stochasticity and self-maintenance in a simple model of metabolic closure**

G. Piedrafita*, F. Montero, F. Morán, M. L. Cárdenas, A. Cornish-Bowden

*University Complutense of Madrid, Spain*

A fundamental landmark in the emergence and maintenance of the first proto-biological systems must be the formation of some sort of 'closed' metabolic organization. More specifically, the theory of (M,R)-systems (Rosen, 1991) suggests that biological organizations exhibit closure to efficient causation, i.e. every catalyst (enzyme) involved in a certain metabolism should be produced by the organism itself in order to counterbalance the continuous degradation to which they are subjected. We have recently proposed a simple metabolic model (Letelier et al, 2006, J Theor Biol; Piedrafita et al, 2010, PLoS Comput Biol), consisting of three intertwined catalytic cycles, that fulfils these requirements, contributing to clarify some ideas of this theory. A first deterministic analysis shows that such a system is able, for a wide range of parameter space, to replenish its own catalysts despite their continuous loss by irreversible degradation, thus achieving a robust self-maintaining regime (a non-trivial steady state). The system shows bistability, as too restrictive initial concentrations lead to collapse to a coexisting trivial steady state. Although this doesnt normally threaten the capacity of this system to maintain itself (indeed it can construct itself by seeding it with just small quantities of at least one catalyst), other factors should be addressed to analyze its relevance as a possible proto-metabolic model. In fact, it is reasonable that the proto-biological systems were developed in confined volumes (Martin & Russell, 2003, Phil Trans Roy Soc B), in which the concentrations should be consequently subject to large fluctuations. Thus, we have supplemented this work with a stochastic analysis to study the effect of internal noise-driven fluctuations on the behaviour of the system. This analysis confirms the ability of the system to reach a robust self-maintaining regime (in this case, a quasi-steady state). Interestingly, however, the internal noise, and thus the system volume, plays an essential role in the evolution of the system either toward recovery or extinction: While the response to disturbances or critical concentrations of the intermediates is faster for lower system volumes, too small volumes are incompatible with the self-maintaining regime and cause irrevocably the collapse of the system, indicating a noise-induced phase transition for some critical volume of the system. This work shows the feasibility of simulating the behaviour of a system that is closed to efficient causation, claiming the interest of simple models of organizational closure to understand the development of the first proto-biological systems. At the same time, it imposes a series of spatio-temporal requirements in the possible

scenarios of prebiotic evolution.

### Language change in a multiple group society

C. Pop*, E. Frey

*Ludwig-Maximilians-Universität München, Germany*

The use of language in society serves several purposes. On the one hand, inside a social group the necessity to communicate meaning leads to agreement on a conventional sign for a recurring problem. On the other hand, speakers want to identify with particular social groups. Through innovations in language and the influence of different social groups on each other, novel forms are spread across the speech community, resulting in a competition between linguistic variants. A mathematical formulation of the linguistic interactions inside a social group is offered by the Utterance Selection Model [1], which explains the mechanisms inducing variant fixation and analyzes the distribution of variant frequencies. In the attempt of describing language change in a society consisting of multiple groups, we take the Utterance Selection Model beyond the one-group boundary and study the effects of different ways of partitioning the speakers into groups. The interactions between these groups counterbalance the formation of consensus in the individual groups and thus offer a further mechanism for the propagation of linguistic changes.

[1] Utterance selection model of language change, G. J. Baxter, R. A. Blythe, W. Croft, Phys. Rev. E 73, 046118 (2006)

### Evolution of human behaviour patterns: data-driven exploration of digital footprints

A. Pozdnoukhov*

*National Centre for Geocomputation, Ireland*

This research concerns building scalable predictive models from human-generated data streams. Ubiquitous sensing technologies provide dense spatially distributed data describing various modalities of urban systems at a variety of spatial and temporal scales which provide opportunities to identify patterns, detect novelties and explore evolution of complex social systems. A scenario where multiple geo-referenced attributes of an urban environment are streamed back from handheld devices of potentially millions of users is becoming a reality. Such "measurements"of the "state of a city"are usually available as geo-referenced streams of time-stamped but asynchronous data sampled irregularly both in time and space. In terms of statistical modelling, there is inherent spatial heterogeneity, temporal non-stationarity and low signal-to-noise ratio one has to deal with. Communication technologies with their very high penetration into society can serve as particularly rich sources of information. In this work we consider a dataset of communication logs from a worldwide instant messaging service aggregated at the level of cities for the duration of 3 months, and a dataset of all individual communication events on a European mobile communication network of more then 1 million customers available for the duration of 1.5 months. For a variety of observable communication channels such as the considered ones, there is little or no access to the content of human-to-human communications, while the data streams on the intensities of such events are more common. In this work we introduce a methodology for exploratory analysis and data-driven predictive modelling for such streams. First we observe that the data presents the aggregated behaviour of many individuals which typically exhibits a temporal periodicity on many scales (daily, weekly, etc.) reflecting the rhythms of related everyday activities in a typical weekday/weekend routines. We demonstrate how the routine periodic component can be extracted and untypical activity levels identified by fitting a non-homogeneous Markov-modulated Poisson processes. We further explore how linear (PCA) and non-linear (Laplacian eigenmaps) dimensionality reduction methods can be applied to the data, as we expect the intrinsic dimensionality of the observed processes to be much lower then a number of streams due to presence of strong spatial autocorrelation. We applied the methods to both raw streams and the extracted extreme component and observed that both systems follow typical trajectories in the space of reduced dimensionality, with distinctive deviations caused by large-scale untypical events. We explored the properties of these trajectories by using tools of non-linear time series analysis, and applied a pattern-matching algorithm based on particle filtering to forecast their future evolution. Our preliminary findings suggest the usefulness of this methodology to identify novel and extreme events in the data, and give promise to further

investigate the fundamental issues of predictability of complex social systems.

### Cycle decompostion of small RNA configuration space

J. Qin*, P. F. Stadler

*Max Planck Institute, Germany*

It is a well known fact that the behavior of simulated annealing algorithms is tightly related to the hierarchical decomposition of their configuration spaces in cycles. We here apply the iterative routine invented by Wentzell and Freidlin to construct the cycle decomposition of small RNA configuration spaces, for instance, hairpins. We furthermore explore the relationships of cycles and the barrier tree of the energy landscape.

### Semiotic freedom – a criterion for conceptual notion of semiotic complexity

J. Queiroz*

*Federal University of Juiz de Fora, Brazil*

The evolution of semiotic complexity is a central theme for the evolution of language research, cognitive science and evolutionary biology. By consensus, complexity has increased in living information systems, giving rise to symbolicity, grammar and semiotic social systems of higher complexity. However, the processes behind the complexification of semiotic processes and their relation to evolution are not well understood. Moreover, evolution of semiotic complexity can mean different things in different contexts and domains. To make matters worse, there is no agreement regarding the most appropriate criteria for measuring levels of semiotic complexity in biological and cognitive systems. Concretely, many open questions related to the evolution of semiotic complexity can be asked. 1. How can semiotic complexity growth be measured in natural living (and artificial) systems? 2. How can existing data from nature be brought to bear on the study of this issue? 3. What are the main hypotheses about semiotic complexity growth that can actually be tested today? 4. Are the principles of natural selection sufficient to explain the evolution of semiotic complexity in biological systems? 5. What is the role of developmental mechanisms in the evolution of semiotic complexity in living systems? 6. What models are most appropriate for understanding the evolution of complexity in living systems? Here I summarize what I consider the most problematic (blurred and obscure) aspect of the notion of "semiotic complexity"and introduce a new perspective based on Jesper Hoffmeyers notion of "semiotic freedom"(Hoffmeyer 2006, 2008) and on Peirces pragmatic theory of signs.

Hoffmeyer, Jesper. 2006. Semiosis and living membranes. In: J. Queiroz & P. Farias (eds.), Advanced Issues on Cognitive Science and Semiotics. Shaker. (pp. 19-36) 2008. Biosemiotics: An Examination into the Signs of Life and the Life of Signs. University of Scranton Press.

### Computational Epigenetic Micromodel for Cancer Prediction

K. Raghavan*, H. J. Ruskin

*Dublin City University, Ireland*

Phenotype or the visible traits of an organism are influenced by 3 main factors, including surrounding environment, genotype (or genetic content) and changes which correspond to heritable modifications of the chromatin structure, which do not involve changes in the DNA sequence –a phenomenon, known as Epigenetics. Characterisation of the epigenetic profile of humans, followed by typing the contents of the human genome, has provided strong indications of the key role played by histone modifications (HM) and stable DNA methylation (DM) in determining the normal level of gene expression in the genome. DM refers to the modification of cytosine base molecules and is the most stable, heritable and well-conserved epigenetic change. Aberrations in DM, specifically hypomethylation was the first such change to be linked to cancer. Histone proteins, apart from protecting and managing DNA molecules, form, with these, the basic unit of nucleosomes in the human genome. A combination of dynamic modifications within specific amino acids in each histone, together with DNA methylation, leads to activation or suppression of genes. While new findings on the impact of DM and HM are reported, precise information on how the network of histone modifications and their combinations operate in conjunction, is lacking. Nevertheless, considerable recent evidences suggest that interactions between the key elements are disrupted at some stage, leading to initiation of disease, such as cancer. This reasoning

has motivated attempts to build computational models in order to represent HM and DM elements and their intrinsic interdependency and hence understand how information is passed from this basic, sub-cellular layer to produce effects at tissue and organ level. Here, we discuss about a prototype model with novel framework for integration of epigenetic information from different sources. The powerful layout of this model permits stochastic investigation of dynamic histone modifications and inherent DNA methylation associated with patterns in DNA sequences, (derived from signal processing methods). The model is tested on a large dataset, in part to address issues of scale and the relevance at genome level for aberrant changes. To demonstrate applicability of the model, we have chosen the example of colon cancer, since it is well-documented and epigenetic information is available on specialised databases. Further model refinements which permit efficient up-scaling are also explained.

### Entropy and Combinatorial Laplacian of Simplicial Complexes

M. Rajkovic*, S. Maletic

*Institute of Nuclear Sciences Vnca, Belgrade, Serbia*

In this exposition we focus on simplicial complexes (obtained from random, scale- free networks and networks with exponential connectivity distributions) and their persistent homological and cohomological properties. Simplicial complexes may be constructed from undirected or directed graphs (digraphs) in several different ways. Here we consider two of them: the neighborhood and the clique complex. We show how a new branch of statistical mechanics may be developed which we call statistical mechanics of simplicial complexes. We also explore the topological properties of independent sets corresponding to each type of complex network, and their statistical features. Of special interest are the properties of eigenvalues and eigenfunctions of non-normalized combinatorial Laplacian. Spectral entropy, obtained from the combinatorial Laplacian, reflects many important properties of a simplicial complex (complex network) and thus has important practical applications. We also derive a an entropy of a simplicial complex from a purely combinatorial aspect, called combinatorial entropy, and explore its properties. In order to illustrate the advantages of simplicial complex approach over standard graph (networks) approach we present results of the analysis of several social type of networks. Relationship between dynamics and structure on simplicial complexes is further explored both in the context of classical and quantum formalism and its relationship with exterior calculus is presented.

### Spatio-Temporal Dynamics on Co-Evolved Stigmergy

V. Ramos*, D. M. S. Rodrigues, J. Louçã

*Technical University of Lisbon, Lisbon, Portugal*

Research over hard NP-complete Combinatorial Optimization Problems (COPs) has been focused in recent years, on several robust bio-inspired meta-heuristics, like those involving Evolutionary Computation (EC) algorithmic paradigms. One particularly successful well-know meta-heuristic approach is based on Swarm Intelligence (SI), i.e., the self-organized stigmergic-based property of a complex system whereby the collective behaviors of (unsophisticated) entities interacting locally with their environment cause coherent functional global patterns to emerge. This line of research recognized as Ant Colony Optimization (ACO), uses a set of stochastic cooperating ant-like agents to find good solutions, using self-organized stigmergy as an indirect form of communication mediated by artificial pheromone, whereas agents deposit pheromone-signs on the edges of the problem-related graph complex network, encompassing a family of successful algorithmic variations such as: Ant Systems (AS), Ant Colony Systems (ACS), Max-Min Ant Systems (Max-Min AS) and Ant-Q. Albeit being extremely successful these algorithms mostly rely on positive feedbacks, causing excessive algorithmic exploitation over the entire combinatorial search space. This is particularly evident over well known benchmarks as the symmetrical Travelling Salesman Problem (TSP). Being these systems comprised of a large number of frequently similar components or events, the principal challenge is to understand how the components interact to produce a complex pattern feasible solution (in our case study, an optimal robust solution for hard NP-complete dynamic TSP-like combinatorial problems). A suitable approach is to first understand the role of two basic modes of interaction among the components of Self-Organizing (SO) Swarm-Intelligent-like systems: positive and negative feedback. While positive feedback promotes a snowballing auto-catalytic effect (e.g. trail pheromone upgrading over the network; exploitation of the search space), taking an initial change in a system and reinforcing that change in the same direction as the initial deviation (self-enhancement and amplification) allowing the entire colony to exploit some past and present solutions (environmental dynamic memory), negative feedback such as pheromone evaporation ensure that

the overall learning system does not stables or freezes itself on a particular configuration (innovation; search space exploration). Although this kind of (global) delayed negative feedback is important (evaporation), for the many reasons given above, there is however strong assumptions that other negative feedbacks are present in nature, which could also play a role over increased convergence, namely implicit-like negative feedbacks. As in the case for positive feedbacks, there is no reason not to explore increasingly distributed and adaptive algorithmic variations where negative feedback is also imposed implicitly (not only explicitly) over each network edge, while the entire colony seeks for better answers in due time. In order to overcome this hard search space exploitation-exploration compromise, our present algorithmic approach follows the route of very recent biological findings showing that forager ants lay attractive trail pheromones to guide nest mates to food, but where, the effectiveness of foraging networks were improved if pheromones could also be used to repel foragers from unrewarding routes. Increasing empirical evidences for such a negative trail pheromone exists, deployed by Pharaoh's ants (Monomorium pharaonis) as a 'no entry' signal to mark unrewarding foraging paths. The new algorithm comprises a second order approach to Swarm Intelligence, as pheromone-based no entry-signals cues, were introduced, co-evolving with the standard pheromone distributions (collective cognitive maps) in the aforementioned known algorithms. To exhaustively test his adaptive response and robustness, we have recurred to different dynamic optimization problems. Medium-size and large-sized dynamic TSP problems were created. Settings and parameters such as, environmental upgrade frequencies, landscape changing or network topological speed severity, and type of dynamic were tested. Results prove that the present co-evolved two-type pheromone swarm intelligence algorithm is able to quickly track increasing swift changes on the dynamic TSP complex network, compared to standard algorithms.

### Development Space - a data-driven approach to human development

S. Ranganathan*, R. Mann, B. Nannyonga, D. J. T. Sumpter

*Uppsala University, Sweden*

Last years release of the World Bank data catalogue contains a wealth of information on development indicators, such as child mortality, GDP and average number of children per woman. We have developed a application called Development Space, which creates a visualisation and fitting tool for data in terms of the interactions between these development indicators.Interactions are modeled as a dynamical system which provides an insight into the historical processes of development, and helps policymakers understand the investment tradeoffs between the variables. Development Space has been submitted as an entry to the World Bank Apps for Development competition and is available for download at www.dev-space.org. The major aim of Development Space is to provide dynamical models which improve our understanding of how indicators interact. We use regression on the rate of change of these indicators on the indicators themselves to obtain a dynamical system model. To make the model tractable we impose the restriction that the models be polynomial in the two variables, and further that the powers in the variables be restricted to -2, -1, 0 and 1 and 2. These restrictions serve to reduce the search space for the models. For example, the best three-term model for the 2-D problem involving child mortality (C) and log GDP (G) is given by: $C(t+1)-C(t) = C(0.002-0.007G+4.6*10-5C)$, $G(t+1)-G(t) = 0.007+(18.3/G-1.7)/C$ Here we see how child mortality interacts with GDP. GDP appears to be the primary factor driving down child mortality. It also appears that when GDP is low, lowering child mortality encourages economic growth. These results must of course be evaluated in the context of known economic constraints, but our data driven approach allows us to determine models without being restricted to particular economic theories. Since human development takes place simultaneously in many directions, there is a need to develop computationally efficient tools to explain more complex systems in n dimensions. We will present results on models with three variables, where nearly half a billion possible models exist with the restrictions used above. We also discuss methods for dealing with more dimensions.

### Persistence properties of market maker intervention in financial markets

F. Redelico*, G. Rotundo, C. Roy

*Catholic University of Argentina, Argentina*

In this paper, a theoretical microeconomic model for an asset traded in a financial market is built and developed. The basic features of the market model we are going to set up, are the existence of two groups of agents, with heterogeneity inside each group, and the presence of market shocks. A market shock can be defined as disruption of market equilibrium caused by a change in the demand or supply determinant. In this paper we are interested in the effects that market shocks can have on the long-term memory of prices and returns

rather than in analyzing the distinction between the four cases of increase/decrease of demand/supply. In our model, each agent carries out price forecasts using a short term approach, but collective behavior can exhibit long-memory property. The contribution of cross-correlation parameters among the agents to the long memory of the aggregate is shown. We present mathematical proof of the exact relationship between the model's parameters and the presence of long memory in asset prices and returns. Furthermore, it is also evidenced that the presence of long memory in the asset price time series implies that the log returns have long memory as well.

**The interplay of microscopic and mesoscopic structure in complex networks**

J. Reichardt*, R. Alamino, D. Saad

*UC Davis, USA*

Not all nodes in a network are created equal. Differences and similarities exist at both individual node and group levels. Disentangling single node from group properties is crucial for network modeling and structural inference. Based on unbiased generative probabilistic exponential random graph models and employing distributive message passing techniques, we present an efficient algorithm that allows one to separate the contributions of individual nodes and groups of nodes to the network structure. This leads to improved detection accuracy of latent class structure in real world data sets compared to models that focus on group structure alone. Furthermore, the inclusion of hitherto neglected group specific effects in models used to assess the statistical significance of small subgraph (motif) distributions in networks may be sufficient to explain most of the observed statistics. We show the predictive power of such generative models in forecasting putative gene-disease associations in the Online Mendelian Inheritance in Man (OMIM) database. The approach is suitable for both directed and undirected uni-partite as well as for bipartite networks.

**Firm size q-distributions: a comparative study between Brazil and USA companies**

M. S. Ribeiro*, G. A. Prataviera

*Universidade de São Paulo, Brazil*

A wide variety of natural and man-made phenomena follow a power law, including frequencies of words in most languages, frequencies of family names, earthquakes, and many other quantities. A successful proposed approach for such phenomena has been obtained through nonextensive statistical mechanics which generalizes the concept of entropy for nonextensive systems. q-distributions, originated from Tsallis entropy, have been explored in several areas, including physics, biology and social science, and have the nice feature of reproducing power-law distributions for extreme values of it variables, and due to their general character they possible may be useful to fit the overall range of values. Among many, the study of firm size distributions has received considerable attention. Firm size is an important variable in several economic and accounting models. It can be a determinant factor in public policies, tax, valuation, and so on. However, firm size distribution studies have, frequently focusing attention to large values of the size variable, where power-law behavior is observed. So, it seems interesting to explore q-distributions for fitting firm size distributions. Such a study, besides looking for a better description of empirical data, may be useful to indicate possible underlying processes which should be included in order to improve theoretical models. In this work, a firm size distribution analysis is performed by considering Brazilian and USA open share companies and their fitting by q-distributions in the overall range of values. Total Assets and Total Revenue are used as firm size measurements. We consider specifically q-exponential and q-Weibull, in order to describe the empirical data distribution. The distributions parameters were estimated using the maximum likelihood method. The best fitting for data of both countries was obtained with the q-Weibull distribution. However, the typical power-law behavior for large values is best in Brazil by q-Weibull distribution, while in USA the best description in given by q-exponential.

**The soundscape dynamics of human agglomeration**

H. V. Ribeiro*, R. T. De Souza, E. K. Lenzi, R. D. S. Mendes, L. R. Evangelista

*Universidade Estadual de Maringa, Brazil*

Concepts and methods of Statistical Physics have become increasingly ubiquitous when dealing with social phenomena. Naturally, the basic constituent of such systems is the human being, which are much more

complicated than idealized physical interacting systems. This complex dynamic is directly related to individual aspects of the social agents and also their relationships. Our work addresses this kind of system by using a simple experiment based on the sound noise of people agglomerations. The empirical findings indicate that a nontrivial dynamic behavior emerge from this time series. Specifically, we found that (i) the distributions of normalized sound amplitudes present heavy tails, (ii) the sound intensity time series present long-range correlations, (iii) the distributions of the times between extreme events (return interval) have a non-exponential behavior, and (iv) the local variances of the sound amplitudes are distributed according to an asymptotic power law pdf. In addition, we verified that all these features are in good agreement with the predictions of a GARCH process, a widely used model in economy.

### On the dynamics of bubbles in boiling water

H. V. Ribeiro*, R. D. S. Mendes, E. K. Lenzi, M. Belancon, L. C. Malacarne

*Universidade Estadual de Maringa, Brazil*

We investigate the dynamics of many interacting bubbles in boiling water by using a laser scattering experiment. Specifically, we analyze the temporal variations of a laser intensity signal which passed through a sample of boiling water. Our empirical results indicate that the return interval distribution of the laser signal does not follow an exponential distribution; contrariwise, a heavy-tailed distribution has been found. Additionally, we compare the experimental results with those obtained from a minimalist phenomenological model, finding a good agreement.

### Coupled Ising and interdependent binary choices: a simple model

A. F. Del Río*, E. Korutcheva, J. D. L. Rubia

*Departamento Física Fundamental UNED, Madrid, Spain*

Coupled Ising models are studied and discussed in a discrete choice theory framework, where they can be understood to represent interdependent choice making processes. Besides this coupling, each of the two spin or choice variables follows mean field Ising dynamics with constant field. This is equivalent to considering homogeneous populations of utility maximising agents with rational expectations, when there is a tendency to conform to social norm through the agent's accurate perception of the average choice of the group. Two different couplings between the two different spin or choice variables are considered. The nonlocal model (mean field type coupling between both variables) can be used to represent two interrelated groups making the same binary choice. The local model (coupling only through each individual) represents a single group where all agents are making two binary choices which affect each other. Both models are studied analytically and numerically and phase diagrams constructed, discussed and compared in the context of interdependent choices in the absence of pure private utilities (zero choice fields). Although these models represent only a first simple step towards the understanding of coupled choices, they already show behaviour with interesting interpretations in the context of groups/choices for which the interrelation is reversing.

### "Cellular Dynamics at the Beginning of Prebiotic World"

W. Riofrio*

*University Ricardo Palma, Lima, Peru and Paris Île-de-France, Paris, France*

It seems that the emergence of cellular dynamic structures were more feasible than previously though. From the results of recent studies, it is likely that in the origins of prebiotic world the appearance of protocells came first. In other words, contending visualizing the dawn of prelife from the perspective of spontaneous emergence of a self-organizing minimal cellularity could shed more lights to this elusive problem than the proposals on metabolism-first and/or replication-first scenarios. And so the rationale of its dynamic self-organization should lead us to some revealing characteristics these entities possessed (which are still present and complexified in living systems). There could be the characteristics we could discern by the way these dynamic entities began to self-organize. If it is possible to contend the existence of two very interconnected processes behaving as the first prebiotic constraints: (1) a container made of amphiphilic molecules and (2) a micro cycle, driving the protocell far away from thermodynamic equilibrium. Then, this last self-constraint causes a change in the

systems free energy (Gsys), i.e. a trend towards negative values, and turned into an unavoidable checkpoint along the pathway of creating a future set of responses that are generated in another part of the interconnected and interdependent processing network. In consequence, it had provided the conditions for the emergence of the first small world structures as core characteristics to the way in which the biological realm computes.

### Dynamical homophily - synchronization-based evolving complex networks

D. M. S. Rodrigues*, M. Tânger, J. Louçã

*ISCTE-IUL, Lisbon, Portugal*

Complex networks are a broad framework to study many interacting nodes connected in a non-trivial manner. Such structures are ubiquitous in nature and their properties are still not fully understood. Interactions between nodes can lead to an emergent phenomena of synchronization among their properties, where the topology and structure of the network as well as the dynamics of the interactions play a key role. In particular, we study organically inspired evolving networks that grow according to a co-evolutionary re-wiring strategy. We consider internal processes that allow for a correlation between nodes by applying simple Kuramoto oscillators whose edges reflect coupling strength. Networks evolve on the basis of this correlation between linked agents as follows: nodes with correlated properties generate new edges while edges connecting uncorrelated nodes are lost. This mechanism gives preference to synchronized sub-graphs that grow as long as they are internally correlated and partially dim out when it is not the case. This process can be seen as dynamical homophily. It should also be noted that such a process may be directly applicable to opinion dynamics, trust dynamics, social group evolution, brand awareness dynamics and so on. In this work we analyze this process for different initial network topologies (from regular lattices to random, small-word and scale-free networks), the whole spectrum of linear coupling strengths and degree dependent coupling strengths. We also show the robustness of such evolving networks under perturbations and noise as well as the characteristic timescale of synchronized/correlated sub-graphs under given conditions. Finally, we end with a discussion of our results as well as some open questions and research directions.

### Robustness, evolvability and complexity in Boolean network robots

A. Roli*, S. Benedettini, M. Birattari, C. Pinciroli, R. Serra, M. Villani

*Università di Bologna, Italy*

Boolean networks (BNs) were introduced by Kauffman (Kauffman, 1993) as genetic regulatory network models. A BN is a discrete-time discrete-state dynamical system whose state is a N-tuple in {0,1}ˆN and it is updated according to the composition of N Boolean functions, each of which rules the update of one variable of the system. Usually, BNs are subject to a synchronous and parallel node update, but other update schemes are possible. BNs received considerable attention in the community of complex system science. Works in complex systems biology show that BNs provide powerful model for cellular dynamics (see, e.g., Aldana et al., 2007 and Serra et al., 2010). In a recent work, we showed that BNs can be utilised to control robots (Roli et al., 2011). In our approach, a BN is coupled with a robot by defining a set of input nodes, whose values are imposed by the robot's sensor readings, and a set of output nodes, which are used to maneuver the robot's actuators. The BN is trained by means of a learning algorithm that manipulates the Boolean functions. The algorithm employs as learning feedback a measure of the performance of the BN-controlled robot (in the following, BN-robot) on the task to perform. The effectiveness of this approach was demonstrated through a simple experiment on a real robot. Initially, the BN-robot must perform phototaxis, that is, move towards a light source located in the environment. Upon perceiving a sound, the BN-robot must switch to antiphototaxis, that is, move away from the light source. In this work, we present the results of a thorough analysis of the BN-robot's dynamics. We analysed the trajectories followed by the BN-robot in the space of the BN states. We found that the best performing BNs show the capability of maintaining previous learned behaviours (robustness), while adapting to new tasks to perform (evolvability). (We use the terms robustness and evolvability with the same meaning as in the work by Aldana et al.). This property seems also to be positively correlated with a measure of the complexity of the BN. The BN-robot is trained in two sequential phases. In the first phase, the learning feedback is an evaluation of the robot's performance in achieving only phototaxis. In the second phase, the learning feedback is composed of a performance measure accounting for both phototaxis and antiphototaxis. In this way, we can study the properties of the evolution of the BN-robot when its behaviour must be adapted to a new operational requirement. The entire training process was repeated 100 times, starting from initial BNs generated at random. For each step of the training process, we test the BN-robot and collect statistics on

the BN states traversed. The initial positions and orientations of the BN-robot while testing are different from those of the training process. The training process involves simulated experiments, while testing is performed both with simulated and real robots. A significant fraction of the training experiments leads to a successful BN-robot, i.e., a robot able to switch from phototaxis and antiphototaxis. The unsuccessful BN-robots are only able to perform phototaxis. In the successful cases, we can observe that the phototaxis capability acquired by the BN-robot in the first training phase is maintained while also the antiphototaxis behaviour is learned. This result provides evidence to the hypothesis that these systems are able to successfully balance robustness and evolvability. It is interesting to investigate the reasons for the success of these BNs. To this aim, we study the properties characterising the BNs along the training process in order to find the factors that discriminate between the BNs that attain the best performance w.r.t. the unsuccessful ones. An in-depth analysis of the BN trajectories in both successful and unsuccessful cases provides very insightful findings. First of all, during the learning process, the successful BNs improve their generalisation capabilities, as the overall number of visited states decreases, while the number of fixed points increases (for BNs with inputs, a fixed point is a state repeated as long as the BN inputs do not change). Fixed points represent micro-behaviours (e.g., 'turn right until the light input changes') which are combined to achieve a global behaviour. The emergence of fixed points reveals that the BN is able to extract regularities in the environment and to classify them, thus achieving generalisation. In addition, we also observe a further remarkable property: the complexity of the best performing BNs increases during evolution. In our experiments, the complexity C of a BN is measured as H x D, where H and D are, respectively, the entropy and the disequilibrium of the BN states observed in the BN trajectories. A high entropy means that the sequences of states in the BN trajectories are highly diversified. Conversely, a high disequilibrium among the states characterises trajectories mostly composed of the repetition of few states. It is conjectured that a complex system operates in a dynamical regime such that a balance between these two quantities is achieved (Lopez-Ruiz et al., 1995). In our experiments, the complexity C of the successful BN-robots increases steadily during the training process, whilst it is almost constant for the unsuccessful ones. In summary, the networks which optimally balance robustness and evolvability are characterised by generalisation capability and high statistical complexity of their trajectories. This result suggests that also artificial systems that must cope with changing environments may have an advantage in enjoying the same properties as living systems, such as cells.

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### MSR approach for spreading disease in the network

F. Roshani*

*Alzahra University, Iran*

We applied a field theoretical approach, Martin Siggia Rose formalism, for solving the spreading disease in the network. For the standard spreading model, the action is calculated by these method. Response function, cumulates, density of the susceptible, infected, recovered individuals are calculated analytically.

### Coupling self-assembly and self-organization: the role of lipid compartments in the origins of biological complexity

K. Ruiz-Mirazo*, F. Mavelli

*University of the Basque Country, Spain*

Complexity sciences hold an enormous potential to illuminate the problem of the origins of life. One major contribution should be to provide theoretical tools for analysis of multi-component chemistries taking place in heterogenous conditions, in which self-organization reaction patterns in aqueous solution and self-assembly processes creating lipid boundaries would come together. We consider that this is a key issue for all bottom-up approaches to the origins of biological order, which always requires the interplay between various types

of dynamical constraints harnessing –or rather, channelling– complex reaction networks. Present difficulties to understand and deal with this type of complex (multi-component, heterogenous) systems could be tackled with new experimental methods coming from the emerging field of systems chemistry, but will surely call for theoretical models and simulations that help in the interpretation of empirical data. We are engaged for some years now in an effort precisely to bridge the gap between in-vitro and in-silico strategies to study chemical reactions in lipid compartments (Mavelli and Ruiz-Mirazo 2007; 2010), and we could present, in the context of this conference, our main results and the consequences that can be drawn for future work on similar lines.

Mavelli, F. & Ruiz-Mirazo, K. (2007): Stochastic simulations of minimal self-reproducing cellular systems. Philosophical Transactions of the Royal Society of London B 362 (1486): 1789-1802. Mavelli, F. & Ruiz-Mirazo, K. (2010): ENVIRONMENT: a computational platform to stochastically simulate reacting and self-reproducing lipid compartments. Physical Biology 7(3) 036002.

### 2D Criticality in a 3D Ising Model

A. A. Saberi*

*Institute for Research in Fundamental Sciences (IPM), Iran*

The fractal structure and scaling properties of a 2d slice of the 3d Ising model is studied using Monte Carlo techniques. The percolation transition of geometric spin (GS) clusters is found to occur at the Curie point, reflecting the critical behavior of the 3d model. The fractal dimension and the winding angle statistics of the perimeter and external perimeter of the geometric spin clusters at the critical point suggest that, if conformally invariant in the scaling limit, they can be described by the theory of Schramm-Löwner evolution ($SLE_\kappa$ ) with diffusivity of $\kappa = 5$ and $16/5$ , respectively, putting them in the same universality class as the interfaces in 2d tricritical Ising model. It is also found that the Fortuin-Kasteleyn (FK) clusters associated with the cross sections undergo a nontrivial percolation transition, in the same universality class as the ordinary 2d critical percolation.

### Solving delayed SIRS meanfield model on homogeneous networks

M. Saeedghalati*, M. Ejtehadi

*Sharif University of Technology, Tehran, Iran*

In this work we simulate SIRS(Susceptible-Infected-Recovered-Susceptible) model on homogeneous networks by means of simulation, then we drove meanfield equations for this model and compared the solution of these equations to the simulations results on the network. To obtain a new model closer to the reality, we modified the SIRS model and introduce history to the convenient model. After simulation of this model we redrive the equations with history and found that this model can show bifurcation so we found the phase diagram for this model. And in the last part we introduced history to a meanfield model with pair approximation and drove the equations and try to solve them numerically.

### Prediction of the biogeochemical cycles of even-aged forest ecosystems by a model coupling growth and yield, process-based and biogeochemical approaches

J. Sainte-Marie*, A. Henrot, L. Saint-André, M. Barrandon, L. Nivet, Y. Nouvellon, O. Roupsard

*INRA Champenoux and Institut Elie Cartan, Nancy, France*

Essentially, forest ecosystems are complex systems. Their study holds several distinct scientific fields leading to varied conceptual approaches. However, environmental issues and sustainable development policies are pushing managers to understand the functioning of these ecosystems in all their components and to overcome any conceptual boundary. Thus, it is necessary to identify and quantify the interactions between many processes by combining modeling and statistical analysis. The objective of our work is to propose a dynamic model of forest growth and biomass production suitable to varied ecosystems (different species and soil and climate growth conditions) and forest managements. This model combines different approaches (growth and yield, process-based and biogeochemical cycles) to take into account carbon, water and nutrient cycles and to include several processes such as wood production, transpiration, litterfall, litter decomposition or losses of nutrients by drainage. Such a model integrates different concepts. The most important motivation is to propose a mutual

enrichment instead of a simple juxtaposition of different equations. Such a model is necessary to anticipate and adapt forest management under different environmental scenarios (global changes). The study of such complex soil/plant interactions pushes the modeler to integrate, and even construct, varied mathematical analysis tools such as: design and analyse dynamic systems, model calibration, analyse and minimize the propagation of the associated error, data reconstruction and implementation of numerical methods. Then, the combination with other scientific fields becomes possible in this mathematical framework, because even complex, the conception of such model rely on rigorous and synthetic methods of analysis and investigation of the forest ecosystem functioning. This approach can also be used to highlight unexpected behavior between different scales of processes and can provide a hierarchical analyses of the main processes at a given scale.

### Pruning a Minimum Spanning Tree

L. Sandoval*

*Insper, Instituto de Ensino e Pesquisa, Brazil*

Minimum spanning trees are networks of nodes that are all connected by at least one edge so that the sum of the edges is minimum, and which present no loops. This kind of tree is particularly useful for representing complex networks, filtering the information about the correlations between all nodes and presenting it in a planar graph. Because of this simplicity, minimum spanning trees have been widely used to represent some important financial structures, namely the structure of stock exchanges, of currency exchange rates, and of world trade. Like any other representation of real world interactions, it is subject to a great amount of random noise, which is sometimes difficult to isolate. This work employs some techniques in order to filter random noise from the information provided by a minimum spanning tree. The networks that are represented are the correlations between international stock exchange indices prior to and during years of well known international financial crises, namely the 1987 Black Monday, the 1997 Asian Financial Crisis, the 1998 Russian Crisis, the crisis after September, 11, 2001, and the Subprime Mortgage crisis of 2008. The reason for choosing international stock exchange indices is because one has some idea of which indices should be more correlated based on information that come from other sources that are not the correlation matrix, and also because one can then follow the interactions of stock markets at different periods of time and in different volatility regimes. One of the techniques is to establish a threshold above which connections are considered affect by noise based on the study of random networks with the same probability density distribution of the original data, what is obtained by shuffling the original data so that correlations between the various nodes is basically random. This eliminates both random connections and true ones, what can be shown by using arguments of geographical, cultural, and financial links between the stock exchanges. This effect is particularly strong for emerging financial markets. The second technique is to judge the strength of a connection by its survival rate, which is the amount of time a connection between two stock market indices endure. The idea is that true connections will survive for longer periods of time, and that random connections will not. That information is then combined with the information coming from the first technique in order to create a smaller network, where most of the connections are either strong or enduring in time. The resulting network is a k-minimum spannig tree, with some nodes and edges attached to it, and the result is then studied using the tools of network analysis. That study brings out important information, like the formation of an American and of an European cluster, both strongly connected in themselves but weakly connected with one another. The study also brings out the importance of the Netherlands in the 80's and 90's, and the emergence of France as the main hub for the European cluster. The study also shows how a Pacific Asian cluster was formed during the last two decades, and of how smaller, weakly interacting clusters, like the one formed by the members of the former Yugoslavia, or the one of Arab indices, have formed in the last decade.

### Statistics of collective human behaviors for extraordinary events in blogosphere

Y. Sano*, K. Yamada, H. Watanabe, H. Takayasu, M. Takayasu

*Nihon University, Japan*

We describe collective human behaviors quantitatively using statistics of word appearances of more than 5,000 million entries in Japanese blogs space (blogosphere). In particular, we focus on three different kinds of words that have specific peaks in appearances; event names such as "Christmas", names of the day such as "9th May", and news words such as "Tsunami". We find that time series of these word appearances before (after) peak can be well described by power laws. Furthermore, independent of words, power exponent of is 0.9 for

before peak and 1.3 for after peak in most of cases.

### Emergence of costly ostracism

T. Sasaki*, S. Uchida

*International Institute for Applied Systems Analysis, Laxenburg, Austria*

How can costly punishment evolve when rare? It is often too costly for a rare punisher to invade into a population of defectors who must be punished. Even in a mixture equilibrium of cooperators and defectors, the presence of defectors will result in a lower payoff for punishers than for cooperators who do not punish (a "second-order"social dilemma). Therefore, costly punishment has seemed to be unlikely to emerge in a state where cooperators and defectors co-exist. Here we show that this is not the case for ostracism. We assume a punisher who is willing to contribute to a joint enterprise and also exclude defectors from there. We consider the one-shot public good game with reputation, in which punishers can notice in advance who is the target. Excluding defectors is costly, and however, may increase the per-head benefit, because the number of beneficiaries of the public good decreases without any change of contributions to the public good. We reveal that such costly ostracism can invade into a mixture equilibrium with cooperators and defectors. Moreover, if participation in the game is optional rather compulsory, the population can subsequently converge to an interior fixed point or to an interior limit cycle.

### Synchronization of bursting oscillators by a common noise source

G. V. Savino*, C. M. Formigli, J. I. Deza, R. R. Deza

*Universidad Nacional de Tucumán, Argentina*

Neuron synchronization is nowadays an active research issue, for its fundamental role in many complex brain functions (memory, control, thought, etc.) Even apparently simple questions are still mysterious: it is not yet understood why (and how) do neurons use either single spikes or bursts to transmit, encode and process information. Since a single neuron typically receives random inputs from other 10**4, the neurocomputational paradigm finally arising will necessarily have noise as a central ingredient. Previous theoretical studies have shown that - against common sense - noise may improve neuron synchronization. To the best of our knowledge, such paradoxical noise effect has still not been reported in any of the very few actual physical devices that emu-late the spiking and bursting neuron electrical activity. In particular, our analog electronic circuit [1,2] is based on the same operating principles (conductance change) as neurons - analogues for potentials, currents and conductances can be easily identified —and exhibits the same bifurcation scenarios as the Hodgkin–Huxley model. Through a single parameter (a conductance) our circuit can be set into different self-oscillating regimes: single spikes at chaotic interspike intervals, and two- and three-spike bursts interspersed with single spikes. The phase portrait shows a stable limit cycle and a saddle point, originating the stable and unstable manifolds necessary to get noise-induced phase synchronization according with previous theoretical models. Here we present experimental evidences of the noise-induced phase synchronization and frequency matching of two nonidentical and weakly-coupled analog models of the biological neuron. These are naturally nonidentical due to their components value dispersion, and unavoidably coupled—even if not deliberately done—when using a common noise source. By applying to two such circuits a common noise of increasing intensity, their initially very different instantaneous frequencies increase and match, and the systems self-oscillation becomes periodic. We show that this effect is noise-mediated rather than due to the (very) weak coupling. The histograms, frequency spectra, correlation and recurrence plots show the measured activation and excursion times as the frequencies of both oscillators become equal for a definite noise intensity. Moreover, the plots for different noise intensities of the spike-sequence phase differences between the two circuits as time goes on show plateaux with different duration, indicating phase synchronization induced by the common noise. Complete synchronization has never been observed.

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### An Emerging Big Picture of Classical Archaeology as a Complex System

M. Schich*, M. Coscia

*Northeastern University, Boston, USA*

In this poster we present a big picture of Classical Archaeology, depicting a complex ecosystem of 45.000 subject themes and 86.000 authors. Using data from "Archäologische Bibliographie" [1], a database that

records and classifies relevant scholarly literature since 1956, we construct networks of subject co-classification and author co-interest, further analyzing their complex interplay and evolution over 50 years. Using complex systems science methods, such as HLC community finding [2], Vespignani graph filtering [3], and association rule mining [4] –a pipeline introduced in a previous proof of concept [5] –we show that it is indeed possible to navigate the complex system in question from the granular to a global perspective over a number of levels, revealing a clear and significant difference of the factual emerging structure to a priori definitions of Classical Archaeology, as they become evident in the now half a century old 'tree of subject headings' in "Archäologische Bibliographie", or the typical shelf configuration of an archaeological library. The example visualization that acts as the centerpiece of our poster, first takes the observer from the level of single subject themes (a), over ego-networks of co-classified subjects, enriched by a rule-mined link-significance (b), all the way up to a network of subject theme communities that emerge from HLC community finding (c). Finally we make clear, that to go even further up, it is not sufficient to threshold the community finding on a more coarse grained level, but that it makes sense to recursively run the community finding again on the network of subject theme communities (d), in order to arrive from the actors (a), over cities (b), and overlapping countries (c), at the conceptual continents (d) of the academic discipline. Similar visualizations, and browsable sets that can be explored by the respective scholars, are produceable for any given library classification such as taken from arXiv, OCLC, Europeana, and maybe in not too far a future even from Google Books. As such, the poster exemplifies the usefulness of complex systems approaches, enabling a wider audience to explore and understand the complexity they are exposed to every day.

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### Computing for Molecular Medicine

W. Schreiner*, M. Cibena, P. Anner, F. Lenz

*Medical University of Vienna, Austria*

Molecular medicine becomes increasingly important for state-of-the-art interventions in a university hospital. Almost each step of work, from bench to bedside, is supported by specific computational tools, either from bioinformatics, biomedical simulation or medical information and retrieval systems. However, full efficacy of patient treatment and research endeavours calls for a seamless interaction between numerous software applications, data formats and means of information retrieval. While specific software for each single purpose is usually delivered by the respective manufacturer of wet lab technology, integration of these heterogeneous tools often remains with the individual researcher and is not supported by appropriate infrastructure. At the section for biomedical computer simulation and bioinformatics at the CMSIS we support integration of -omics data with clinical registries within the project AMIM Bio. Additionally we perform projects in computational biology on a research basis. Thus, a comprehensive system biology approach is enriched by simulation of molecular interactions, either between ligands and bio molecules (docking) or between macromolecules (molecular dynamics). These techniques allow to scrutinise binding mechanisms and signal transduction on a molecular dynamics basis. Another aspect of a refined phenotype description is achieved by mathematical modelling of pharmacokinetics. All in all, computing for molecular medicine provides a framework of cutting edge technology to foster biomedical research devised to improve and optimise patient treatment.

### System Description Framework for the Study of Living Complexity

M. Segerståhl*

*Aalto University, Finland*

Complexity is present everywhere in biology, from the gene regulatory networks of single cells to the evolution patterns of different kinds of organisms. But it has been difficult to find an approach that could actually

capture this particular aspect of natural life. Here, I present a conceptual method for studying living complexity. Cells, the basic constituent units of biological organization, are the starting point of the method. They only need to be considered as information containing structures (compartment + genome). An interesting picture emerges when these cells are assigned the ability to alternate between two mutually exclusive developmental states. In one state they will be metabolically active and reproductive, in the other state they are completely passive—living is "on hold". By considering how this system behaves in different energy environments, (stochastic, stable, periodic), it was possible to identify a self-organizing selection pressure that can drive complexity increase in this biphasic system structure. The obtained information was reflected back to real organisms, and additional rules and constraints were identified that can control the evolution of this system structure. It appears that all kinds of biological organisms can be understood and examined as complexity variants of this initially simple description of biological living cells. Major events of evolution, such as eukaryotic sexual reproduction and evolution of multicellularity can also be addressed using this simple thought model. The proposed description framework can be presented with rather general system terms. All this helps in structuring the overall problem of living complexity and makes it more accessible for multidisciplinary scientific enquiry. Other kinds of complex systems may also be examined in the light of the basic principles that this work reveals.

**Detailed studies of agent dynamics in models of econophysics:comparison with biased random walks**

P. Sen*

*University of Calcutta, India*

We study the agent dynamics at a microscopic level for kinetic models of wealth exchanges with or without saving propensity. When the saving propensity is either zero or uniform, i.e., same for all agents, the equilibrium distribution of gains and losses is found to be symmetric. However, for the CCM model (A. Chatterjee, B. K. Chakrabarti and S. S. Manna (2004), Physica A335, 155) in which $\lambda$ is considered to be a quenched random variable, this distribution for a given agent depends on his/her saving propensity $\lambda$ and is in general skewed. Defining a walk in the abstract gain-loss space as one in which the agent walks a step on the left (right) following a loss (gain), for the uniform $\lambda$ case, the walks are like random walks with the square of the displacement $x^2$ scaling linearly with time $t$ . However, for the CCM model, after an initial diffusive behaviour, the walks show ballistic diffusion, i.e., $x \propto t$ . Interestingly, the slope of this linear variation is positive for small $\lambda$ and negative for large $\lambda$ and becomes zero for $\lambda^{*\simeq 0.469}$ . We investigate the dynamics further and get the intriguing result that in general, an agent gains while interacting with an agent with a larger saving propensity. Since the walk in the abstract gain-loss space shows ballistic nature for all values of $\lambda \neq \lambda^*$ , we next compare its properties to a biased random walker. We estimate the so called bias of the walk using different measures and check whether they turn out to be identical for a given value of $\lambda$ . In particular, we investigate the properties related to the distributions of lengths walked without change of direction. It is found that some macroscopic behaviour may correspond to a biased random walk for large values of $\lambda$ , however, major differences appear when microscopic properties are considered for all $\lambda$ .

**Osmoregulation in fresh water - a model for the contractile vacuole**

P. Sens*, M. S. Turner

*CNRS, France*

Fresh water dwelling unicellular organisms must maintain and tolerate a very high osmotic pressure difference (of order one atmosphere) between their interior and the environment. Organisms such as amoebae and other protists do not possess a strong cell wall able to mechanically balance this pressure difference. They must somehow expel the continuous influx of water entering by osmosis which would otherwise lead to a dramatic increase of the cell volume and, ultimately, to the cell bursting. This is done by way of the Contractile Vacuole (CV), a membrane-bound organelle in which phases of water influx from the cell interior (diastole), periodically alternate with phases of contraction and water expulsion out of the cell (systole). Despite extensive research, evidence for the existence of an active (energy consuming) machinery involved in CV contraction has proved elusive. Here, we present a model of the CV as a self-organized dynamical system, where the only active mechanism is the pumping of ions and other solutes from the cell interior into the vacuole by membrane transport proteins (a well established experimental fact). Water expulsion is shown to naturally follow by passive osmosis into the CV. We argue that the periodic filling and contraction, which results from

the unstable nature of the system's dynamical fixed point, is not required for osmoregulation, but strongly improves the efficiency of water expulsion.

### Self-adaptability in glass-forming network systems: from mean-field rigidity theory to real experimental observations

O. Shpotyuk*, R. Golovchak

*Lviv Scientific Research Institute of Materials of SRC "Carat", Ukraine*

The real self-organizing systems are known to consist of a huge number of components, which makes nearly impossible to build them artificially with conventional mathematical or computational techniques. So understanding processes leading to self-adaptation is an actual task. In this view, the network glasses offer a unique possibility. They allow covalent-bonded disordered networks of different connectivity defined by mean coordination number (average number of covalent bonds per atom). According to mean-field rigidity percolation theory [1,2], such networks are characterized by three distinct topological phases in dependence on their composition –floppy, intermediate and rigid. The networks having less or more constrains than space dimensionality are under-constrained (floppy) or over-constrained (rigid and stressed), respectively, while those with number of constrains just equal to space dimensionality are considered as optimally-constrained (rigid but unstressed). Topological self-organization occurs if network keeps its optimal arrangement as long as possible (changing in glass composition) to avoid stress due to over-constrained fragmentation. As a result, the solitary percolation transition from floppy to stressed-rigid network [1,2] splits into two points revealing self-adaptive phase filled with optimally-constrained structural configurations. We have developed an experimental approach based on differential scanning calorimetric measurements in a real-time chronology as an experimental testing tool to determine compositional boundaries of self-adaptive topological phases in covalent-bonded glass-forming network systems.

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### Model of emotional dialogues based on entropy growth

J. Sienkiewicz*, M. Skowron, G. Paltoglou, J. Hołyst

*Warsaw University of Technology, Poland*

We process emotionally annotated (negative, neutral, positive) data from Internet Relay Chat (IRC) extracting 90.000 one-to-one dialogues between users. Statistical analysis shows that, regardless of the length of the dialogue measured in the number of comments, each dialogue ends when the probabilities of finding positive and neutral emotional value equalize. Moreover, the entropy of the emotional probabilities distribution increases with the dialogue evolution. Additionally we observe clustering of comments with the same emotional value. Basing on entropy growth and emotional clustering, we construct a model of dialogues that reproduces the characteristics of the real data and we show how it can be useful for an automatic moderator in this medium.

### Epidemic centrality - identifying "superspreaders" in complex networks

M. Sikic*, A. Lancic, N. Antulov-Fantulin, H. Stefancic

*University of Zagreb, Croatia*

In the study of disease spreading on empirical complex networks in SIR model, initially infected nodes can be ranked according to some measure of their epidemic impact. The highest ranked nodes, also referred to as "superspreaders" are associated to dominant epidemic risks and therefore deserve special attention. In simulations on studied empirical complex networks it is shown that the ranking depends on the dynamical regime of the disease spreading. A possible mechanism leading to this dynamical dependence is illustrated in an analytically tractable example. In systems where the allocation of resources to counter disease spreading to individual nodes is based on their ranking, the dynamical regime of disease spreading is frequently not known before the outbreak of the disease. Therefore we introduce a quantity called epidemic centrality as an average over all regimes of disease spreading as a basis of the ranking. A recently introduced concept of phase diagram of epidemic spreading is used as a framework in which several types of averaging are studied. The epidemic

centrality is compared to structural properties of nodes such as node degree, k-cores and betweenness. There is a growing trend of epidemic centrality with degree and k-cores values, but the variation of epidemic centrality is much smaller than the variation of degree or k-cores value. It is found that the epidemic centrality of the structurally peripheral nodes is of the same order of magnitude as the epidemic centrality of the structurally central nodes. The implications of these findings for the distributions of resources to counter disease spreading are discussed.

### A network approach for the determination of the critical exponents for high aspect ratio composites

J. Silva*, R. Simões, S. Lanceros-Mendez

*University of Minho, Braga, Portugal*

One of the main problems in composites formed by dispersing random particles in a polymeric matrix is the determination of the percolation threshold or the critical volume fraction at which an infinite cluster appears. The inclusion of high-aspect-ratio fillers like carbon nanotubes (CNT) or vapour-grown carbon nanofibers (VGCNF) in a polymeric matrix enhances the electrical and mechanical properties [1] of the matrix. It is demonstrated that filler concentration, aspect ratio (AR), and dispersion, affect the material response [1]. Both for CNT/polymer and VGCNF/polymer composites, a divergence in the composite conductivity is expected for a critical volume fraction. In a recent review [2], the experimental percolation thresholds for CNT composites revealed the existence of a wide range of values for the same type of CNT/polymer composites, a deviation from the bounds predicted by the excluded- volume theory and a dispersion for the values of the conduction critical exponent (t) [3]. The latter exponent is expected to be independent of filler geometry or matrix, taking a value that just depends on the system dimension. In a recent work [4], it was demonstrated that the theoretical framework of complex networks typically used to study systems such as social networks or the World Wide Web can be also applied to material science, allowing deeper understanding of fundamental physical relationships. In particular, through the application of the network theory to carbon nanotubes or vapour-grown carbon nanofiber composites, by mapping fillers to vertices and edges to the gap between fillers, the percolation threshold has been predicted and a formula that relates the composite conductance to the network disorder has been obtained. The theoretical arguments were validated by experimental results from the literature. In this work, the critical exponents $\beta, \gamma, \tau, \nu$ and the fractal dimension of a system composed of hard-core cylinders dispersed in a 3D domain are studied using the complex network theory framework. A finite-size scaling analysis of the percolation threshold is also presented.

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### Detecting and characterizing emergent scientific trends

J. A. Silva*, J. Louçã

*Lisbon University Institute, Portugal*

Nowadays, the easy access to significant amounts of digital data allow uncovering the process of emerging ideas and research domains in the scientific corpus. Using the facilities provided by the arXiv database (http://arxiv.org/) we analysed a dataset composed by more than 650.000 metadata records regarding articles written since 1991, in the main domains of computer sciences, mathematics, nonlinear sciences, physics, quantitative biology, quantitative finance and statistics. Aiming to identify and characterize new scientific trends, we propose an original real-time framework composed by a network-type representation of domain related articles, and an algorithm to detect novelties based on semantic topic detection. The framework comprises the combined behaviour of a self-organizing network with an algorithm co-responsible for driving network nodes in a semantic space. Nodes represent sets of related abstracts, i.e., potential scientific topics. Instead of just deleting ancient nodes that might no longer represent novelties, we observe and characterize nodes evolution through the semantic space. This approach has two main benefits: firstly, we observe that ancient nodes representing old active topics tend to catch newer related abstracts; secondly, novelties tend to behave independently and navigate through different regions of the semantic space, which facilitates their identification. The main theoretical and methodological foundations of this work concern Kohonen's Self-Organizing Maps (2001), inspiring the structure of the main algorithm; Starzyk's Hierarchical Self-Organizing

Learning (2007) and Johnson's Hyper-Networks (2006), supporting the hierarchical conception of semantic topics; and Mei's semantic annotations for frequent patterns (2006), which has been taken into account when describing and characterizing node semantics. Our presentation will start by mentioning the most interesting and the most recent proposals for characterizing scientific trends, will detail our proposal including a self-organized network of articles and an algorithm to detect novelties in a semantic space; and finally will demonstrate its application to the arXiv metadata, through the example of the recent research on graphene, which leaded to the Nobel Prize for Physics in 2010.

### The bistable system: an archetypal model for complex systems

B. Spagnolo*, P. Caldara, A. L. Cognata, D. Valenti, A. Fiasconaro

*Università di Palermo, Italy*

We investigate the nonlinear relaxation in a bistable system in classical and quantum systems. Specifically: (i) as a first classical system, the role of the multiplicative and additive noise in the mean life time of the metastable state of an asymmetric bistable system is investigated. This model is useful to describe the dynamical behavior of an out of equilibrium Ising spin system. Nonmonotonic behavior of the average lifetime as a function of both additive and multiplicative noise source intensities is found. (ii) The dynamics of two competing species in the presence of Lévy noise sources is analyzed in the second classical system. The interaction parameter between the species is a random process which obeys a stochastic differential equation with a generalized bistable potential in the presence both of a periodic driving term and an additive alpha stable Lévy noise. The role of the two non-Gaussian noise sources in the exclusion and coexistence regimes is analyzed. Quasiperiodic oscillations and stochastic resonance phenomenon in the dynamics of the competing species are found. (iii) Finally the dynamics of a quantum particle subject to an asymmetric bistable potential and interacting with a thermal reservoir is investigated. We obtain the time evolution of the population distributions in both energy and position eigenstates of the particle, for different values of the coupling strength with the thermal bath. The calculation is carried out by using the Feynman-Vernon functional under the discrete variable representation.

### Modeling optimal dynamics and architecture design in the medical malpractice system

C. Stan*, L. Picioruş, C. I. Imbrişcă, R. R. Purnichescu

*The National Institute of Legal Medicine Mina Minovici and Titu Maiorescu University, Romania*

Over the years, societies have been confronted with an intricate dilemma: parsing reality and designing efficient medical malpractice systems. Besides, the individual interconnected parts of the system generate a unique complex structure subordinated to more than one multi-agent model (MAS). Under these assumptions, we applied optimization techniques from a dual perspective. Firstly, we performed a screening of the medical malpractice system in use to determinate the parameters of the equilibrium point, and to identify the process dynamics parameters which contribute to an optimal incentive scheme. Secondly, a similar examination was carried out for an equilibrium situation of a perfect system. The results indicated the architectural structural units of the systems and allowed us to determine the underlying characteristics. The case study reveals the architectural structure of an improved version of the current medical malpractice system, based on the particularities of the functional units we discovered. Therefore, we mapped the causal relations between agents (medical personnel, public health services consumers, managers, institutions, and other stakeholders), the feedback and coordination mechanisms, evaluating the dynamics and the process functionality validation conditions. The final objective of this study is to refine the archetypal medical malpractice system, through derivations in order for it to meet the compulsory requirements (acknowledgment of professional responsibility and ethics) imposed by international standards, correct the past errors and quantify also the impact of the cultural component when designing the medical systems.

### ON DYNAMICS OF ONE THREE-DIMENSIONAL MODEL OF CANCER

K. Starkov*, A. P. Krishchenko

*CITEDI-IPN, Mexico*

In this work we examine dynamical properties of one system arisen in the tumour growth modeling, [1]: $dx/dt = x(1-x) - axy - bxz$,

$dy/dt = ry(1-y) - cxy$,
$dz/dt = ((lxz)/(x+k)) - exz - fz$,
where by x(t) (y(t);z(t) correspondingly) we denote the number of tumour cells (healthy host cells; effector immune cells ) at the moment t in the single tumor-site compartment; all parameters are positive, [1]. In [1] it was established that all trajectories in the positive orthant are positively Lagrange stable; the existence of the Shilnikov-like connections and the chaotic attractor for some set of parameters. Here by using the concept of a localization of compact invariant sets and applying the extremal approach, [2], we prove that the positively invariant polytope P=([0,1]ˆ2)× [0,$z_{max}$ ] in the positive orthant exists and find the explicit upper bound for $z_{max}$ ; study the case when the lower bound $z_{min} > 0$ exists and compute it; show how to refine the localization polytope P by using a few localizing functions in order to get closer to the attractor. In addition, we continue study of stability/instability properties initiated in [1], derive a number of sufficient conditions on parameters of (1) under which there are no compact invariant sets in the interior of the positive orthant. Next, we apply additive positive parameters to the vector field of our system in order to model immunotherapy treatment terms, see [3], and we study dynamical properties of the system obtained. Finally, we give biological interpretation of our results.

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### Modeling entrepreneurship and the dotcom bubble by a multi-agent system

R. Stijl*, S. Kraus, C. H. Reschke

*Universiteit Utrecht, The Netherlands*

Complexity science is a relatively recent addition to the entrepreneurial field of research in which knowledge from multiple disciplines fields is combined. The behavior of complex systems is similar to the constantly changing realm entrepreneurs live and flourish in. The complexity sciences thus may offer a glimpse at what causes entrepreneurial success. In this paper we use a novel multi-agent based model, Artificial Model of Innovation (AMI), to describe, the entrepreneurial environment at both a low level (e.g. entepreneurs) and, using emergent properties, high level (e.g. markets). Weve devised AMI as a means to visualize complexity and understand under which conditions companies can flourish in it. We have based the model on the multi-agent based models which are found in biology (E. Merelli et al. 2007), economics (M. Bartolozzi 2010), neuroscience (M. Schlesinger 2001) physics (F. Ghoulmie et al. 2003) and only very recently and sparsely in entrepreneurship (B. McKelvey 2004). The model was programmed in Matlab. For visualization purposes we have reduced the environment to a 2D field with finite dimensions. We give a practical example of the models application; the dotcom bubble. We ran the model 1000 time using the values representing the dotcom situation. 25% of the simulation was considered a crisis. Every simulation ran until equilibrium was reached. At equilibrium, on average, only 23.8 agents survived. This is surprisingly similar to a 95% death rate reported in literature (R.J. Hendershott 2004). A Gaussian distribution for the function relating speed and survival rate is found. Hence an "ideal"company would have a speed at the center of this peak. However, even for these ideal companies the fatality rate is non-zero. Agent based modeling is an effective way to explain properties of complex markets. It visualizes the different aspects that companies have to deal with in an orderly manner. Competition, newcomer fatality (Umesh 2005) and the inhomogeneity of the markets that are happening in reality is made visible. The effects of a crisis are clear. Companies that innovate either too little or too much fail.

### Complexity and Paradigmatic Trends in Higher Education

M. C. Suciu*, V. S. Caragea, L. Piciorus, C. Imbrisca, A. Radu

*Academy of Economic Studies Bucharest, Romania*

The paper examines the elements of the innovative alternative educational model, trying to identify both its limitations and advantages, with a view to its possible adoption by the Romanian education system of all or some of the elements included. The current model of higher education institutions are evaluated by comparison between them, the quality criteria are defined in terms of inputs and measures taken in the processes (number of students enrolled, income earned, extension courses, etc.), while the results of work performed, those pertaining to student learning, are almost ignored. An example is teacher evaluation systems, where performance is evaluated in terms of teaching and not in terms of learning. In the Learning Paradigm model, the strength of a learning environment or method is judged in terms of impact on learning: an environment where learning

occurs then has the force, whether students learn more in environment A than in environment B means that A is a strong environment. It is therefore constantly need to assess student learning, to always choose the most powerful environment. Feedback on learning outcomes is an important element in the Learning Paradigm model, referring both to teachers and institution. Learning outcomes include everything students performed as a product of the learning experience. From this perspective, any measurement of student products, obtained after a learning experience is one way of measuring learning outcomes, which are due to be taken more into account than any other input resource. Regarding the structures responsible for teaching and learning, in the instructional model, they are considered atomistic, the "atom" of the universe being the classroom, and the "molecules", the words "a teacher –a classroom - the number of credits allocated to classes". Starting from these basic units, all other structures are built: the architecture of physical space, administrative structure and daily work of students and teachers. In this way, the resulting structure is strong and rigid. One of the rules governing the education received through the Instruction Paradigm model is that time will remain constant while the learning varies. However, practice and learning theories confirmed that people learn at different paces and in different ways, different topics. Institutions which operate under the Instruction Paradigm organize their courses and professors in an atomist manner in departments and programs of study, which hardly communicate with each other. This is well captured by the famous sociologist of higher education, Burton Clark (2008), the phrase "small worlds, different worlds" referring to the academic communities. From Learning Paradigm perspective, however, the teaching-learning structures built by the instructional model presents huge barriers in improving student learning and their success, because it does not provides space and support for redesigned learning environments or experimenting with alternative learning technologies, do not provide measures, reward or justify the evaluation results, whether student learning has occurred or is aware that it improves.

### Predictability of communication patterns and its correlates to individuals' positions in social networks

T. Takaguchi*, M. Nakamura, N. Sato, K. Yano, N. Masuda

*University of Tokyo, Japan*

Recent developments of sensing technologies have enabled us to examine the nature of human social behavior in great details. By applying an information theoretic method to the spatiotemporal data of cell-phone locations, Song et al. (2010) found that human mobility patterns are remarkably predictable. Inspired by their work, we ask a similar predictability question in a different kind of human social activity: conversation events. The predictability in the sequence of one's conversation partners is defined as the degree to which one's next conversation partner can be predicted given the current partner; we quantify it by using the mutual information. We examine the predictability of conversation events for each individual using the longitudinal data of face-to-face interactions collected from company offices in Japan. Each subject wears the name tag equipped with an infrared sensor node, and conversation events are marked when signals are exchanged between close sensor nodes. We find that the conversation events are predictable to some extent. In addition, the degree of the individual's predictability is correlated with the position in the static social network derived from the data. Finally, we discuss our results in relation to the community structure of the social network.

### Formation of cooperative society in the iterated prisoners dilemma game with evolving genes

M. Tanaka-Yamawaki*, R. Itoi

*Tottori University, Japan*

We reconsider the IPD(Iterated Prisoner's Dilemma) in an agent-based model with evolving genes, similar to the one considered by K. Lindgren [1]. We have found a case in which the agents cooperate for a long time in the course of evolution without any external element of cooperation. During the term of cooperation, the agents steadily gains diversity in the population of the strategies, quantified by the entropy monotonically increasing. Moreover, the dominant strategies during this term show high level of friendliness, tolerance, and flexibility.

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### Spreading of gossip in weighted complex networks

M. Tasgin*, H. Bingol

*Bogazici University, Turkey*

In this work, we investigated gossip spreading in weighted networks. The proposed algorithm is based on the gossip spreading model introduced by Lind et.al. and is enhanced by the addition of a decision mechanism of spreading or stopping the gossip according to the weight between nodes in the network. This decision mechanism introduces new features in information spreading; strongly connected nodes are more vulnerable to be being gossiped when they have more than a certain number of connections but have influence on the behavior of other nodes. This property leads to a new metric; minimum number of connections to be considered as "important" in the networks. The algorithm is run on co-authorship network and Reuters news co-occurrence networks.

### Universal patterns in sound amplitudes of songs and music genres

A. A. Tateishi*, R. D. S. Mendes, H. V. Ribeiro, E. K. Lenzi, F. C. M. Freire

*State University of Maringa, Brazil*

We report a statistical analysis over more than eight thousand songs. Specifically, we investigate the probability distribution of the normalized sound amplitudes. Our findings seems to suggest a universal form of distribution which presents a good agreement with a one-parameter stretched Gaussian. We also argue that this parameter can give information on music complexity, and consequently it goes towards classifying songs as well as music genres. Additionally, we present statistical evidences that correlation aspects of the songs are directly related with the non-Gaussian nature of their sound amplitude distributions.

### Random Matrix Analysis of Human Brain fMRI data

J. Tyburczyk*

*Jagiellonian University, Krakow, Poland*

We apply random matrix techniques to analyse correlations in Human Brain fMRI data. We reconstruct correlations between different regions of brain. These regions are selected either by purely geometrical voxel position or by physiological a classification given by Brodmann's areas. We analyse spectral properties for covariance matrices and also for lagged correlation that is for signals measured at different moments of time (shifted by a given lag). We compare the results to some classical results from random matrix theory including Marcenko-Pastur eigenvalue density for Wishart matrices and some newer results for lagged correlation matrices for uncorrelated data. These result provide us with reference points - a sort of a null hypothesis. We also perform graph theoretical analysis of correlation matrices applying ideas of threshold graphs. Such graphs are constructed using the idea of metric space that is constructed from the correlation matrix for the set of vertices representing different voxels or Bordmann's areas. A threshold graph is a graph between vertices whose distance in this metric space is smaller than a given threshold.

### Survival counting processes in the Laplace transformation space

M. Uchinami*

*Meiji Pharmaceutical University, Japan*

A large class of stochastic processes are survival counting processes, in company with the times when survival processes break down. The survival counting processes are mostly used to model independent identically distributed (iid) occurrences. Technically, an ordinary survival counting process is a sequence of partial sums of iid positive random variables, and it may be considered as a sequence points in time when the lifetimes of some objects of the same type end. The survival counting process counts the number of occurrences of the same type event in the interval [0,t), so that such a survival counting process is a random piecewise continuous

function. A convenient analytical procedure to determine the properties of this kind of process was evolved in the Laplace transformation space. When $\psi(t)$ is the (probabilistic) waiting time distribution density for a single event occurrence, and $\psi_{n(t)}$ is the distribution density for the occurrence of the n-th event at time t, their probabilistic distribution densities for the case of iid events are linked via the integral equation of convolution form. By using the survival function S(t), defined by $S(t) = \int_t^\infty d\tau\psi(\tau)$, the distribution density $\chi_{n(t)}$ for the occurrence of n events up to time t is also formulated via the integral equation of convolution form. For some cases of exponential, Gamma distributions, and so on, based on the study about evolving their integral equations on the distribution densities $\psi_{n(t)}$ and $\chi_{n(t)}$ in the Laplace transformation space, we have investigated the properties of the survival counting processes systematically.

**A cellular automaton based network meta-model for simulation of city traffic including bicycles**

J. Vasic*, H. J. Ruskin

*Dublin City University, Ireland*

The 'greening' of cities as hubs of human activity is an important part of addressing environmental concerns of today's world. Vehicular traffic in particular, as one of the dominant contributors to green-house gas emissions, is being targeted for radical review. This includes, amongst other things, encouragement and facilitation of alternative transport mode use, through special awareness campaigns on the one hand and infrastructure provision on the other. The latter, inevitably, requires strong arguments on properties of alternative modality flows, their interactions and cost-effectiveness. Simulation can play an important part in the acquisition of such knowledge. In this paper, we present research focused on defining a novel simulation model for network traffic, to include cars and bicycles, associated with low carbon footprint. Core problems of heterogeneous traffic simulation are addressed and include representation of different vehicle sizes for the different modalities, their spatial occupancy and vehicle type-specific interactions at intersections. The general spatial modelling approach readily permits definition of arbitrary network components and their connections, using a one-dimensional cellular automaton system as the building block. As a result of building a network model in this way, a topology-independent set of rules for network navigation can be used to define vehicle behaviour, an example of which is presented. We also describe several examples of network elements and their corresponding model forms, together with their linked operation in a network as a whole. Finally, we present simulation results that demonstrate the use of the network model.

**Towards accessible terra-scale individual-based simulations of collective behaviour**

M. Vigelius*, B. Meyer, A. Lane

*FIT Centre for Research in Intelligent Systems, Melbourne, Australia*

Reaction-diffusion systems can be used to model a large variety of complex self-organized phenomena occurring in biological, chemical, and social systems. Such models are usually described on the macroscopic level with a Fokker-Planck equation. Examples from the literature where this approach has successfully been applied include cell migration, social insect foraging, quorum sensing in bacteria, and invasion processes. However, a macroscopic approach has two major shortcomings: Firstly, as a Fokker-Planck equation is essentially a mean-field description, it does not do full justice to the inherent probabilistic nature of the problem. This can be particularly problematic where systems with low densities are analysed. Secondly, modelling exclusively on the macro-level means that it is impossible to incorporate experimental observations on the individual level or hypotheses about the individual behaviour in a principled way. On the other hand, Langevin-type individual-based microscopic models can in principle address these issues. However, a statistically faithful implementation of complex Langevin models is challenging, and as yet no implementation exists that incorporates inhomogeneous drift fields and inhomogeneous diffusivity. Since such simulations are also computationally expensive, hardware limitations severely restrict their applicability to models of realistic size. Thus, to analyse individual-based Langevin models of systems that would normally be modelled on the aggregate level, the performance of the corresponding algorithms is inadequate and speed-ups of several orders of magnitude are required. Parallelization is a natural approach to attain the desired performance increase and graphics processors provide a cheap and accessible hardware platform for high performance implementations of massively parallel algorithms. We present a graphics-processor accelerated implementation of a parallel stochastic-simulation algorithm for Langevin models that exhibits performance gains of up to two orders of magnitudes even on widely-available standard workstation graphics cards. Furthermore, we provide a versatile web interface that allows the user to run computational experiments on our dedicated GPU cluster. We allow maximum flexibility through this

interface, enabling researchers to perform, e.g., parametric searches and sophisticated output processing. The combination of GPU speed-up and parallelization on a cluster can provide realistic performance gains of up to four orders of magnitude, making complex experiments possible. We demonstrate the applicability of our approach with biological case studies.

### Modeling of the language competition dynamics

E. Vlasova*, T. Progulova, B. Gadjiev

*International University for Nature, Society and Man, Russia*

We discuss the generalization of D. A. Abrams and S. H. Strogatz [1] model which allows to describe a competition of languages. We consider a system of two competing languages and introduce the master equation in the form of

$$\frac{dx}{dt} = yy_0x^a + (1-x-y)z_0x^a - xx_0y^a - xx_0(1-x-y)^a$$
$$\frac{dy}{dt} = xx_0y^a + (1-x-y)z_0y^a - yy_0x^a - yy_0(1-x-y)^a \quad (1)$$

where $x$ is a fraction of the population speaking $X$, $y$ is a fraction of the population speaking $Y$ and $z = 1-x-y$ is a fraction of the population speaking both languages. We suppose individuals to convert from the given state to another one according to the nonlinear preferential attachment principle [2]. We show that system (1) has four fixed points $(x*, y*, z*)$, and the stability of states depends on the value of the parameters $x_0, y_0, z_0$ and $a$. For example, if $a > 1$, taking into account that $(x, y, z) \in [0, 1]$, the fixed point $(x* = 1/3, y* = 1/3, z* = 1/3)$ is always unstable. At $a < 1$ the fixed point $(x* = 1/3, y* = 1/3, z* = 1/3)$ is stable whereas all the other fixed points are not stable. We present data on the small nations living in Russia. These data have been obtained from the various censuses. We present a solution of the model in equation (1) and determine the parameters of the model from the comparison with the results of the data analysis. We discuss a political and socio-economic meaning of the model parameters.

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### Dynamics and Evolution of Languages in the Indo-European and Austronesian Language Families

D. Volchenkov*

*University of Bielefeld, Germany*

The new developments in the Markov chain approach to the analysis of networks generated by the matrix of lexical distances is shown to allow for representing complex relationships between different languages in a language family geometrically, in terms of distances and angles. We have developed a fully automated method for construction of language taxonomy and tested it on a sample of fifty languages of the Indo-European language group. The method uncovers the origin, relationships, and migration chronology of Indo-European population. We have applied the method to a sample of fifty languages of the Austronesian language group and to dialects of the Malagasy language spoken in Madagascar to resolve the recalcitrant problem of colonization of the Pacific Islands and Madagascar. We thoroughly discuss the Anatolian and Kurgan hypotheses of the Indo-European origin, as well as the 'express train' model of the Polynesian origin.

### Tumbling Dice with Classical Music

D. Volchenkov*

*University of Bielefeld, Germany*

Studies of Markov chains aggregating pitches in musical pieces might provide a neat way to efficient algorithms for identifying musical features important for a listener. It is clear that the Internet based economy calls for robust recommendation engines for appreciating and predicting the musical taste of customers, since any improvement in the accuracy of predictions might have an immense economic value. In order to pursue this goal, we consider a simple model based on a system for using dice to compose music randomly (known as the "Musical Dice Game"/ "Musikalisches Wuerfelspiel" since 1757). In particular, we have studied the discrete time MIDI models of 804 pieces of classical music written by 29 composers encoded into the transition

matrices of Markov chains. Contrary to human languages, entropy dominates over redundancy, in the musical dice games based on the compositions of classical music. The maximum complexity is achieved on the blocks consisting of just a few notes (8 notes, for the musical dice games generated over Bach's compositions). Statistics of complexity measured by the past-future mutual information suggests that pieces in classical music might contain a few melodic lines translated over the diapason of pitches by chromatic transposition. First passage times to notes can be used to resolve tonality and feature a composer. The names of composers that are contiguous in the tonality preferences are often found together in musical concerts and on records performed by commercial musicians.

### Modularity and Informational Aspects of Classical Dance

D. Volchenkov*

*University of Bielefeld, Germany*

Classical dance is a highly technical art with its own specialized movement vocabulary that has been developed within more than three centuries. Excellence in dance, characterized by maximum perfection and expressiveness of movement at a minimum energetic input and visible effort, arises due to the exquisite coordination of all body movements, resulting from the advantageous cooperation of cognitive and sensorimotor control systems. To identify the spatio-temporal characteristics of dance figures, we collected 3D kinematic data using a VICON motion capture system with 12 infrared cameras, for ballet movements performed by 11 students aspiring to a career of professional dancers (aged 13-17 years, 9 girls) and 2 professional dancers (1 man, 1 woman). The relative dynamics of 42 retro-reflective markers fixed on defined positions of the dancers bodies was studied by the various methods of the multivariate signal analysis such as the biorthogonal decomposition, structural component analysis, Lagrangian coherent structures, etc. Spatio-temporal movement characteristics of a full-body kinematic model reveal a complex hierarchical structure of movements in classical dance. This structure is characterized by the strong ordering of the spatio-temporal configurations amassing the most of specific kinetic energy of motor actions and providing a natural ground for modularity and compact representation of human movements. The hierarchy of spatio-temporal configurations measured by the normalized entropy of human movements might explain how a single correction given verbally by an expert has the potential to change the quality of movement performance dramatically. Entropy quantifying the space-time complexity of the dancers' movements relates classical dance to the informational aspects of modern communication theory, together with other interactions between humans via speech, gesture and music. We have found that for all trials the magnitudes of entropy fluctuated in the range between 0.7 and 0.98, well fitting with the entropy range in usual human languages.

### The complex dynamics of institutional trajectories

M. Wäckerle*, B. Rengs, W. Radax

*University of Technology Vienna, Austria*

The paper emphasises a unified rule-based approach within the realm of evolutionary institutional economics, which is then discussed by means of an exemplary agent-based model of institutional change. We highlight commonalities in the generic characteristics of institutional economics in the work of Th. Veblen, F.A. Hayek and J.A. Schumpeter. Schumpeterian institutional change is not driven by economic regularities, but by economic singularities, i.e. creativity-driven change. This notion can be conceived as the rule to innovate or create, whereas the Veblenian and Hayekian approaches capture more the rule to imitate and adapt through cultural habituation. Those two major types of rules govern a co-evolutionary process of institutional change, they set up institutional trajectories. The proposed paper deals with heterogeneous agent-based computer simulations visualising the dynamics, the parametric space and the rhythm of such complex institutional trajectories, emerging on the grounds of local rules. The model consists of an agent-based simulation with endogenous network formation of institutional systems, consisting of two layers: a micro layer and an institutional layer. Hence emergence and exit of organized institutions/institutionalized organizations is modelled in an artificial political economy, based on trust interactions of individuals on a micro-level (Veblenian habits and Hayekian rules of conduct). This layer is then integrated within a second model logic, handling the power interactions among evolved institutions on a network layer (Schumpeterian entrepreneurship), i.e. the institutional environment. The primary object of investigation is the variety and diversity of emerging institutional patterns and trajectories due to co-evolving trust and power relations of heterogeneous learning agents. Simulation runs of this model lead to trajectories or cycles of institutional regimes. Preliminary results have shown

that we are able to identify three basic scenarios of institutional change. In the first scenario institutions are not highly demanded, because overall-societal trust converges very fast to collective cooperation. In the second scenario institutions are highly demanded, because societal trust is very low and agents are looking for protection (enforced cooperation) in front of defecting free-riders. The third scenario can be best described along long-run cycles of institutional regimes, where leading institutions establish powerful networks. In this paper, new data sets from simulation runs are presented and conclusions are driven for a generic approach to evolutionary economic institutionalism.

**Modelling the Evolution of Spatially Distributed Populations in a Uniformly Changing Environment - Sympatric Speciation**

W. Waga*, S. Cebrat

*University of Wroclaw, Poland*

It is very hard to imagine the emergence of a new species inside large populations of totally randomly mating individuals with independently assorted genes (sympatric speciation). In fact, in natural populations individuals are spatially distributed and at least the distances between them could account for an obstacle in random mating. Additionally, in natural genomes, the recombination rate between homologous chromosomes is restricted. Under such conditions whole series of genes tend to form clusters which are not independently assorted to the gametes. In computer models, some defects in these clusters of genes tend to complement rather than undergo the Darwinian purifying selection. The further restriction of recombination inside these clusters is observed. Since clusters complement each other, the random mating is not the winning strategy any more and speciation could be observed. If the environment changes in such a way that it does not require particular features of individuals for some time, even if those changes are uniform for the whole territory, it enhances the sympatric speciation.

**Neural mass models for epilepsy:**

Y. Wang*, M. Goodfellow, P. Taylor, G. Baier

*University of Manchester, UK*

Epilepsy is neurological disease that is characterized by reoccuring seizures. A seizure in this case is defined as "transient of signs and/or symptoms due to abnormal excessive or synchronous neuronal activity in the brain"[1]. Clinically, seizures correlate with many abnormal forms of EEG activity that depend strongly on the type of epilepsy. So far little is known about the underlying mechanisms of the transition between the "normal"state and the seizure state of the brain. We suggest to use neural mass models ([2], [3], [4]) to investigate spatio-temporal dynamics of the epileptic EEG activity. We demonstrate that a number of dynamics observed in the seizure and pre-seizure state can be reproduce with these models. Additionally, we explore different transition modes to the seizure state and especially highlight the importance of using spatially extended models and the consequences for the transitions to seizure. Finally we discuss the biological relevance of these results.

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**Antiferromagnetic Character of Stress in Workplaces**

J. Watanabe*, T. Akitomi, K. Ara, K. Yano

*Hitachi, Ltd., Central Research Laboratory, Japan*

We study the nature of workplace stress from the aspects of human-human interactions. We investigated the distribution of Center for Epidemiological Studies Depression Scale scores, a measure of the degree of stress,

in face-to-face communication networks. We found that the degree of stress people experience when around other highly stressed people tends to be low, and vice versa. A Monte Carlo simulation based on a mathematical model describing micro-level human-human interaction reproduced this observed phenomena and further revealed that the energy state of a face-to-face communication network correlates with the workplace stress macroscopically. Mental health problems seriously affect not only an individuals physical health and happiness through his/her lifetime, but also the effective functioning and economy of his/her community or country. The worldwide prevalence and seriousness of mental diseases have promoted interdisciplinary research, and many individual factors including gender, stressful life events, personality, brain activities, and gene functionality, have been pointed out. Recent studies have revealed, however, that social factors, such as neighborhood characteristics, affect stress levels. For example, Rosenquist et al. reported that the likelihood of a person becoming stressed is higher when next to other stressed people compared to that of a person who is not in contact with anyone who is stressed. Their noteworthy results suggest that this tendency noticeably appears in homophilic networks of people who know each other well, such as mutual friends or next-door neighbors, and diffuses stress. It is surprising that stress seems to be contagious like other pathogenic diseases, especially in such networks. However, for face-to-face communication networks in the workplace, any such characteristics of stress have not been revealed in spite of the fact that work-related stress has been an important concern worldwide. In this study, we used a large amount of data gathered using wearable sociometric sensors reflecting micro-level activities of interactions between individuals and the framework of statistical physics for modeling human-human interaction. We show that, contrary to the contagious character of stress in homophilic networks, the degree of stress people experience when around other highly stressed people tends to be low in the workplace, and vice versa. A Monte Carlo simulation based on a mathematical model describing this nature of human relations reproduces the observed tendency. Furthermore, we show that the energy state of face-to-face communication networks, which is determined by the way in which nodes (people) are connected, correlates with the degree of stress in the workplace. This indicates that complex human behavior can be described using the framework of well established statistical physics.

### Grand canonical Minority Game as a sign predictor

K. Wawrzyniak*, W. Wiślicki

*University of Warsaw, Poland*

We present a comprehensive study of an extended model of Minority Game (MG), incorporating variable number of agents and therefore called Grand Canonical. It is used for prediction of both the autoregressive stochastic process and the real time series. We study how to optimize parameters of the predictor and offer some extensions improving its efficiency. We prove that the best MG-based predictor is defined by an extremly degenerated game, when only one agent is involved. The prediction is most efficient if the agent is equipped with all strategies form the Full Strategy Space. Such degenerated game corresponds to the bank of simple filters, where each recognizes a different pattern. Each of these filters is evaluated and, in every step, the best one is chosen. Despite the casual simplicity of the method we find it invaluable in many cases, including real problems. Then, we introduce a modification, the so called lambda-GCMG, well suited for quasi-stationary signals. The significant power of the method lies in its ability of fast adaptation if lambda-GCMG modification is used. The success rate of prediction is sensitive to the properly set memory length. In all experiments, where the autoregressive process was involved, we compare the MG results to those achieved by the best theoretical predictor found for the analyzed process. It is seen, that under some conditions, the MG works only slightly worse than the optimal forecaster. This indicates high predictive potential of the MG-based models. Another examined issue is the feasibility of prediction for the Minority and Majority games. These two games are driven by different dynamics when self-generated time series are considered. Interestingly, both dynamics tend to be the same when a feedback effect is removed and an exogenous signal is applied. Finally, the properly tuned MG model was applied as a forecaster of assets prices on financial markets (Warsaw and London Stock Exchange). For some intraday data the achieved success rate of one-step prediction is around 70% what significantly exceeds the random case. However, we showed that it is still difficult to construct the profitable investing strategy. Such a strategy would require prediction for at least two steps ahead. Interestingly, the agents with shorter memory length do better than those characterized by longer $m$, what we also explained analytically.

### Generalized Associativity of a Complex Network Describing Conscious and Unconscious Processes

R. Wedemann*, L. A. V. De Carvalho, R. Donangelo

*Universidade do Estado do Rio de Janeiro, Brazil*

We have described the mental pathology known as neurosis, in terms of its relation to memory function and proposed neural network mechanisms, whereby neurotic behavior is described as a brain associative memory process. Modules corresponding to sensorial and symbolic memories interact, representing unconscious and conscious mental processes. Memory was first modeled by a Boltzmann machine (BM), represented by a complete graph. Since it is known that brain neural topology is selectively structured, we have further developed the memory model, including known microscopic mechanisms that control synaptic properties and self-organize the complex network to a hierarchical, clustered structure. The resulting power-law and q-exponential behavior for the node degree distribution of the network's topology suggest that memory dynamics and associativity may not be well described by Boltzmann-Gibbs (BG) statistical mechanics. We thus model memory access dynamics by a generalization of the BM called Generalized Simulated Annealing (GSA), derived from the nonextensive formalism. Our main contribution with respect to current work regarding machine models of consciousness is to propose a neuronal associative memory mechanism that describes conscious and unconscious memory activity involved in neurosis. The unconscious compulsion to repeat is explained as an associative memory mechanism, where an input stimulus of any kind associates with a pattern in sensorial memory, which cannot activate symbolic brain processing areas. Neurotic (unconscious) acts are isolated from symbolic representation and association (similar to reflexes). With our network model, we illustrate how Freud's ideas regarding the unconscious show that symbolic processing, language and meaning are essential for consciousness. We illustrate the neurocomputational substrate model with simulations, showing some properties of these complex networks' topological structures and behavior.

### Comparing Principles of Robustness in Biological and Socio-Technical Systems

J. Whitacre*, M. Ulieru

*University of New Brunswick, Canada*

Robustness is an important property for socio-technological artefacts operating in dynamic and uncertain environments. Although terminologies differ greatly, the mechanisms and principles known to support robustness are surprisingly similar to those observed in biological systems. In this article, we discuss recent developments in understanding biological robustness and we propose important and thus far overlooked principles that could further enhance the robustness of socio-technical systems. First, we briefly review basic control concepts, heuristics from engineering, and management principles from organization science. Comparing these with systems principles derived from the study of multi-cellular development, protein conformation dynamics, cell signalling, metabolic networks, and gene regulatory networks, we outline surprising similarities in the mechanisms and systems principles that support robustness in biological and socio-technical systems. However one clear point of distinction is found to arise in the presence/absence of degeneracy; a common facilitator of robustness in biology. Degeneracy is a relational property that describes the presence of structurally dissimilar components/modules/pathways that are each multifunctional and when compared are found to perform similar functions (i.e. are effectively interchangeable) under certain conditions yet perform distinct functions in many others. Here we describe different types of robustness that arise from degeneracy and we propose simple ways that systems of degenerate components can violate classic robustness-efficiency tradeoffs in engineering. We also propose how degeneracy can facilitate pervasive system flexibility through a type of distributed robustness known as networked buffering. Finally, we speculate on how degeneracy might be harnessed in organizations to better deal with crises and unanticipated challenges.

### A multi-agent system for the simulation of fishing fleet dynamics.

L. Wise*, J. P. Carvalho, S. Carvalho, A. Murta, J. Reis

*IPIMAR, Portugal*

Knowledge on the dynamics of fishing fleets is crucial for their appropriate management and for a sustainable exploitation of marine resources. Therefore, a model which is able to predict the behavior of a fishing fleet faced

with a given set of management rules can be a very valuable tool to test the efficiency of different management plans. This paper describes the dynamics of a fishing fleet in a multi-agent context that is able to incorporate a higher level of detail than traditional models of fishing fleets. Each skipper, or agent, is associated to a dynamic cognitive map based on qualitative information collected on-board fishing vessels. These dynamic cognitive maps represent the skippers decision-making process (when, where and what to fish). In every step of the simulation, agents have in mind their current situation, and observe some of the other agents behavior (choice of fishing area, time they start heading to port, etc). Using these observations, the agents re-evaluate their current situation and make decisions using fuzzy rules (e.g. to stay or not in the same fishing area, to head to port or to change fishing area in the next fishing trip). By simulating these processes for an adequate time interval, it is possible to evaluate the long-term benefits of a given management plan for a specific fishery.

### Stirring effect on the Belousov Zhabotinsky reaction

F. Wodlei*, M. R. Hristea

*Rudolf Steiner Schule Salzburg, Austria*

We have studied the effect of stirring on the oscillatory behaviour of the Belousov Zhabotinsky reaction. Recently we found that the lifetime of the periodic colour change in the Belousov Zhabotinsky reaction can be prolonged by a limited stirring phase (with a certain stirring rate) right after the first disappearance of the colour change. In our setup this stirring effect increased the initial lifetime up to 60-fold. As a first theoretical approach to explain this effect we propose a qualitative model which is based on the autocatalytic nature of the system completed by a term which incorporates the rotational flow induced by the stirring of the system.

### Modeling the Coevolutionary Dynamics of Knowledge Diffusion and Network Change

H. Xia*, Z. Xuan, Y. Du, S. Luo

*Dalian University of Technology, China*

Knowledge diffusion in social networks is today's hotspot of academic inquiry. However, in literature less attention has been paid on the coevolution of knowledge and network. In the present work a simple agent-based model is proposed to study such coevolutionary dynamics. In the proposed model, a set of agents, which are initially interconnected to form a random network, either exchange knowledge with their neighbors or "move" toward a new location through an edge-rewiring procedure. The activity of inter-agent knowledge exchange is determined by a Knowledge Transfer rule that two interacting agents make knowledge exchange only if their distance in knowledge is less than a given threshold. The activity of agent movement is determined by a Neighborhood Adjustment rule that one agent may move toward a remote location or reside in the local cluster, dependent on a given probability value. By simulating this model, a series of interesting phenomena are observed and discussed. The key findings include: 1) The threshold of the distance of knowledge affects not only the performance of knowledge diffusion but also the connectivity of the network structure; 2) the structural change of the social network facilitates the transfer of knowledge in the long run; 3) under some parameter conditions, the fully-random social network would self-organize into a small-world network by the edge-rewiring process; 4) the tendency for an agent to migrate to a remote location is a positive factor for both maintaining the network connectivity and facilitating knowledge diffusion. The overall results indicate that the activities of knowledge transfer and of neighborhood adjustment influence with one another and such mutual influence gives rise to the coevolution of the network structure and the diffusion of knowledge at the global level. The study presented in this work may shed light on the further research on the social process of knowledge diffusion in social networks from a more dynamic point of view.

### Power Law Distributions in Complex Polymers as an Electronic Description

G. Yalcin*, Y. Skarlatos, K. Akdeniz

*Istanbul University, Turkey*

Recently we have shown that q-Gaussian analysis in context of q-Statistics[1] may help obtain more information on the temperature dependence of the weak chaotic behavior of the electrical conductivity in PMMA thin films[2]. More recently, we have also considered power law distributions of PMMA thin films transient current

data when subjected to an electric field at various temperatures [3]. In this presentation we review the above results on chaotic properties of the electrical conductivity of PMMA thin films, and we show that the temperature dependence (295K, 303K and 313K) of power law distributions in PMMA may also relate to the electronic critically self organizations as an effective description.

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### Counting for Synchronizable Oscillator Networks by Monte Carlo simulations

T. Yanagita*, A. Mikhailov

*Hokkaido University, Japan*

Starting with an initial random network of identical oscillators with uncommon noise, its autonomous synchronization ability can be largely improved by appropriately rewiring the links between the elements. Ensembles of synchronization-optimized networks with different connectivities are generated and their thermodynamic properties are studied.

### Redundant Modelling of Multiscale Interactions with Multi-Agent Systems. Application to Pharmacokinetics / Pharmacodynamics of Vitamin K Antagonists

S. L. Yaouanq*, C. L. Gal, P. Redou, J. Abgrall, J. Tisseau

*European Center for Virtual Reality, France*

The study of complex systems consists in considering entities submitted to interactions which define the system's dynamics. Virtual reality opens the way to interactive simulation of complex systems, so called the in virtuo experimentation, especially useful in the domain of biochemical kinetics. An expert can be immersed in real time within a virtual laboratory, mock up the system he wants to study and experiment it, without any danger or consequences. The model can be built incrementally, by successive additions of phenomena. This is a phenomenological approach for modelling that enables to analyze interactions entanglements. For that purpose we use multi-interactions systems, based on the reification of interactions and multi-agent systems. A classical agent generally represents a little part of a system which acts locally with its neighborhood. Thus we can split the system's complexity and see an emerging global behavior. Despite its attractiveness this is a very costly method because of the need to simulate each component of the system. Multi-interactions systems supply a solution to this by allowing the expert to replace entity agents by interaction agents that now represent his understanding of the relations between the constituents of the system. Thus, we talk about descriptive models. The price is that we often have to define parameters in models, such as diffusion or reaction rates for instance. Moreover this parameters can be fluctuant, or even unknown, during a simulation in relation to the system's dynamics or user interventions. To respond to this problem, we will expose in this paper a redundant multiscale architecture which rests upon the fact that we can establish models of a same phenomenon at heterogeneous time and space scales. Parameters of a macroscopic model are in fact related to the system's dynamics at the microscopic scale. For instance, diffusion rate of a chemical concentration can be determined using brownian motion of molecules and statistical physics. Heterogenous Multiscale Method provides a general framework to mix levels of description of a system. It introduces compression and reconstruction operators to link scales states. We propose to implement these operators in multi-interaction systems by means of a Scale-Interaction agent. Then we illustrate our architecture through a pharmacokinetics / pharmacodynamics model of the vitamin K antagonists. Indeed biochemical kinetics abounds of phenomena whose parameters closely depend on the environment. Finally we discuss about some questions raised by this methodology, such as synchronicity, organization detection and genericity.

### Model gene regulatory networks under mutation-selection balance

M. Zagórski*

*Jagiellonian University, Krakow, Poland*

We propose a gene regulatory network (GRN) model which incorporates the microscopic interactions between

genes and transcription factors. In particular the gene's expression level is determined by deterministic synchronous dynamics with contribution from both excitatory and inhibitory interactions. We study the structure of networks that have a particular "function"and are subject to the natural selection pressure. The question of network robustness against point mutations is addressed, and we conclude that only a small part of connections defined as "essential"for cell's existence is fragile. Additionally, the obtained networks are sparse with narrow in-degree and broad out-degree, properties well known from experimental study of biological regulatory networks. Furthermore, during sampling procedure we observe that significantly different genotypes can emerge under mutation-selection balance. All the preceding features hold for the model parameters which lay in the experimentally relevant range. Finally, using formulated framework we analyse certain subgraphs of interactions or "motifs"that appear at anomalously high frequencies in GRNs having a prescribed function. We ask whether this phenomenon may emerge because of the functions carried out by these networks. In the case where the regulatory networks are constrained to exhibit multi-stability, we find a high frequency of gene pairs that are mutually inhibitory and self-activating. In contrast, networks constrained to have periodic gene expression patterns (mimicking for instance the cell cycle) have a high frequency of bifan-like motifs involving four genes with at least one activating and one inhibitory interaction.

### Positive plus negative feedback loops as an energetic efficient control in molecular systems

J. Zaldivar*, F. Strozzi

*European Commission, Joint Research Centre, Belgium*

Many biological oscillators consist of a positive plus a negative feedback loop even though a negative feedback loop is enough to generate oscillations. In this work, we have analyzed from the point of view of the divergence of the system and, hence, the variation of energy in the system, the advantages that the addition of a new loop may provide. We have compared the values of the divergence for negative, negative-plus-negetaive and negative-plus-positive feedback oscillator models. Finally, we have analysed in detail the cyanobacteria circadian oscillator model that has been reproduced in vitro using three proteins: KaiA, KaiB and KaiC plus ATP.

### Inferring HIV transmission networks form epidemic and genetic information

N. Zarrabi*, M. Prosperi, A. De Luca, P. Sloot

*University of Amsterdam, The Netherlands*

The spread of infectious diseases in a population is an emergent behavior of the social interactions among individuals, hence, the disease transmission can be studied using complex system approaches. Social and computational scientists have been trying to study the spread of infectious diseases using social and sexual contact networks. The complexity of human immunodeficiency virus (HIV) transmission has been investigated by modeling the population as a complex network (nodes are individuals and links are relationships) and running models of disease on top of that. However, many simplifying assumptions are being made on the network structure and topology. Another approach to infer the transmission and evolution of HIV, used by molecular virologists, is a bottom-up approach based on phylogenetic trees analysis. Such hierarchical binary trees can be used to infer both species taxonomy and the transmission of pathogens in a population. Nevertheless, these methods have limitations and may not necessarily accurately represent the transmission due to their topological limitations. In this study we propose a novel filter-reductionism approach to create a network of HIV sequences of infected patients called social sequence network (SSN). Information in both genetic (derived from RNA sequences) and epidemic scales was used to infer a transmission network of HIV. This multi-scale, multi-function, approach helps us to overcome the limitations of pure-genetic phylogenies for obtaining a better understanding of the transmission dynamics of HIV in a population. We compute the intersection of SSN with genetic clusters obtained by partitioning a phylogenetic tree. Basic characteristics of the intersection network such as degree distribution and centrality measures are analyzed. Sub-networks corresponding to different risk groups of HIV infection (male homosexuals, heterosexual, injecting-drug users) are also analyzed separately. The intersection network satisfies both social and genetic criteria for transmission. The proposed method for network construction is based on real patient data and does not make any pre assumptions on the structure of the network. Furthermore the network structure for heterosexual population

is in agreement with the recognized network structure of social and sexual contacts.

### Hybrid Coupling Techniques in Modular Infectious Disease Modeling

G. Zauner*, P. Einzinger, F. Miksch, N. Popper, F. Breitenecker

*dwh simulation services, Vienna, Austria*

The increased necessity of fast reaction on new upcoming infectious diseases (e.g. influenza) in combination with narrow resources regarding vaccine doses and/or treatment capacities lead to advanced modeling demand. Hybrid coupling of agent based modeling and cellular automata as well as system dynamics offer the necessary flexibility. The overall model steering/control/management is realized using agent based modeling techniques predefining the behavior of each agent and setting up the daily routine. The main benefit of this modeling approach is the flexibility in implementation of different boundaries or behavior of persons during a fixed time interval. The modular developed contact models have to fulfill a predefined interface, but the lapse of time in each sub model can be chosen freely as well as the used algorithm. Based on these assumptions parallel computing and modular refinement as well as stepwise system verification can be used. In one of the actual applications these techniques are used for the contact generation of modeled inhabitants of Austria on their working places, in schools and in the time span when they are assumed to stay at home and meet their families. The whole behavior depends on their infection status. All calculations are generated using realistic population data in combination with results from POLYMOD study (EU Research &Innovation –Health, project number: SP22-CT-2204-502084) for contact number calibration. Another utilization of hybrid coupling is done in the field of demand generation (using system dynamics SIR –models) in combination with agent based modeling of the occurring patient ways through the health care system. Outlook: Based on this modeling structure in broad application fields in public health as well as resource planning the decision and strategy discussion can be supported.

### Competing technologies and social interactions

P. Zeppini*

*University of Amsterdam, The Netherlands*

I propose a discrete choice model of technological competition that focuses on network externalities and social interactions. The idea is to detect their effect through the dynamics of agents' choices. First I study the structure of equilibria when social interactions and network externalities give the same feedback. Later I modify the model in order to discriminate between them and indicate how to identify social interactions. A third specification of the model introduces endogenous technological progress and studies its interaction with technological competition. One application of the model is proposed for the case of polluting technologies. In a competition between "dirty" and "clean" technologies, social interactions are important in designing incentives for agents' choice that may trigger a coordination towards less polluting scenarios.

### Modelling stock prices dynamics by means of the finite range contact model

J. Zhang*

*King's College, London, UK*

We present an application to different financial market data of the finite range contact model. This model mimics the interplay of local infections and recovery of individuals in an epidemic spreading process [1]. The motivation of such a study is to uncover the stylized facts present in real markets [2,3], and to better understand the behaviours of these systems. In this model, the set of investors are assumed as agents with different attitudes (bullish, bearish or neutral), who can spread information to their neighbors according to the one-dimensional finite range contact model at different values of the range of the model [4,5]. Probability density functions and autocorrelation functions of returns are computed and compared with those of daily closing prices from 14 major world stock market indices, including 6 from Europe, 3 from US, 4 from Asia/Pacific, 1 from America in the time period from 9 April 1991 to 26 April 2011. We find the evidence of absence of simple arbitrage, volatility clustering and fat-tailed behaviours.

# Satellites

# Complex Dynamics of Human Interactions

**Organizers: E. Moro, K. Kaski**

### Taming Complexity: Controlling Networks

A.-L. Barabási*

*Northeastern University, Dana-Farber Cancer Institute and Harvard Medical School, Boston, Massachusetts, USA*

The ultimate proof of our understanding of natural or technological systems is reflected in our ability to control them. While control theory offers mathematical tools to steer engineered and natural systems towards a desired state, we lack a framework to control complex self-organized systems. Here we develop analytical tools to study the controllability of an arbitrary complex directed network, identifying the set of driver nodes whose time-dependent control can guide the system's entire dynamics. We apply these tools to several real networks, finding that the number of driver nodes is determined mainly by the network's degree distribution. We show that sparse inhomogeneous networks, which emerge in many real complex systems, are the most difficult to control, but dense and homogeneous networks can be controlled via a few driver nodes. Counterintuitively, we find that in both model and real systems the driver nodes tend to avoid the hubs. In collaboration with Y. Liu and J.J. Slotine.

### Mining networks of human contact with wearable sensors

A. Barrat*

*Centre de Physique Thorique, Marseille, France and Institute of Scientific Interchange, Turin, Italy*

Due to the development of sensors of various types and the use of digital media and computational devices, we increasingly leave digital traces of our daily activities. The scale at which such data can be gathered and analyzed affords a novel, data-driven approach in the investigation of various aspects of human behavior. In this talk, I will focus on the research done within the SocioPatterns project (www.sociopatterns.org), in which we have developed the SocioPatterns sensing platform to obtain longitudinal datasets on face-to-face contact events between individuals in a variety of contexts ranging from scientific conferences to museum, school or hospitals. I will describe some properties of the gathered datasets, which reveal interesting similarities and differences of human interaction patterns across contexts. In cases such as hospitals or schools, the measures can also inform epidemiological models by giving access to contact matrices and contact networks. I will also consider the impact of the temporal resolution, which allows to take into account causality constraints, on dynamical processes occurring on networks, such as spreading processes.

### Entropy of dynamical social networks

G. Bianconi*

*Northeastern University, Boston MA, USA*

Human dynamical social networks encode information and are highly adaptive. To characterize their information, here we introduce the entropy of dynamical social networks. By analysing a large dataset of phone-call interactions we show evidence that the dynamical social network has an entropy that depends on the time of the day in a typical week-day. Moreover we show evidence for adaptability of human social behavior showing data on duration of phone-call interactions that significantly deviates from duration of face-to-face interactions. This adaptability of behavior corresponds to a different information content of the dynamics of social human interactions. We quantify this information by the use of the entropy of dynamical networks on realistic models of social interactions.

### Emergent properties of networks of mobile agents

A. Diaz*

*Universidad de Barcelona, Barcelona, Spain*

We consider agents that can move on a plane. Two agents interact if they are within a finite range. In this type of problem there are two characteristic time scales: one for the agents motion and another one

for the interaction dynamics. We show that depending on the parameters characterizing both scales, the mechanisms that lead to a global behavior are different. In particular, we analyze synchronization dynamics and characterize dynamic network properties by means of instantaneous Laplacian matrices.

### Complex dynamics of election campaigns: Interaction among politicians in the media

W. de Nooy*

*University of Amsterdam, Amsterdam, The Netherlands*

This paper conceptualizes the interaction among politicians as a dynamic process. Interactions among politicians are important because they are linked to high-level decision making in society. Politicians are assumed to act rationally on their ideological positions. Democratic politics, however, is a collective process requiring coalitions and concessions; politicians have to react to previous interactions among their peers rather than just stick to fixed ideological positions. As a consequence, it is necessary to take into account the dynamic of action and reaction to understand the structure of issue positions and alliances among politicians at a particular moment.

### Update rules and interevent time distributions: Slow ordering versus no ordering in the voter model.

V. M. Eguíluz*

*Instituto de Física interdisciplinar i Sistemas Complejos, Palma de Mallorca, Spain*

We introduce a general methodology of update rules accounting for arbitrary interevent time (IET) distributions in simulations of interacting agents. We consider in particular update rules that depend on the state of the agent, so that the update becomes part of the dynamical model. As an illustration we consider the voter model in fully connected, random, and scale-free networks with an activation probability inversely proportional to the time since the last action, where an action can be an update attempt (an exogenous update) or a change of state (an endogenous update). We find that in the thermodynamic limit, at variance with standard updates and the exogenous update, the system orders slowly for the endogenous update. The approach to the absorbing state is characterized by a power-law decay of the density of interfaces, observing that the mean time to reach the absorbing state might be not well defined. The IET distributions resulting from both update schemes show power-law tails.

### Fellows: Crowd-Sourcing the Evaluation of an Overlapping Community Model based on the Cohesion Measure

A. Friggeri*, G. Chelius, C. Fleury

*LIP/ENS de Lyon – DNET/INRIA, France*

Although community detection has drawn tremendous amount of attention across the sciences in the past decades, no formal consensus has been reached on the very nature of what qualifies a community as such. We take an orthogonal approach by introducing a novel point of view to the problem of overlapping communities. Instead of quantifying the quality of a set of communities, we choose to focus on the intrinsic community-ness of one given set of nodes, regardless of the presence or absence of other communities. To do so, we propose a general metric on graphs, the cohesion, based on counting triangles and inspired by well established sociological considerations. The model has been validated through a large-scale online experiment called Fellows, in which users were able to compute their social groups on Facebook and rate the quality of the obtained groups. By observing those ratings in relation to the cohesion we assess that the cohesion is a strong indicator of users subjective perception of the community-ness of a set of people, thus validating the definition of the cohesion.

### Spreading dynamics following human activity patterns

A. Min, K. I. Goh*, I. M. Min, A. Vazquez

*Korea University, Seoul, Korea*

Spreading dynamics have been studied for many years as a model of emerging epidemics, virus outbreaks and information flows. Human activity patterns affecting spreading processes empirically show high heterogeneity,

often described by a power-law waiting time distribution $P(\tau)) \sim \tau \sim \alpha$, where $\tau$ is time interval between two successive activities. To understand the impact of heterogeneous human activity patterns on spreading dynamics, we study the susceptible-infected model with power-law waiting time distributions. We found that the average number of new infections $n(t)$ at time $t$ decays as a power law in the long time limit, $n(t) \sim t \sim \beta$, leading to extremely slow prevalence decay. We also found that the exponent in the spreading dynamics $\beta$ is related to that in the waiting time distribution? in a way depending on the interactions between agents but insensitive to the network topology. We will also briefly discuss the effects of power-law waiting time distributions on the epidemic threshold of the SIR/SIS-type models as well.

### 1 versus 100: Integrating social information in decision making by human groups

B. Granovskiy*, R. Goldstone, D.J.T. Sumpter

*Uppsala University, Uppsala, Sweden*

Do people rely more on themselves or on the opinions of others when making decisions? How do people reconcile information about others's judgments with their own beliefs? In this paper, we study how individuals integrate social and personal information when answering trivia problems by conducting an experimental group study and creating a mathematical model that tries to explain the way individual behavior contributes to emerging patterns on the group level. Additionally, we test the "wisdom of crowds" idea to see if groups are able to make more accurate judgments than individuals, and if groups' judgments improve through the exchange of information. We do this by comparing the performance of individuals and groups when answering a number of trivia questions. In all experiments, individuals have a chance to change their original guess multiple times. Individuals are organized into either group or solo conditions. When in groups, individuals can see the estimations of others and potentially use these responses to adjust their own estimations. In the solo condition, no new information is provided to individuals. Analysis of the experiments shows that the average guesses of the groups improve with group size, which is consistent with the wisdom of crowds idea. With larger groups, there is also an improvement in the groups's average guesses as more rounds of estimation pass, but the strongest effect we observed was that the guesses of individuals within a group got closer together over the course of the experiment. Based on experimental results, we fit a model to the data that predicts the change in an individual's guess based on their guess in the previous round and on the distance from their guess to the mean of the other guesses in her group. We also propose a mechanism explaining the process by which guesses of a group get closer together over time while showing only negligible improvement in the average guess. We predict that a group's average guess will not improve over time if the original guesses of the group members are sufficiently close together or biased in some way.

### Co-evolution of links and nodes: A complex network model of cultural dynamics face to social intolerance

C. Garcia-Lazaro, F. Quijandria, Floría-Peralta, L. Hernández*, Y. Moreno

*Laboratoire de Physique Théorique et Modélisation, Cergy-Pontoise, France*

Studies of social systems often require a simultaneous treatment of both, the dynamics of the variables associated to the nodes of the network, and that of the topology of the network, as they vary in the same time scale. The emerging organization of the society is the result of the interaction between these two processes. In this work we present a complex network model of cultural dynamics in a society of N agents. The nodes are characterized by a *cultural vector*, $\rho$, of dimension F, where each component represents a cultural feature of the agent that may take q different integer values. Following Axelrod's model [1], at each step, an agent may adopt a cultural feature of one of its neighbors with a probability that depends on their degree of similarity. Moreover, an agent may also disconnect from one of its neighbors if their disagreement is high enough, and rewire this connection to another neighbor. In [2] it has been considered the case where an agent disconnects one of its links and rewires it randomly, only when it has no common feature with the corresponding neighbor. Here we study the effect of a given level of tolerance that characterizes the society, representing the fact that agents may be more or less ready to accept differences in their social neighborhood. We introduce a "tolerance threshold", Z, as a parameter that governs the rewiring process. Rewiring is possible when the cultural difference between two agents is greater than Z. Our results show a non monotonous behavior of the transition value, $q_c$, with the tolerance threshold. The dynamics is also highly dependent on Z; according its value, the dynamics of the system is lead either by the "Axelrod-like" process or by the rewiring process.

[1] R. Axelrod. J. Conflict Resolut. 41, 203 (1997). [2] F. Vazquez, J.C. Gonzalez-Avella, V.M. Eguiluz, and M. San Miguel. Phys.Rev.E 76, 046120, (2007).

### Mathematical Model for Human Interaction and its application to hit phenomena

A. Ishii*, H. Arakaki, N. Yoshida

*Tottori University, Tottori, Japan*

In the human interactions especially for word of mouth, the interactions between human are affected by advertisement on TV, the words of mouth and rumors. We present here a mathematical model for hit phenomena where we model human interactions for word of mouth to determine purchase intentions for each human in the society as time-dependent quantity [1,2]. In our model, we introduce the quantity, *purchase intension*, and we consider that the variation of $I(t)$ is caused by mass media advertisements, direct communications from his/her friends and indirect communications. The equation of the purchase intention $I(t)$ has been presented as follows.

$$\frac{dI_i(t)}{dt} = A(t) - aI(t) + \sum_{j\neq i}^{N} D_{ij}I_j(t) + \sum_j \sum_k P_{ijk}I_j(t)I_k(t) \quad (1)$$

Our mathematical model can reproduce the daily revenue for movie entertainment very well. We have also applied our mathematical model to the local event *Sazo festival* in Tottori in 2009. The attendance can be reproduce well by our mathematical model.

[1] A Ishii, S Umemura, T Hayashi, N Matsuda, T Nakagawa, H Arakaki, N Yoshida, arXiv:1002.4460 (2010). [2] A Ishii, H Arakaki, S Umemura, T Urushidani, N Matsuda and N Yoshida, Proceedings of 2011 International Conference on Data Engineering and Internet Technology (DEIT 2011).

### Emergence of Bursts and Communities in Evolving Weighted Networks

H.-H. Jo*, R.K. Pan, K. Kaski

*Aalto University, Espoo, Finland*

The large scale data analysis of social networks including mobile phone call network has revealed the existence of community (modular) structure with many links between nodes of the same community and relatively few links between nodes of different communities. The weights of links, e.g. the number of calls between two users, and the network topology are also correlated such that intra-community links are stronger compared to the weak inter- community links. This feature is known as Granovetter's "strength of weak tie hypothesis". In addition to the inhomogeneous community structure, the temporal patterns of human dynamics turn out to be inhomogeneous and bursty, characterized by the heavy tailed distribution of time interval between two consecutive events (inter-event time). In this paper, we study how the community structure and the bursty dynamics emerge together from the simple evolving weighted network model. The principle mechanisms behind these patterns are the cyclic closure (links to friends of friends) and the focal closure (links to strangers with the same attributes) for social interaction, and task handling process for human dynamics. We numerically show that the interplay of these mechanisms leads to the emergence of heavy tailed inter-event time distribution and the evolution of Granovetter-type community structure.

### Edit wars in Wikipedia

R. Sumi, T. Yasseri, A. Rung, A. Kornai, J. Kertész*

*Budapest University of Technology and Economics, Budapest, Hungary*

We present a new, efficient method for automatically detecting severe conflicts, 'edit wars' in Wikipedia and evaluate this method on six different language Wikipedias. We discuss how the number of edits, reverts, the length of discussions, the burstiness of edits and reverts deviate in such pages from those following the general workflow, and argue that earlier work has significantly over-estimated the contentiousness of the Wikipedia

editing process.

**Link activation sequences, waiting times, and spreading in temporal networks**

M. Kivelaä*, M. Karsai, R.K. Pan, K. Kaski, J. Kertész, J. Saramäki

*Aalto University, Espoo, Finland*

In temporal networks links are not always active, but the nodes are connected by sequence of link activation events. In such networks, the spreading of information or infection can only happen via time respecting paths. Dynamic processes in temporal networks are thus affected by both topo- logical and temporal correlations, both of which can be studied using reference models. Temporal correlations in event sequences have recently been shown to slow down the spreading in mobile phone call networks. Most of the slowing down on the network scale was attributed to correlations in event sequences on links. However, there are large correlations between the sequences such as the daily pattern and one call between nodes A and B triggering another call between B and C. We look at the event sequences of each link separately, and calculate the average time between a node getting infected to the next event. This is the first time when information can be transmitted through that link. The time when the information first arrives to the node pair is of importance, and we consider three ways of choosing that time: by selecting a uniformly random point in time, by selecting a random event that can transfer the infection to one of the two nodes, and finally by measuring the infection times based on a system-wide spreading process.

**Two and more heads deciding: models of information-sharing and aggregation for two-choice discriminative tasks**

P. Migdał*, M. Denkiewicz, J. Raczaszek-Leonardi, D. Plewczynski

*Institut de Ciències Fotòniques, Barcelona, Spain and University of Warsaw, Warsaw, Poland*

Everyone who ever took part in a group decision making or problem solving, probably asked oneself whether it actually made any sense - wouldn't it be better if simply the most competent person made the choice? Put differently, the question is whether a group can outperform its most capable member. We investigate mathematical models for estimating performance of a group solving a two-choice task. The models of our interests are these in which visibility of the difference is parametrized by a continuous parameter, i.e. such that probability of giving the right answer is linear for small contrasts (its slope characterizes the performance). We calculate slope for a group as a function of slopes of its participants. Our research follows Bahrami et al. (Science 2010), who provided deep introduction and model foundation for describing experimental data gathered from dyads (a pairs) of people solving a difficult perceptual task. It is important to underline that the models incorporate processes of perception (what the subjects may know), state of mind (what the subjects know) and the actual communication and the decision-making process (usually Bayes- optimal). In particular, we propose 5 different models, most of which are motivated by previous experiments. For groups larger than two or three people we compared models with gathering information all-at-one and as a dynamical process, when only 2-3 subgroups can communicate at a time. It turns out that in most models a group decision outperform decision made by the most skilled member, as long as performance of different participants is relatively similar. Also, dynamical information-sharing affects the outcome only a little. For every model we investigated the group performance (measurement in the terms of slope) is a product of a scaling factor depending of the group size and an average performance. The scaling factor ranges from a constant, through e.g. a square root, to a linear scaling. The average varies - it is arithmetic mean, quadratic mean or maximum. The paper is an invitation for an experiment, as it proposes how to distinguish different models of information-sharing and decision making in terms of simple and easily measurable quantities. Furthermore, it provides formalism for quantifying group vs individual performance, for a far wider class of models than we investigated.

**Time allocation in social networks: correlation between social structure and human dynamics**

G. Miritello*, E. Moro, R. Lara

*Telefónica Research and Universidad Carlos III de Madrid, Madrid, Spain*

Recent research has shown the deep impact of the dynamics of human interactions on the spreading of information, opinion formation, etc. In general, the bursty nature of human interactions lowers the interaction

between people to the extent that both the speed or reach of information diffusion is diminished. Using a large database of 20 million users of mobile phone calls we show evidence that there is a large correlation between this effect and the social topological structure around a given interaction. In particular we show that social relations of hubs in a network are relatively weaker from the dynamical point than those that are poorer connected. This means that, dynamically, hubs have a relatively lower importance on information transmission than poorer connected people. A detailed analysis shows that this happens because hubs tend to allocate time in an efficient way so that they manage a (bounded) number of social interactions within a given time interval. We propose a model of time allocation to explain the observed phenomena and discuss the importance of our results in general problems of information diffusion, coordination, opinion formation etc. in social networks.

### Social dynamics of ICT-mediated interaction

K. Lisiecka, K. Samson, M. Ziembowicz, A. Rychwalska, A. Nowak*, A. Szostek

*University of Warsaw, Warsaw, Poland*

Increasing commonness of ICT tools poses important questions about the effectiveness of ICT-mediated communication, as well as its social and psychological consequences. A study was conducted to investigate how communication media affect the dynamics of dyadic interaction. The experiment used a 3 (communication channel) by 2 (task type) between subjects and involved 146 participants (73 dyads) from a student population. We analyzed how communication communication means affect the efficiency of the interaction, impact the participants' emotions and process satisfaction, and later the extent of social influence. Additionally, after having completed the study, the participants underwent the mouse procedure (Vallacher, Nowak, Kaufman, 1994), which involved moment-to-moment assessment of own interaction on two dimensions - positive/negative emotions and the importance of achieving consensus. The results show that the time needed to accomplish a common task varies between conditions; text-bases chat communication is the least time consuming, although the objective results, as well as participant satisfaction do not differ. Moreover, communication channel influences the dynamics of the interaction - time series data from the mouse procedure show different patterns for face-to-face, mobile phone and internet chat conversations.

### A Metapopulation Model for the Spread of the Chikungunya Virus

D. Moulay, Y. Pigné*

*University of Luxembourg, Luxembourg*

We are interested in the spatiotemporal spread of the chikungunya viral disease under the effect of human and mosquito mobility. This disease needs a vector, the mosquito, to propagate to human. The geographical environment and the mobility of populations are key issues for epidemiologists. To this purpose models that consider the spatial distribution of a natural environment are of great interest. In this work we propose to couple two models: a mosquito dynamics model (growth and evolution of the population) with a transmission model between two populations (humans and mosquitoes). Those two dynamical systems are formalized using the metapopulation theory. It considers a network where nodes represent real habitats of the environment. In each node, transmission and population dynamics models appear and are coupled with neighboring nodes. Links represent mobility for both humans and mosquitoes. This human mobility is constructed according to a study based on real human mobility datasets (cell phone probes). In order to validate the approach, we focus on a real case of chikungunya epidemic with the 2005-2006 event that occurred on the Reunion Island, Indian Ocean. Real data about the seroprevalence of the disease in the population allowed validating the model. Moreover the small spatiotemporal resolution we consider allows the modeling and testing of various prevention and action plans.

### Trust Transitivity in Social Networks

O. Richters*, T.P. Peixoto

*Technische Universität, Darmstadt, Germany*

Non-centralized recommendation-based decision making is a central feature of several social and technological processes, such as market dynamics, peer-to-peer file-sharing and the web of trust of digital certification. We

investigate the properties of trust propagation on networks, based on a simple metric of trust transitivity. We investigate analytically the percolation properties of trust transitivity in random networks with arbitrary in/out-degree distributions, and compare with numerical realizations. We find that the existence of a non-zero fraction of absolute trust (i.e. entirely confident trust) is a requirement for the viability of global trust propagation in large systems: The average pair-wise trust is marked by a discontinuous transition at a specific fraction of absolute trust, below which it vanishes. Furthermore, we perform an extensive analysis of the Pretty Good Privacy (PGP) web of trust, in view of the concepts introduced. We compare different scenarios of trust distribution: community- and authority-centered. We find that these scenarios lead to sharply different patterns of trust propagation, due to the segregation of authority hubs and densely-connected communities. While the authority-centered scenario is more efficient, and leads to higher average trust values, it favours weakly-connected "fringe" nodes, which are directly trusted by authorities. The community-centered scheme, on the other hand, favours nodes with intermediate in/out-degrees, in detriment of the authorities and its "fringe" peers.

Richters O, Peixoto TP (2011) Trust Transitivity in Social Networks. PLoS ONE 6(4):e18384. doi:10.1371 / journal.pone.0018384

### Statistics of collective human behaviors for extraordinary events in cyberspace

Y. Sano*, K. Yamada, H. Watanabe, H. Takayasu, M. Takayasu

*Nihon University, Tokio, Japan*

We survey collective human behaviors quantitatively using statistics of word appearances of more than 1.8 billion entries in Japanese blogs. In particular, we focus on words that have specific peaks in appearances. We find that time series of these word appearances before/after peak can be well described by power laws. Furthermore, independent of words, power exponent of after event is larger than before in most of cases. Additionally, we also show some examples of word appearances in Twitter at the time of the Great East Japan Earthquake.

### Phase transitions in contagion processes mediated by recurrent mobility patterns

A. Vespignani*

*Indiana University, Bloomington, USA and Institute for Scientific Interchange, Torino, Italy*

Human mobility and activity patterns are often dominated by specific locations and recurrent flows and poorly modelled by the random diffusive dynamics generally used to study them. Here we develop a theoretical framework to analyze contagion within a network of locations where individuals recall their geographic origins. We find a phase transition between a regime in which the contagion affects a large fraction of the system and one in which only a small fraction is affected. This transition cannot be uncovered by continuous deterministic models because of the stochastic features of the contagion process and defines an invasion threshold that depends on mobility parameters, providing guidance for controlling contagion spread by constraining mobility processes.

# XNet – Complexity and Networks

**Organizers: R. Lambiotte, J.P. Onnela, R. Sinatra, M. Szell**

### Extracting similarity information from word association networks

A. Arenas*

*Universidad Rovira i Virgili, Tarragona, Spain*

Word association networks (WAN) are among the possible representations of semantic relations between concepts. Moreover, the particular structure of the empirical networks of words association is a rich projection of the intricate structure semantic knowledge. In this work, we aim to extract ontologies from the complex structure of these networks of words. The main idea is to escrutinize the structure of WAN's using Markov processes, in particular random walkers, assigning to each word a tag that indicates its relative view of the whole network. Ontologies emerge in our scenario as the result of the similarity between these tags during the metastable states of the Markov process. The stationary state of the Markov proceess is congruent with a whole hierarchy of ontologies. Moreover, the method allows to identify those words that bridge different ontologies.

### Identifying communities by locally optimal coarsening

M. Barber*

*Austrian Institute of Technology, Vienna, Austria*

Agglomerative, hierarchical clustering is a well established strategy for identifying communities in networks. Communities are successively merged into larger communities, coarsening a network of actors into a more manageable network of communities. The order in which merges should occur is not in general clear, necessitating heuristics for selecting pairs of communities to merge. We consider a multi-step merging algorithm based on a local optimality property of the network of communities. For each edge in the network, we associate the modularity change for merging the linked communities. For each community vertex, we call the preferred edge that edge for which the modularity change is maximal. When an edge is preferred by both vertices that it links, it appears to be the optimal choice from the local viewpoint. We use the locally optimal edges to define an agglomerative, hierarchical clustering algorithm: simultaneously merge all pairs of communities that are connected by locally optimal edges that would increase the modularity, redetermining the locally optimal edges after each step and continuing so long as the modularity can be further increased. We apply the algorithm to model and empirical networks, demonstrating that it can efficiently produce high-quality community solutions. The resulting dendrogram more closely approximates a balanced binary tree than, e.g., that produced by Newman's landmark greedy algorithm, favoring higher modularity values and better performance.

### Human Brain Networks

E. Bullmore*

*University of Cambridge, United Kingdom*

In this talk I will rehearse some of the basic concepts and techniques involved in modelling brain networks using tools drawn from graph theory. I will cover some of the key methodological issues entailed in graph analysis of network topology based on human neuroimaging data; rehearse some of the key findings that have emerged from this rapidly growing field to date; and point to some possible growth points for future methodological and scientific development in the use of brain graphs to understand structural and functional connectomes.

### Co-evolution of strategies and update rules in the prisoner's dilemma game on complex networks

A. Cardillo*, J. Gomez-Gardenes, D. Vilone, A. Sanchez

*University of Zaragoza, Spain*

In the past five years, many papers have been published on evolutionary games on complex networks. However, up to few years ago, no one has ever tried to study systems in which both the strategy of players and the way

they choose it (i.e. the update rule) could change simultaneously. Here I will present the results of a paper, published in late 2010 on New Journal of Physics, which extends the pioneering work of Moyano and Sanchez on co-evolution of strategy and update rule on regular lattices. Using the paradigmatic game of Prisoner's Dilemma, I will examine the emergence of a collective behavior such cooperation in systems that undergo an evolutionary process, in which players could change both their strategy and update rule. Several scenarios, in terms of both network topologies and update rule, have been considered in order to span the widest set of conditions available. After introducing the basics of evolutionary game theory on complex networks, I will discuss the results of the paper which show how co-evolution helps in the survival of cooperation even when the temptation to defect is relatively high.

### Critical Phenomena in Heterogeneous k-Core Percolation

D. Cellai*

*University College Dublin, Ireland*

k-core percolation is an extension of the concept of classical percolation and is particularly relevant to understand the resilience of complex networks under random damage. A new analytical formalism has been recently proposed to deal with heterogeneous k-cores, where each vertex is assigned a local threshold $k_i$. We identify a binary mixture of heterogeneous k-core which exhibits a tri-critical point. We investigate the new scaling scenario and calculate the relevant critical exponents, by analytical and computational methods, for Erdős-Rényi networks and 2D square lattices. As a result, we identify a new tri-critical universality class in a percolation-type model. We find critical exponents different from classical percolation and we compare them with those recently found in other percolative models.

### Relative effect of centrality based on maximum flow

D. Czegel*

*Lorand Eotvos University, Budapest, Hungary*

Measuring centrality of nodes plays an important role in network analysis. Numerous centrality measures exist for studying real-world networks, making different assumptions how traffic flows through the network.Most of these consider how node i is related to the other nodes, but ignore their attributes, i.e., the amount of traffic received by the given node. In some cases, however, it would be more appropriate to compute the relative effect, taking into account incoming traffic to a node $i$. For example, in food webs, it is a very relevant question that if a species became extinct, what impact it would have on the other species of the ecosystem. In that case, suppose that j is a predator species, and one of its prey species is $i$. Then, the more other prey species $j$ has, the less impact i's extinction will have on it. If we model the food web by a weighted graph in which the species are the nodes, and the weights of the edges are proportional to the biomass flow between the two species, it means that although node $i$ has the same absolute effect on $j$ (because if we delete $i$, the same amount of biomass flow will be missing for $j$), it has less relative impact on $j$ because $j$ has more species to choose from. A completely different real-world example, where the idea of relative effect is also useful, occurs if we ask to what extent a member is able to shape the opinion of others in a given community. In other words, there is a given weighted network where the weight of the edge between two people is proportional to how much they talk with each other. In this situation, if $i$ is the only friend of $j$, then the influence of $i$ on the opinion of $j$ is much bigger, than if $j$ had more other friends. (Of course the weight of the edge between $i$ and $j$ remains the same and does not depend on how many other friends $j$ has.) In this paper, a new concept of node centrality measure is proposed that assesses the power nodes have in influencing others by taking into account the maximum amount of information that can flow between the nodes. For this, we use the concept of network flow. In addition to the introduction of the new centrality measure, we also discuss the computational aspect of calculating it. As an illustration, we calculate the proposed Relative Effect Centrality (REC) for the nodes of an example graph.

### Multiscale analysis of biomolecules using graph partitioning

A. Delmotte*, S. Yaliraki, M. Barahona

*Imperial College, London, United Kingdom*

The interplay between structure and dynamics is essential to the biological function of proteins. The complexity of protein dynamics is a direct consequence of the wide spectrum of intertwined spatial and temporal

scales spanned by proteins, which, despite being defined at the atomic level, evolve and function over more than ten orders of magnitude in time. Crucially, it is recognised that the large scale organisation in proteins is not independent from the smallest scales, but results directly from the initial arrangement of atomistic interactions [1]. The analysis of such wide-ranging coupled dynamics lies beyond the capabilities of current computational and simulation methods. We have recently proposed a method to uncover the spatio-temporal organisation of biomolecules spanning their full spectrum of scales [2]. Using a graph representation of protein structures, this method allows the fast computation of the overall organisation of biomolecules at different scales and relates the high-level organisa- tion to the details of the biochemical interactions, thus allowing to uncover the coupling between the different levels of organisation. Starting from experimental molecular structures, the method constructs a weighted graph with a fully atomistic description that encapsulates the biochemical details of atomistic interactions. This graph is analysed through a multiscale partitioning algorithm that employs a recently introduced quality function called Stability, which is based on a Markov dynamic process taking place on the graph [3, 4]. Sta- bility optimisation allows communities to be identified at different Markov time scales, which can be related to the successive levels of organisation of the molecular structure such as small chemical groups, amino acids, secondary structure and large functional domains, and to their corresponding physical time scale of motion. Our methodology also includes a robustness analysis of partitions, which is used to identify substructures of biochemical significance through the use of surrogate random graph models constrained to include relevant biochemical features. Finally, we introduce a tool for computational mutagenesis that can be used to identify the residues of the protein that are critical in defining the spatio-temporal organisation of the protein at different scales. The method has been applied to various biomolecular structures, from small and well-known proteins, such as Adenylate kinase, to large molecular complexes of many subunits such as Rubisco, and including recently identified protein structures, such as the myosin tail interacting protein from the malaria parasite, as well as particular DNA conformations, such as the G-quadruplex involved in ageing and cancer. Our results, which cover biological properties at various scales, from mutations to global opening-closing mechanisms, are shown to be supported by various types of experimental data, including binding assays, X-ray and NMR data.

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### Strategic bipartite network formation in interlocking corporate directorates

M. D'Errico*, R. Grassi, A. Uristani

*University of Milan, Italy*

In 1914, U.S. Supreme Court justice Louis Brandeis wrote: "The practice of interlocking directorates is the root of many evils. It offends laws human and divine. [...] Applied to corporations which deal with each other, it tends to disloyalty and to violation of the fundamental law that no man can serve two masters. [...] it removes incentive and destroys soundness of judgement." The expression interlocking directorates refers to the well known practice of corporate directors serving on more than one corporate board. As a consequence, linkages within companies and directors tend to emerge and such an interlocking structure plays a crucial role in how information flows. Notwithstanding Brandeis concerns, such a phenomenon is now widely observable both at national and international level. The purpose of this work is to provide an analysis of the dynamic evolution of such linkages over time. Network analysis offers a convenient representation of this situation by using a two-mode data approach, i.e. data partitioning in two different sets of entities (companies and directors), allowing for a formal mathematical description of the interlocking by means of a bipartite network. Common affiliations might allow, e.g., to share business information, thus leading to coordinate decisions and actions: such hidden ties can be analyzed with a network approach. Moreover, vertex centrality measures have been widely employed to investigate the structural properties of interlocking directorates (see [1], [5] and [8]). Focusing on the dynamic aspects, we intend to study the evolution of the bipartite network (where the two sets represent companies and directors) and its two one-mode projections (we refer, for instance, to [2] and [9]). The intent of this work is to put the basis of an explicative model in the light of the networks emerging characteristics, allowing to explain the dynamic evolution taking into account events of diverse nature. The basic features of such a dynamic agent-based model are that it steps from a given initial network configuration and, on the basis of the interactions dynamics at micro-level, accordingly allows to describe the network evolution at subsequent time steps. The model should capture the strategic decisions of each agent and the impact on the network's evolution, and vice versa. Such decisions depend on companies preferences, which

depend in turn on the characteristics of the agents in the directors network. The second aim of this work is to test such a model against historical data. The dataset includes information on companies listed from 1998 to 2009 in the Italian stock exchange (managed by Borsa Italiana SpA) and has been extracted from Consobs (the Italian Securities and Exchange Commission, which keeps such information up to date) official website (www.consob.it).

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### Structure of the hyper-brain network during social interactions

F. De Vico Fallani*, V. Nicosia, R. Sinatra, L. Astolfi, F. Cincotti, D. Mattia, C. Wilke, A. Doud, V. Latora, B. He, F. Babiloni

*University of Rome, Italy*

The comprehension of the mechanisms subserving the social interactions in groups of individuals can be addressed through mathematical frameworks belonging to the so-called game theory. In particular, researchers have investigated what happens in the brain of subjects involved in games where each player can choose between cooperative and non-cooperative behaviors, or between altruistic and selfish behaviors, with the aim of understanding the modification of brain activity related to the selected strategy. Most of the approaches used so far to characterize brain responses during social interaction have the major limitation of measuring signals from just one player at a time. The functional connectivity between the brain activities of two interacting individuals is thus not measured directly, but inferred from independent observations subsequently aggregated by statistical models, which associate observed behaviors and neural activation. In the present study, we used i) simultaneous neuroelectric recordings from two subjects, i.e. EEG hyper-scanning ii) localization of cortical activity, i.e. high-resolution EEG iii) and spectral Granger causality indexes, i.e. Partial Directed Coherence (PDC) to estimate, in the frequency domain, the information propagation among different cortical regions within- and between-brains. We considered one of the most common cooperation games, the Iterated Prisoner's Dilemma (IPD), where each player can either defect or cooperate with the other player and might punish the opponent for previous non-cooperative behavior. The EEG period of interest (POI) is the time interval during which both players are formulating the strategies to adopt in the next round of the game i.e. the initial decision-making phase. The resulting networks of functional connectivity estimated from the cortical activity of the two players were described by a directed weighted graph. Each node corresponds to a specific cortical region - also called region of interest (ROI) - of one of the two subjects brain. A weighted link between two ROIs indicates the degree of their interaction as estimated by the PDC. In practice, we represented the functional connectivity of the two brains altogether in the same graph: a link in the graph can be either an intra-brain or an inter-brain connection, according to the fact that it expresses the relationship between two ROIs belonging to the same brain, or between a region of one brain and a region of the other brain. We named such a graph a hyper-brain network. The obtained hyper-brain networks were analyzed using tools and measures coming from complex networks theory, such as efficiency and modularity. The results obtained by analyzing 26 couples of subjects show that the structure of the hyper-brain networks corresponding to situations in which individuals play cooperatively is significantly different from cases of couples playing in a selfish way. Specifically, the hyper-brain network obtained from a couple of players both playing as defectors exhibits the best modular separation into two clusters corresponding to the ROIs of the two distinct brains. On the contrary, the ROIs of the two brains are more intertwined when the two players adopt cooperative or tit-for-tat strategies. We also found that the modifications of the connectivity between ROIs in the frontal and pre- frontal areas of the couples brains are the main responsible of the structural changes discriminating collaborative from selfish behaviors. Finally, we tested the possibility to predict the outcome of a game from the structural analysis of the hyper-brain network obtained from signals recorded during the decision- making process. This suggests that EEG hyper-scanning and hyper-brain networks allow the direct observation of

neural signatures of human social interactions, and might play a key role in understanding the cerebral processes generating and generated by social cooperation or competition.

### Bargaining Dynamics in Exchange Networks

M. Draief*

*Imperial College, London, United Kingdom*

The concept of Nash bargaining on general graphs has been the focus of much recent research in economics, sociology and computer science. In a bargaining system, players make pairwise agreements to share a fixed wealth available to each pair of players. Bargaining solutions provide predictions on how the wealth will be shared and how this sharing would depend on players positions in a network describing some notion of relationships among players. The concept of Nash bargaining solution was introduced by Nash for two players, each having an exogenous, alternative profit at its disposal if they were to disagree. Recent research has focused on the concept of Nash bargaining with multiple players where each player has alternative profits determined by trading opportunities with neighbours in a graph. In this talk, we will discuss on the recent progress made in understanding such solutions for networks by focusing on dynamics that yield Nash bargaining stable outcomes.

### Globalization and international integration in the world trade web

G. Fagiolo, R. Mastrandrea*

*Sant'Anna School of Advanced Studies, Pisa, Italy*

The issues of globalization and international integration have received a great deal of attention in the last decade. However, we are still far from reaching a consensus on fundamental questions such as: (i) what do we exactly mean by globalization? (ii) how can one measure globalization? (iii) what level of globalization did we attain? (iv) do we live in a fully globalized world, or can we expect some further increase of the globalization level in the future? In this paper we try to address these questions by proposing a series of statistical indicators measuring globalization and international integration from a complex-network perspective. We employ data on international trade bilateral flows(1948-2000) to build a sequence of weighted-directed networks in order to study network-based distances between countries. We study globalization by exploring the evolution of binary and weighted country-country distances, under the assumption that shorter distances and more concentrated distance distributions implies an increasing integration and world globalization. We also ask whether country average distance is correlated with country per-capita GDP and GDP growth to study the relationship between integration and country size and income. Finally, we compare network-based measures of globalization and integration with more traditional ones (e.g., trade openness), to understand if the former better capture the complexity of the ITN and its non-trivial evolution. Preliminary analyses show that both from a binary and weighted perspective distance distributions have been shifting to the left, hinting to an increasing integration and globalization of trade. Distributions are strongly bimodal, suggesting the presence of two groups of countries in world trade, one belonging to a core characterized by very short bilateral distances, and a fringe or periphery composed of countries that are far from every other in the network.

### The Effects of Network Structure on the Stability of Genetic Control: From Models to Data

M. Girvan*

*University of Maryland, USA*

The complex process of genetic control relies upon an elaborate network of interactions between genes. Our goal is to use simple mathematical models to understand the role of network structure in gene regulation. Here, we focus on Boolean systems, which have received extensive attention as useful models for genetic control. An important aspect of Boolean network models is the stability of their dynamics in response to small perturbations. Previous approaches to stability have assumed uncorrelated random network structure. Real gene networks typically have nontrivial topology significantly different from the random network paradigm. To address such situations, we present a general method for determining the stability of large networks of any specified network topology and predicting their steady-state behavior in response to small perturbations.

Additionally, we generalize to the case where individual genes have a distribution of expression biases, and we consider a nonsynchronous update, as well as extension of our method to non-Boolean models in which there are more than two possible gene states. We find that stability is governed by the maximum eigenvalue of a modified adjacency matrix, and we test this result by comparison with numerical simulations. We also discuss the possible application of our work to experimentally inferred gene networks, and propose that a dynamical instability in the gene regulatory network may be a causal mechanism associated with some cancers.

### Multiplex Modeling of Complex Networks

K. I. Goh*, K. Lee, I. M. Kim

*Korea University, Seoul, Korea*

Most studies on complex networks thus far have focused on the properties of networks with a singular or aggregated link-type. Recently, it is increasingly appreciated that many real-world systems are better represented by a network of multiplex structure with coupled, interacting, or interdependent connection types. In such systems, the collective dynamics may exhibit behaviours unanticipated from a simplex network approach. In this perspective, we study cascading dynamics on multiplex network systems, generalizing our recent work on cascade dynamics in the global economic system [1]. By comparing with its simplex counterpart, we study how the collective dynamics of cascading failures is affected, finding that multiplex modeling reveals much richer and consequential dynamics than a simplex modeling considering only aggregate connectivity [2]. In particular, we show that a simplex modeling severely underestimates the degree of potential systemic risks as probed by the avalanche sizes obtained from the cascade model. Therefore, we suggest that the multiplexity should be considered an essential concept for a better understanding of real-world complex system dynamics. As a related topic, we also study the connectivity of multiplex network systems under correlated interlayer coupling [3], finding that the correlated coupling may strongly affect the connectivity of multiplex networks.

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### Explosive Transitions in the Synchronization of Complex Networks

J. Gomez-Gardenes*, A. Arenas, S. Gomez, Y. Moreno

*Universidad de Zaragoza, Spain*

Explosive collective phenomena have attracted much attention since the discovery of an abrupt (explosive) percolation transition [1,2]. However, several questions about the microscopic mechanisms responsible of such an explosive transition, its first-order nature and their possible existence in other contexts remain open. In this talk, we report the results shown in [3] where an explosive transition was discovered in the context of the synchronization of Kuramoto oscillators in scale-free networks [4]. The microscopic mechanism responsible of such explosive transition rely on the positive correlation between the structural and the dynamical properties of the system. The characteristics of the explosive transition are intensively studied in several scale-free network models. We also study analytically its properties in a star-graph reproducing the results obtained in synthetic scale-free networks. Our findings represent the first abrupt synchronization transition in complex networks and also provide with a deeper understanding of the microscopic roots of explosive critical phenomena

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### Data clustering using the modular structure of complex networks

C. Granell*, S. Gomez, A. Arenas

*Universitat Rovira i Virgili, Tarragona, Spain*

Unsupervised clustering, also known as natural clustering, stands for the classification of data according to their similarities. Here we study this problem from the perspective of complex networks. Mapping the description of data similarities to graphs, we propose to extend two multiresolution modularity based algorithms to the

finding of modules (clusters) in general data sets producing a multiscales' solution. We show the performance of these reported algorithms to the classification of a standard benchmark of data clustering and compare their performance. Our results are encouraging and open the door for the application of methods developed in the finding of the modular structure of complex networks to data clustering problems.

**The effect of nonlinearity in computing graph theoretic characteristics of complex networks**

D. Hartman*, J. Hlinka, M. Vejmelka, M. Palus

*Institute of Computer Science, Prague, Czech Republic*

Many complex systems can be analyzed as networks of mutually interacting subsystems [1, 2]. These subsystems represent nodes of a graph and edges substitute mutual dependencies between the subsystems. The critical step in constructing such graphs is the choice of a measure of dependence used to define the edges. In many studies linear (Pearson) correlation coefficient has been used. On the other hand, potential use of nonlinear measures has recently been discussed in many fields. In particular, nonlinear approaches uncovered phenomena apparently not detectable using linear measures, e.g. in MEG brain network studies [3] or in climate networks [4]. Nevertheless in many areas more systematic analysis is missing. In this work we compare network characteristics based on graphs computed using either the nonlinear measure of mutual information or the linear (Pearson) correlation. Recently, we have obtained results that for the functional connectivity in the brain resting-state networks computed from fMRI BOLD signals the effect of nonlinearity in computing of network characteristics is negligible, esp. in comparison with intra- and inter-individual variability [5, 6]. Crucially, direct comparison of linear correlation and mutual information might confound the results through the differences between numerical/statistical properties of the used estimators. Instead, we sidestep this effect by applying a common mutual information estimator on two datasets: the original data and their linearized version, where mutual information effectively reduces to linear correlation. The question, whether connectivity is linear or nonlinear, is relevant for any field where mutually dependent subsystems are used as building elements for complex networks. There is an increasing interest in the investigation of climate networks where some studies pointing to nonlinear effects already exist [4], however, these should be understood in the context of nonlinearity observed in long-term meteorological records [7].

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**Gephi: An Open Source Software for Exploring Complex Networks in real-time**

S. Heymann*, J. Bilcke

*Université Pierre et Marie Curie, France*

Gephi is a new open-source network visualization platform for all kinds of networks and relational data: internet topology (machines to machines), peer-to-peer file-sharing networks, biological networks, online social networks, communication and financial networks, but also semantic networks, inter-organizational networks and more. It aims at creating a sustainable software and technical ecosystem, driven by a large international open-source community, who shares common interests in networks and complex systems. Designed to make data navigation and manipulation easy, it covers the entire process from data importing to aesthetics refinements and interaction. Users interact with the visualization and manipulate structures, shapes and colors to reveal hidden properties. The goal is to help data analysts to make hypotheses and to intuitively discover patterns or errors in large data collections. Created with the idea to be the Photoshop of network visualization, Gephi combines a rich set of built-in functionalities and a friendly user interface aggregated around the visualization window. Our approach is to provide a visual tool with a smooth learning curve and an active open-source community supporting the project. The rendering engine can handle networks larger than

100K elements and therefore guarantees responsiveness. In addition of interactive exploration, Gephi embed most critical metrics used in Social Network Analysis, including Betweenness Centrality, Clustering Coefficient, PageRank or Modularity (community detection). More metrics can be added thanks to the extensible software architecture and the open-source code. The modular architecture allows any researcher or developer to extend, reuse and mashup Gephi features in different forms. Efforts are made to facilitate the community growth, by providing plug-ins development documentation, support and student projects. Focus is also made on interoperability, as Gephi can open major file formats, including GraphML, UCINet DL or Pajek. Network results can be exported as PNG, SVG and PDF. Current developments include Dynamic Network Analysis (DNA) and improvements on visualization capabilities on desktop using shader techniques on GPU, WebGL for the Web and customizable renders for information visualization research. The talk is a general presentation of the Gephi project and the opportunities for researchers to use it in practice, build added-value plug-ins based on their studies and engage with the international community.

### Inferring coupling structure from dynamics in complex systems: consequences for graph-theoretical analysis

J. Hlinka*, D. Hartman, M. Vejmelka, M. Palus

*Institute of Computer Science, Prague, Czech Republic*

Characterisation of complex systems commonly involves the study of their interaction structure using graph theory [1]. In the study of real-world dynamical complex systems, the location and relative strengths of the underlying structural links is usually not fully known. Sometimes, theoretical models and available data are used to infer the structural links through model inversion, however there are limitations to such approach. Therefore, the interactions are commonly quantified directly from the dynamical data by the dependence or synchronisation of the generated time series rather than the underlying physical or coupling network of connections. While one still has to deal with the difficult question of choice of suitable dependence measure, this can be in principle answered by statistical and quantification methods [2,3]. It is increasingly recognised that various confounding factors may affect graph theoretical analysis of complex systems, such as the system spatial structure and its sampling [4]. In the presented study, we study the hypothesis that there may be implicit tendencies towards specific graph structures due to the very approach of quantifying of links by the dependence between time series, rather than from strength of the structural coupling. An example of such an effect lies in potentially increased levels of clustering in Pearson correlation coefficient-based graphs, further affecting the estimates of small-world indices. In an extreme case we show that, even with a random coupling matrix, the dependence time series can show signs of small-world structure, particularly increased clustering under conserved average path length with respect to a corresponding random graph. After elucidating this effect using simple multivariate linear process with Gaussian innovations, we document it on example nonlinear systems. We also study the dependence of this effect on parameters such as coupling matrix density and coupling strength and assess the remedy potential of methods controlling for common drivers, such as partial correlation or various directional (causality) measures. The described phenomena have direct relevance for the study of a wide range of complex dynamical systems, including but not limited to climatic [5] and brain [6] networks. Most importantly, the interpretation of results of graph-theoretical analysis of these systems should with great care take into account the specific origin of the analysed connectivity patterns.

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### Complex systems science: dreams of universality, reality of interdisciplinarity

P. Jensen, J.-B. Rouquier*

*Rhone Alpes Complex Systems Institute (IXXI), Lyon, France*

Databases on scientific publications (bibliometry) have recently reached a scale and quality allowing to shed new light on the structure of science (scientometry). Some even expect a new "quantitative science of science".

However, current publications are still mostly descriptive, which nonetheless allows to better understand the global structure of science thanks to rich maps of science [1]. Thanks to a database of almost all European articles published in hard science in 2000 and 2007, where each article is geolocalized (thanks to author's affiliations), we study the network of European cities through their scientific collaborations. We also offer some quantitative and geographic analysis. We give special attention to the role of hubs cities, to the competition among cities from one country with respect to the rest of Europe, to the most visible articles, and to distance and borders.

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### A measure of individual role in collective dynamics: from critical spreading to diffusive processes

K. Klemm*, M. Angeles Serrano, V. M. Eguíluz, M. San Miguel

*Leipzig University, Leipzig, Germany*

Identifying key players in collective dynamics remains a challenge affecting a great variety of research fields, from the efficient dissemination of ideas to drug target discovery in biomedical problems. The difficulty lies at several levels: how to single out the role of individual elements in such intermingled systems, or which is the best way to quantify their importance. Centrality measures aim at capturing the influence of a node from its position in a network. The key issue obviated is that the contribution of a node to the collective behavior is not uniquely determined by the structure of the system but it is a result of the interplay between dynamics and network structure. Here we show that dynamical influence measures explicitly how strongly a node's dynamical state affects collective behavior [1]. The dynamical influence of a node is obtained as its entry in the eigenvector of largest eigenvalue of a coupling matrix specific to the dynamics. For epidemic spreading and dynamics of Boolean (Kauffman) networks, the coupling matrix is essentially the adjacency matrix. The Laplacian matrix is considered for diffusive processes such as phase-coupled oscillators and the voter model. For critical and moderately supercritical epidemic spreading, dynamical influence targets nodes according to their spreading capabilities. Predictions by dynamical influence are found to be more accurate than those based on shell-index [2]. For diffusive processes, dynamical influence quantifies how efficiently real systems may be driven by manipulating the state of single nodes.

[1] Klemm, Serrano, Eguiluz, San Miguel, e-print arXiv:1002.4042. [2] Kitsak et al., Nature Physics 6, 888 (2010).

### A study of Online Geo-Social Networks: Metrics and Applications

C. Mascolo*

*University of Cambridge, United Kingdom*

The use of online social network tools from mobile phones has recently opened the door to very fine grained research on human behaviour and use of space. Mobile phones are equipped with GPS which gives users the ability to signal their position with high accuracy. Online social networks allow the users to indicate whom they are friend with and whom they interact with. As a result, data sets collected from these geo-social network tools are very rich, offering geographical, temporal and social dimensions of users. In this talk I will introduce generally our work on new metrics to analyze location based social networks, giving examples from our analysis of Gowalla, Twitter, Foursquare and Brightkite. In particular I will define metrics to express the locality of a user (i.e., how local a user is based on where his friends in his social networks are) and the geographic clustering coefficient (which defines how geographically spread friendship triangles are). The metrics allow us to perform a number of analysis in terms of user profiling as well as space profiling on which i will report. I will then discuss application of these metrics which include a friendship prediction framework and the study of geo-social content cascades on these networks which may lead to improvement in content delivery network caching.

### Multi-stage cascades on networks

S. Melnik*, J. Ward, J.P. Gleeson, M.A. Porter

*University of Oxford, United Kingdom*

Cascades resulting from initially localized events manifest in many areas of human life and society and attracted a considerable amount of recent interest [1-5]. The transmission of epidemics and the dissemination of fads

and innovations in social networks, or the spread of computer viruses and cascading failures in infrastructure networks can all be viewed as cascades of activations in which agents become active as a result of a contact with single or multiple sources of activation. Studying models of cascades allows us to gain insights into these processes, to determine conditions for the appearance of global cascades, and to open new prospects for applications ranging from the estimation of systemic risk in financial systems to finding the best strategies for viral marketing. To date researchers have mostly focused on binary dynamics, meaning that each agent can be in two possible states which are termed, for example, inactive and active [1-5]. Active agents influence their inactive peers by persuading them to adopt a certain behaviour, idea or product. When the total amount of influence on a given agent exceeds some threshold, specific to the agent, the inactive agent becomes active and starts influencing its own inactive friends, thereby promoting the spread of the cascade. It is usually assumed that all active agents exhibit the same amount of influence on their peers. Very often, however, such binary description of agents in a system is not adequate. Regular users of, say, a certain product are often more enthusiastic in recommending the product to their friends than just casual users. Supporters of a political party can vary significantly in their desire and ability to recruit new members, and so do fans and fanatics of a sport team, a gadget, or a website. These examples suggest that new models for describing spreading dynamics that will include multiple stages of adoption are needed. We introduce an analytically tractable threshold model of multi-stage cascades on networks, in which agents can exert different amount of influence on their peers depending on the stage of their adoption (i.e., the level of their commitment to a certain product or idea). This model allows us to track the evolution of several subpopulations which can describe, for example, agents who are completely unaware of a certain idea, those who have somewhat accepted the idea, and those who have become keen adopters of that idea. As the agents transition through different stages of adoption, they can exert a different amount of influence on their peers. Therefore, the multi-stage model should provide a more realistic description of cascades running in real systems, and enable the observation of new dynamical behaviour. We investigate the dynamics of our multi-stage cascade model on various networks and observe the interplay between cascades, i.e., one cascade driving the other one or vice versa, that cannot be observed in single-stage cascade models. We also provide an analytical method for solving the model which, for example, gives a good prediction for the expected sizes of cascades on configuration model networks.

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### Components in time-varying graphs

V. Nicosia*, J. Tang, M. Musolesi, G. Russo, C. Mascolo, V. Latora

*Università di Catania, Italy*

The classic theory of complex networks treats graphs as static objects, in which the ties representing the relationships among nodes are given once and for all. However, links in complex networks from the real world are inherently fluctuating over time and exhibit more dimensionality than an analysis based on standard static graph measures can capture. In this work we extend the notion of connectedness, and the definitions of node and graph components, to the case of time-ordered sequences of graphs representing time-varying networks. We show that the problem of finding strongly connected components in a time-varying graph is NP-complete, since it can be mapped to the problem of discovering maximal-cliques on a suitable static graph: the affine graph. We report and discuss the results of temporal component analysis we have performed on different empirical human contact networks. These results clearly show that even simple properties of temporal graphs, such as connectedness, are not appropriately modelled by a static representation of the graph, and that the introduction of time in the description and modelling of complex networks produces a much richer and more authentic picture of reality.

### Collapse of network complexity promotes rapid escalation in conflicts

A. Nowak*, W. Borkowski, L. Bui-Wrzosinska

*University of Warsaw, Poland*

Empirical data in social psychology show that low complexity of cognitive representations is associated with intense interpersonal conflicts. Our experiments with human subjects show that simple representations of the

partner are associated with abrupt, catastrophic pattern of escalation, while complex representations promote incremental patterns of escalation. Computer simulations were used to explore the nature of the relationship between complexity of networks representing cognitive representations and the escalation of conflicts. The results indicate, that in networks with low complexity of connections opinions evolve to extreme values, while in networks of high complexity moderate opinions are likely to be adopted. The analysis of the vector space clearly indicates that the network dynamics corresponds to fold catastrophe, both with respect to the linearity of change and hysteresis. Computer simulation results closely match empirical results obtained in experiments with human subjects. The results have clear practical implications for both conflict resolution and strategies for mediations in conflicts.

### Rotated multifractal network generator

G. Palla*, P. Pollner, T. Vicsek

*Eötvös University, Budapest, Hungary*

Network models have been always playing a crucial role in complex network theory. On the one hand they enable singling out the simplest aspects of the studied systems and, thus, are extremely useful in understanding the underlying principles. On the other hand they can also help testing hypotheses about measured data. A recently introduced general network model is provided by the Multifractal Network Generator, which was inspired by the recent discovery of the intimate connection between the limiting objects of graph sequences and 2d functions. This approach is based on drawing link probabilities from a 2d multifractal measure obtained from a very simple generating measure in a recursive multiplicative process. A very unique feature of this construction is that with the increasing systems size the generated graphs become topologically more structured. By changing the parameters of the generating measure the obtained random graphs can show diverse features (e.g., the degree- or clustering coefficient distributions can take up very different forms). Although the described network generator has been shown to provide a simple and very flexible tool for creating random graphs, a slight disadvantage is that it can also lead to isolated nodes, whose number is relatively low for realistic cases, but may become dominant in the limiting case of infinitely large network sizes. Here we discuss the relation between this effect and the information dimension for the 1d projection of the link probability measure, and argue that the node isolation can be avoided by a simple transformation of the link probability measure based on rotation.

### Characterization of spatial network-like patterns from junctions geometry.

A. Perna*, P. Kuntz, S. Douady

*Institut des Systemes Complexes, Paris Ile-de-France, Paris, France*

We propose a new method for quantitative characterization of spatial network-like patterns with loops, such as surface fracture patterns, leaf vein networks and patterns of urban streets. Such patterns are not well characterized by purely topological estimators: also patterns that both look different and result from different morphogenetic processes can have similar topology. A local geometric cue -the angles formed by the different branches at junctions- can complement topological information and allow to quantify the large scale spatial coherence of the pattern. For patterns that grow over time, such as fracture lines on the surface of ceramics, the rank assigned by our method to each individual segment of the pattern approximates the order of appearance of that segment. We apply the method to various network-like patterns and we find a continuous but sharp dichotomy between two classes of spatial networks: hierarchical and homogeneous. The first class results from a sequential growth process and presents large scale organization, the latter presents local, but not global organization.

http://arXiv: 1101.1133

### Finding and testing network communities by lumped Markov chains

C. Piccardi*

*Politecnico di Milano, Italy*

Identifying communities (or clusters), namely groups of nodes with comparatively strong internal connectivity, is a fundamental task for deeply understanding the structure and function of a network. Yet, there is a lack

of formal criteria for defining communities and for testing their significance. We propose a sharp definition which is based on a significance threshold. By means of a lumped Markov chain model of a random walker, a quality measure called "persistence probability" is associated to a cluster. Then the cluster is defined as an "alpha-community" if such a probability is not smaller than alpha. Consistently, a partition composed of alpha-communities is an "alpha-partition". These definitions turn out to be very effective for finding and testing communities. If a set of candidate partitions is available, setting the desired alpha-level allows one to immediately select the alpha-partition with the finest decomposition. Simultaneously, the persistence probabilities quantify the significance of each single community. Given its ability in individually assessing the quality of each cluster, this approach can also disclose single well-defined communities even in networks which overall do not possess a definite clusterized structure.

### Information Theoretic Measures of Network Structure

J. Reichardt*

*UC Davis, USA*

In many systems, complexity arises through the interplay and interdependence of system constituents in interaction networks. Network function is intimately linked to the structure of these interaction networks. Understanding these structures holds the key to understanding the function of the system. Of particular interest are structures arising due to latent characteristics of system constituents. Recent years have witnessed a surge of methods and algorithms to detect latent classes of nodes in networks. In this talk, I will give a brief overview of the different approaches underlying these methods. In particular, I'll show how information theory can be used to ground them on a common basis and how it motivates and connects with a network's spectral properties and probabilistic generative models of network formation.

### Maps of non-random walks on networks

M. Rosvall*

*Umea University, Sweden*

Researchers often use random walks as a model for information flow on networks to, for example, identify influential nodes or find integrated communities. But real information flow in social and biological networks is rarely random but often highly structured. In my talk, I will discuss how the code structure of the map equation can make use of and reveal regularities in empirical information flow or higher order models of real information flow.

### Path lengths, correlations, and spreading dynamics in temporal networks

J. Saramäki*

*Aalto University, Finland*

In temporal networks, where nodes are connected through sequences of temporary events, information or resources can only flow through paths that follow their timeordering. The properties of these temporal paths play a crucial role in dynamic processes: consider, e.g., simple SI spreading dynamics, whose speed is determined by the time it takes to complete such paths. I will discuss temporal path lengths and distances, their measurement, and their relationship to static graph distances. With the help of time-domain null models, one can also measure the effects of temporal correlations and heterogeneities, such as burstiness, on temporal distances and spreading processes. These effects may be very different: in human communication networks, temporal heterogeneities are seen to increase temporal distances and slow down spreading dynamics, whereas in an air transport network their effect is the opposite.

### Detecting non-cliquish communities in complex multiscale networks

M.T. Schaub*, J.C. Delvenne, S. Yaliraki, M. Barahona

*Imperial College, London, United Kingdom*

The recent interest in complex networks has resulted in an increasing number of methods for community detection in graphs. As part of this trend, there has also been a development of benchmark graphs with

well- defined community structure (see e.g. [1]) that can be used to assess the performance of different algorithms [2]. Although not always obvious, some community-detection methods as well as benchmark graph models adopt implicitly a particular notion of community that assumes communities can be described approximately as a probabilistic realisation of a clique or a block model. This means that the intra- and inter-community connectivities are described only by their average values. However, many real networks with marked community structure do not conform to this notion in that the connection probability between nodes is not homogeneous within (or between) communities. We show that certain community-finding heuristics can lead to over-clustering in graphs where the community structure is far from being clique-like. Consequently, the evaluation of algorithms on cliquish benchmarks may also vary significantly from their performance in such real applications. This failure is particularly prominent in community-detection methods that can be recast as one-step methods: for clique- like communities, one-step transitions, as encoded by the adjacency matrix, suffice to span the communities and find the correct community structure, while this is not the case for non-cliquish communities. A remedy is provided by community-finding methods that exploit fully the structural information of the graph and the multi-step flows it can support to identify communities that are not clique-like. The recently introduced framework of stability [3,4] provides such a link through the use of time as a tool to uncover graph structure consistently at all scales, in what amounts to a multi-step approach to community detection. Examples of graphs where these effects are relevant include grids and graphs with significant local structure such as geometrically (or geographically) embedded networks, e.g., supply and transportation networks including the Internet autonomous-system network, power grids, sensor networks and other biological and technological systems. In these networks, the connection probability between nodes is strongly influenced by the distance between the nodes and thus communities do not display a clique-like structure. We illustrate our work with examples drawn from diverse areas, such as image segmentation, structural clustering of proteins and the analysis of power grids.

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### Epidemic spreading on evolving networks: a quarantine-generated phase transition

F. Vazquez*, C. Lagorio, L.A. Braunstein, P.A. Macri, M.V. Migueles, M. Dickinson, H.E. Stanley, S. Havlin

*Max-Planck Institute for the Physics of Complex Systems, Germany*

In this work, we study the propagation of epidemics on evolving social networks. We focus on the susceptible-infected-recovered (SIR) model, and explore how the spread of the disease is effected by a quarantine mechanism, in which the susceptible population try to isolate infected individuals by reducing contacts with them. This is achieved in the model by allowing susceptible individuals to disconnect their links to infected neighbors with probability w, and reconnecting them to other susceptible individuals chosen at random. Starting from a single infected individual, we show by an analytical approach and simulations that there is a phase transition at a critical rewiring (quarantine) threshold $w_c$ separating a phase ($w < w_c$) where the disease reaches a large fraction of the population from a phase ($w > w_c$) where the disease does not spread out. We find that the initial topology of the network strongly affects the size of the propagation and that $w_c$ increases with the mean degree and heterogeneity of the network. We also study a preferential disconnection mechanism in which the probability that an infected node loose a link is proportional to its degree. We find that this heterogeneous rewiring rule is much more efficient in preventing the spread of the disease, as compared to the constant rewiring rule.

C. Lagorio, M. Dickison, F. Vazquez, L. A. Braunstein, P. A. Macri, M. V. Migueles, S. Havlin and H. E. Stanley, PRE 83, 026102 (2011).

### Spatial alignment of physical and social ties in daily dynamics of urban communities

F. Walsh*, A. Pozdnoukhov

*National University of Ireland, Maynooth, Ireland*

This work explores the evolution and spatial organization of urban communities in a daily cycle of a city using scalable social network analysis methods. Using mobile phone records we investigated calling and movement

patterns of about 500.000 citizens of Dublin in a course of a typical weekday. The analysis revealed spatial patterns in community structures at fine spatial scales which are most likely related to the activities typical to the different functional regions of a city. To our knowledge this is the most detailed analysis both in terms of spatial and temporal resolution carried out to date on this type of data. We combined two methods adopted from the study of complex networks to examine the time varying spatial structure of communities in an urban environment. The spatial structure of these communities was observed from the analysis of the short-term aggregates of traffic on a mobile telephone network. The analysis was based on an origin destination matrix of calls and text messages between customers. In our case study we used the cells of the network as the spatial areas rather than administrative boundaries. Cells in urban areas are typically very small due to high population densities and so offer high spatial resolution. Rather than using the customer's home address, each end of the call was geo-located to the cell used at the time of the call. The mobile phone network is by definition dynamic, with phone users constantly moving. We use time-of-call locations in an attempt to capture these dynamics. Finally, and most importantly, we perform community detection at multiple snapshots in time, and then analyse the change in community composition. We use a combination of geographical and graph-based layouts tied into a single view with a joint color space and a 3D alluvial diagram to visualize and interpret these changes. We observed that different communities are found at different times of day, especially in urban areas where the population and communication habits vary with the time of day. A distinct pattern of transitions and transformations of the communities at the temporal scales of several hours and sub-kilometer distances was observed. This is most likely related to the cycles in professional and social activities of the citizens, showing the tendency to communicate locally within professional and social groups localized at particular city districts during the course of the day. Our combined fine resolution movement-communication analysis has several implications for understanding urban structure. It is able to capture the fundamental properties of human behavior in terms of communication and transportation habits, as well as opening ways to aid decision making in introducing social policies, optimise resource allocation and refine planning of the city infrastructures. Particularly, we have observed a distinct North-South divide that splits the city into two parts separated both in terms of communication and physical movement. We observed an existence of small distinctive communities showing poor communication with the outside world that might indicate ongoing alienation and segregation processes. Generally, these findings also show a further need to extend the typology of community evolution events used in state-of-the-art network evolution models to implicitly incorporate spatial relations at a variety of temporal scales.

### Self-organized criticality in a model of trade: aggregate fluctuations from independent sectoral shocks investigated on a mixture of randomly distributed and scale free topologies

N. Zachariou*, P. Expert, K. Christensen

*Imperial College, London, United Kingdom*

A long standing problem in macro-economy is explaining the mechanisms leading to the large fluctuations in aggregate production across different sectoral activities. This question can be rephrased to "How is it that many different industries decide to produce more synchronously or why the do the sectors go down at the same time and the economy as a whole reaches a crisis?" Even though this phenomenon is observed, and is crucial in the creation of business cycles, it is rather counter-intuitive, as independent sectoral excitation would tend to average out. Bak et al. [1] proposed a simple directed lattice model exhibiting self-organised criticality to explain these high fluctuations. The key ingredient is that industrial sectors are not independent, but correlated via indirect interaction coming from the structure of the consumer-producer network, hence potentially leading to large fluctuations. The production cycles are initiated by stochastic demands from end consumers, at the top layer of the lattice. As pointed out in Carvalho [2] the layered and directed lattice topology is highly unrealistic. In this study, we generalise the model and systematically investigate the effect of topology on the behaviour of aggregate production. More specifically we try to establish the conditions under which self-organised criticality is realised in these models [3]. The system consists of a large number of production units each, where the dynamics evolve from simple trade rules. Each production unit buys goods from its supplier neighbouring units (k-out degree). It then produces goods proportionally to the number of units to which it sells goods (k-in degree). In Bak's original model, k-in=k-out=2. As we change the topology of the interaction network, we adapt the rules of the model, such that demand and production are conserved. We start with a higher coordination number on directed lattices and then generate networks with Erdos-Renyi randomly distributed in and out-degrees, whilst keeping a layered organisation. We then generate networks with scale-free distributed in and out-degrees in an overall layered organisation. Finally, we marry the two topologies to produce a more realistic economy consisting of networks with Erdos-Renyi in-degree and scale-free out-degree distributions, as is observed in real systems.

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# Complexity in Energy Infrastructures: Models, Metrics and Metaphors

**Organizers: M. Zanin, F. Lillo**

### A framework for development of energy security indicators

V. Kopustinskas, R. Bolado*, M. Masera

*European Commission, Institute for Energy, Petten, The Netherlands*

This paper presents a framework for the development of a composite energy security indicator in the European Union. Various energy supply sources are analyzed: oil, gas, coal, nuclear, renewables, each providing a number of individual indicators that are combined into a uniform metrics of energy security level for each EU member state. Having a framework for quantification of energy security, the effect on energy security of different policy options, infrastructure changes or supply diversification can be analyzed. Although analysis performed by indicators cannot substitute a detailed system level analysis, it can provide an overview of the current energy security situation and highlight strength and weaknesses of the energy infrastructure in the EU. The framework can also be used for determining the needs for a detailed system level analysis of a particular energy infrastructure network and its interdependency study with other energy infrastructures (e.g. gas pipeline network dependence on electricity grid reliability).

### Assessing the reliability of the European power grid using load curve indicators and topological characteristics

C. Brancucci Martinez-Anido*, G. Fulli, M. Vandenbergh, R. Bolado, M. Masera

*European Commission, Institute for Energy, Petten, The Netherlands*

The European power grid is the largest complex physical network ever made by human kind.The assessment of its reliability has been an ambitious and attractive as well as necessary research field over the past decades. In particular, the assessment of the European power grid by means of topological measures has garnered a great deal of interest among the scientific community.The extension of its analysis and the correlation between load curve indicators and fault events in the European power grid are the main goals of this paper. The mission of a power grid is to transmit and distribute electricity in order to reliably serve the load. This objective is, inter alia, challenged by the variations of electricity demand over time. In other words, the load curve shape, featuring large fluctuations over a 24 hour period, determines the amount of energy which must be delivered. Two very important measures for power system reliability are the energy not supplied and the restoration time after a fault event. Both values affect electricity consumers who at the same time drive the dynamics of the balance between generation and demand. Therefore, the comparison and analysis of load curve shapes throughout Europe can contribute to explanations of complex and variable fault events in the power grid. The paper intends to expand previous work assessing the European power grid reliability in terms of topological measures by extending the time frame of events and taking into account the effect of a large blackout. Moreover, load curve indicators throughout several European countries, derived from load curve characteristics such as peak and valley power levels or power over energy ratio, are described and used as additional factors to assess European power grid reliability. Considering these attributes, the central question arises, is there any correlation between load curve indicators and occurrence of power disruptions in the European power grid? The approach used in the paper leaves some open questions to be discussed. For instance, are 9 years of registered fault events in the European power grid sufficient to analyse their correlation with load curve indicators and topological characteristics?

### An uncertainty analysis of the potential impact of shale gas on the global energy system

F. Gracceva*, A. Costescu Badea

*European Commission, Institute for Energy, Petten, The Netherlands*

Energy systems are complex systems, i.e. sets of interconnected components forming an integrated whole. Their collective properties cannot be found among the properties of the elements, and their behaviour cannot

be explained just in terms of the behaviour of the parts. Traditional energy system definition is technology oriented, including all the extremely complex, interrelated chains of commodities and processes linking the extraction of primary energy to the satisfaction of the demands for energy services. In this paper we use the ETSAP-TIAM model to carry out an uncertainty analysis of the potential impact of unconventional gas on global energy trade. ETSAP-TIAM (TIMES Integrated Assessment Model) is a detailed, technology-rich global TIMES model. It is a multi-region partial equilibrium model of the energy systems of the world divided in 15 regions. Trade variables of energy forms and of emission permits are linking the regional modules. The model comprises explicit descriptions of more than one thousand technologies and one hundred commodities in each region, logically interrelated in a Reference Energy System covering extraction, processing, conversion, trading, and end-uses of all energy forms. On the one hand, such technological detail allows precise tracking of capital turnover and provides a description of technological competition: model constructs a coherent image of the future energy system by choosing a mix of technologies to invest in and operate at each future period, with the objective of maximizing total surplus, while respecting the many constraints of the model. On the other hand, the technological detail of a TIMES model, if high from an energy system perspective, is clearly too limited to address the complex behavior of energy infrastructures, whose simulation calls for higher granularity in terms of time steps and network representation. But energy system scenarios can be complemented with network simulators: the former can provide the necessary consistent technological evolution of the whole energy system, while the latter can be useful to identify the more technical requirements demanded by the energy system scenarios. The strengths of TIMES models lie in the fact that they are systems model. The interactions and feedbacks in the energy system are not always intuitive: reducing demand for a fuel in one economic sector, for instance, might lower its cost and therefore increase its use in another. Such real-world trade-offs in technological and economic feasibility often emerge only at the systems level. TIMES models quantify the system-wide effects of changes in resource supply and use, technology availability, environmental policy. Unconventional gas is often portrayed as a game-changer in both the regional and global gas markets, after its recent unprecedented growth in the United States. Interest has spread to potential resources in other geographical locations, but there is still a large uncertainty around the global potential of shale gas, due to both the actual level of its resources in different world regions and to their actual cost of extraction. As such, an energy system uncertainty analysis is particularly suitable to explore the potential impact of shale gas on the global energy market and its trade infrastructures. To perform this uncertainty analysis, we first need to identify the main uncertain parameters of interest related to shale gas. They are uncertain because it is not possible to know them exactly as a single value; moreover they might have large variabilities (as is often the case for new technologies). In a second step we will characterize their probability distribution using the existing literature. Complex models, such as TIMES, are often costly and time-consuming to run; for this reason we are able to run the model only a limited number times. At the same time, for meaningful results, we need a good coverage of the input parameters space. The solution we chose is to sample the joint distribution of the input parameters by space-filling latin hypercube sampling. Finally, after running the model as many times as the sample size, we use the corresponding values of the outputs to statistically characterizes the distribution(s) of the outputs. The high level of uncertainty surrounding shale gas, combined with the complexity of the global energy system, means that the actual evolution of the technology can indeed lead the global energy system towards very different directions. Our purpose in this paper is to explore the extent of those possible directions. We will also carry out a sensitivity analysis, which consists in apportioning the variation in the output of a model to different sources of variation in the input of the model, enabling us to decide which are the more influent input parameters. The limitation of this approach, even if take into account all the pertinent input parameters, is mainly the limited number of runs of the code. A possible amelioration is to use the limited number of runs to build a surrogate model of the energy system model and then perform the uncertainty and sensitivity analysis using Monte Carlo simulations of the surrogate model.

### Smart Grid as a Complex Multilayer Interacting System

E. Bompard, B. Han*, E. Pons, M. Masera

*Politecnico di Torino, Dipartimento di Ingegneria Elettrica, Torino, Italy*

In this paper, we consider emerging decision making problems confronted with large penetration of distributed generations and storages. Especially, we address the problem of searching a solution for decision makings with intensified complexity coming from diversified behaviors of independently initiated prosumers, as well as interactions among them and with other system players. Such problems are oriented in our framework of complex power system, thus incorporating related social, technical, economical and environmental issues as a whole to be optimized. Within each issue, underlying individual objectives, behaviors and constrains have to be considered. Such multiple interactive issues are already too heterogeneous to be expressed within a single set

of equations, let alone computations. Based on MAS (multi-agent simulation), where individual arbitrariness and realities can be considered almost as detail as game designers want, complex decision making problems generated from our framework can be implemented, learned, and evaluated through predesigned MAS models; evolutions of complex power system and interactions inside can be captured with utmost concretes. Future projections such as Smart Grids can be simulated ex-ante; perplexities that may arouse can be diagnosed and even resolved in advance. In addition, simple application examples are provided as an illustration of how we use the framework of complex power system and MAS for such emerging decision making problems.

### Price Spikes in Electricity Markets and Stochastic Resonating Spiking

C. Lucheroni*

*Università di Camerino, Camerino, Italy*

Hourly electricity price time series show peculiar patterns very different from those found in the more studied stock and bond price series, like spikes and antispikes that are fired occasionally but only in specific parts of the day. Standard top-down models try to capture electricity prices behaviour in path and distributional properties only, whereas hybrid models try to include in a few degrees of freedom physical and organizational features coming from the intrinsic network structure of power markets. In such markets agents coordinate strategically through partially competitive market institutions about electricity delivery through the physical power grid. Consequently, network congestions and other tight market conditions can show up in price series as strong nonlinearities and threshold effects, and often appear as price spikes. Effective models should be able to relate microeconomics with complex financial behaviour. In this talk, a class of nonlinear hybrid models for electricity prices will be presented, that use a Hopf critical point stochastic dynamics to generate price spikes, and that are able to include in their degrees of freedom typical and more general tight markets behaviour. A first model will be presented in the frame of SETARX (Self-Excited Threshold AutoRegressive eXternally driven) and switching regime modelling of electricity time series, a second model will be presented in the frame of FitzHugh-Nagumo models. The major microeconomic feature included in the models is the presence of capacity constraints and power grid congestions, that can act on prices at varying levels of demand. These factors introduce a demand threshold in the price formation mechanism. Below the threshold prices react smoothly to demand variations, above the threshold prices can react in a non-smooth way, with spike-like patterns. In the SETARX frame, a three-regimes SETARX is chosen, where one AR sector is set in the usual stable regime, two other sectors are set respectively in unstable and metastable regimes in a specific sequence. These two not-stable regimes together allow of nonlinear deviations from the stable regime, sustaining spikes. TARX self-excitation avoids linking the regime thresholds to data different from the prices themselves, and demand data are unnecessary to calibration as far as a sinusoidal driver is embedded in the model. If desired, real world demand data can be used as an external driver process in substitution of the embedded driver. In the presentation, it will be discussed how to estimate the models on hourly electricity data.

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### Capacity analysis of DC Power Grids.

J. van Mourik*, R. Kühn

*Aston University, Birmingham, United Kingdom*

We introduce semi-realistic models of DC power distribution networks based on modular random graphs of finite connectivity. The nodes of the graph represent the hubs of the network, while the edges of the graph represent its lines/links. We impose Ohm's and Kirchoff's laws, and distinguish between production, distribution and consumer (end-user) nodes. Both the line resistances of the links, and the degree distributions of the nodes (determined by the inter- and intra-group connectivities), can be chosen to reflect the statistical properties of realistic power grids. We analyse these models using thermodynamic equilibrium techniques to obtain the limits of capacity of such networks in terms of average connectivities under various load conditions (demand). Since we can distinguish between the contributions for the different types of node and link, we are able to identify the part of the distribution grid that forms the bottle neck. The theoretical results are

confirmed qualitatively and quantitatively by those obtained for explicit realisations of the graph, thus confirming the validity of our approach.

**Towards an interdisciplinary approach for the simulation of future smart grid architectures from a complex systems science point of view**

P. Viejo*, E. Kremers, M. Hernandez Tejera, J.J. Hernandez, J. Evora, P. Langlois, E. Daude, J.M. Gonzalez de Durana, O. Barambones

*European Institute for Energy Research, Karlsruhe Institute of Technologie, Karlsruhe, Germany*

Energy systems worldwide, and specially power infrastructures, are facing major changes this century. There are a number of challenges related to the introduction of renewable energy sources, new usages and behaviors as well as the introduction of IT systems, which are emerging into a paradigm change in energy infrastructures. This article presents an overview of the interdisciplinary research work under development in three different countries on the creation of methods and tools for the simulation, analysis and planning of future smart grid architectures. In opinion of the authors, future smart grid systems will evolve toward complex systems architectures, and therefore, new tools and methods are needed. This change is closely related to the main changes in production means, the evolution of consumption patterns and the decentralization of decisions. Furthermore, interdisciplinary approaches will be necessary to deal with these new challenges, as for example: geographical (local) approaches, IT systems and new software development, engineering competences and operational research. The work presented here shows the benefits of this approach and the opportunities open for the future. Two case studies are presented: the PREMIO platform simulation, first Smart Grid of France; and the project MILLENER, and its simulation of the energy systems of the Reunion Island. Both examples are based on interdisciplinary approaches, and developed in an international context. A methodology has been developed to represent, in an easy and flexible way, all the entities that are present in a complex energy system, as well as their behavior. Through this framework, simulation models can be created, as well as easily add or remove elements, introducing constraints and create scenarios. As result of these collaborations, the new simulation tools developed are able to encapsulate the complexity of the system and its emergent behavior.

# Econophysics Colloquium

**Organizers: T. Di Matteo, P. Richmond, S. Thurner**

### Comparison of multivariate time series methods for financial time series

J. Abilio, J. A. O. Matos*

*University of Porto, Porto, Portugal*

The focus of this study is the analysis of multivariate time series. There are several methods suitable to be applied to multivariate time series like the traditional covariance, either simple or weighted (giving more weight to more recent values and with a geometrical decay in time), or the more recent Brownian distance covariance. There are other intrinsically non linear methods like the similarity measures based on mutual information and more generally on other Kullback-Leibler distances. When the results are given in a matrix form we can decompose the matrix using either the Principal or the Independent Component Analysis. The similarity measures allow us to create (hierarchical) clusters grouping the related series using the closeness relations defined by the similarity measures. The interest and application of these methods is recognized both in Econophysics as well in other areas. In this work these methods are applied to financial time series and its results are compared with the results available in the scientific literature.

### Understanding logistics, internet and corporate through the dynamic triangle of performance

A. Angheluta, C. Costea*

*ASE, Bucharest, Romania*

As the incredible growth of the Internet has dramatically changed the way corporations conduct their business, Logistics service providers must consider it when rethinking the e-Logistics system to accommodate it to the dynamics of the commercial world. The purpose of this paper is to provide a better understanding of how organizations utilize e-Logistics within their supply chain and how to flexibly the competitive advantage along with the economic crisis so that losses diminish. The complex approach of transportation and logistics chain and processes together with their collateral consequences moves our study to better model the utilization of the Human Resources. To reach this purpose, we focused on the factors that influence the e-Logistics system. From the interviews and collected data, the findings show that the e-Logistics system can be described as a network creating value process. The findings further indicate that reliability factors, maintainability factors, software factors and facility, transportation and handling factors, all influence the e-Logistics system. On the other hand, availability factors, economic factors, organizational factors and test and support equipment factors are of low-level importance for e-logistics system. The second part of the paper focuses on how e-logistics will change the multinational traditional logistics systems and how we can measure (Key Performance Indicators) these changes.

### Statistical Physics of Labor Productivity

H. Aoyama*

*Kyoto University, Kyoto, Japan*

While main-stream economics insists that labor productivity is equal among firms and sectors based on the general equilibrium theory, the truth is far from it. Empirical study of the labor productivity in various industrial sectors of Japan and several European countries reveal that labor productivity is distributed with fat tail at the higher end, which is described very well by the power laws. This shows the complete failure of the equilibrium theory and necessitates new theoretical framework in which this empirical fact is explained. Because of this, theories of labor productivity is rapidly being developed during the last few years. In this talk, we will present our empirical facts and theoretical frameworks, including negative temperature theory,

in which empirical facts are explained.

### Information Filtering by Complex Networks

T. Aste*, T. Di Matteo

*University of Kent, Canterbury, UK*

The continuous increase in the capability of automatic data acquisition and storage is a fundamental element for our progress that is providing unprecedented potentials. However, despite the fact that huge amount of data are accumulating the relevant information remains hidden and information filtering is becoming a crucial bottleneck of the present times. The need for better analytical tools to handle high dimensional data is broad and demands are coming form several research fields across physics, engineering an biology. We are developing a novel framework to study and model high-dimensional complex data by combining graph theory approaches with statistical physics methods. Our approach is based on the idea of building graphs associated to the information contained in the original data-set and then reducing redundancy and interwovenness by means of a topological embedding on surfaces. We have been developing a technique that is effective in capturing both the local clustering and the global emerging dynamics. In the talk the concepts underneath our methodology will be explained in general terms and applications to biological and financial datasets will be shown.

T. Aste, W. Shaw and T. Di Matteo, New J. Phys. 12, 085009 (2010). T. Di Matteo, F. Pozzi, T. Aste, Eur. Phys. J. B 73, 3 (2010). M. Tumminello, T. Aste, T. Di Matteo, R.N. Mantegna, PNAS 102, 10421 (2005).

### Asymmetric transmission of long-run volatility in the stock market

S. Bentes*, R. Menezes

*ISCAL, Lisboa, Portugal*

The last two decades have been characterized by a growing interest in the application of nonlinear time series techniques to the analysis of financial data. Nowadays, ample empirical evidence has been gathered for both nonlinearity and structural changes in the dynamic properties of many observed time series. In this work, we employ models based on abrupt transition autoregressive (TAR and M-TAR) techniques in order to investigate the impact of volatility in the US stock returns on the volatility of stock returns in Portugal and Germany. The asymmetric effects both in the mean and variance render the behavior of financial time series a complex process which is difficult to be captured by linear models. While most researchers agree that volatility is predictable in many asset markets, what differs among them is how this prediction should be modeled. Variations are necessary to adapt the standard GARCH model to the need arising from examining the time series properties of specific issues in finance and economics. In recent years the evidence for predictability has led to a variety of approaches, among which the most interesting are the asymmetric volatility models. One of the established stylized facts of financial markets is that, generally, volatility after negative shocks is higher than volatility after positive shocks. The aim of this paper is to investigate the changes in the long-run asymmetric equilibrium relationships between two developed stock markets of different sizes (Portugal and Germany) by using the Enders and Siklos (2001) asymmetric threshold models TAR and M-TAR. The preliminary results show that there is evidence of asymmetric effects of the US volatility on the volatility of Portugal and Germany both in the TAR and M-TAR and that both deep and steep asymmetric movements co-exist in the volatility. Future work will be directed to analyze other nonlinear endogenous effects in these series and to expand the analysis to other world financial blocks.

### Extracting similarity information from word association networks

M.L. Bertotti*, G. Modanese

*Free University of Bolzano, Bolzano, Italy*

We propose a family of models for the taxation and redistribution process in closed market societies. The models are expressed by systems of nonlinear ordinary differential equations, which describe the evolution in time of the income distribution over the population based on the interactions of single individuals. Investigation of the long-time behavior of the solutions of these systems provides evidence of asymptotic stationary

distributions with power-law tails of Pareto type. Anomalous price impact and the critical nature of liquidity in financial markets

### Multiplicative noise, moment scaling, and fast convolution

G. Bormetti*, D. Delpini, S. Cazzaniga

*Scuola Normale Superiore, Pisa, Italy*

Many different physical phenomena exhibit a complex behavior characterized by long-range correlations, long-time memory, scale invariance, and the emergence of non Gaussian distributions associated to their statistical description. Deviations from the Maxwell-Boltzmann statistics were usually considered as a clear mark of an out of equilibrium system, but in the last years it has been recognized that Normality is not the most general paradigm describing the equilibrium state. Indeed, in terms of a microscopic description provided by the Langevin equation, power-law tails stem naturally assuming the damping coefficient to have a stochastic nature. From a macroscopic point of view, the superposition of an additive Gaussian noise with a multiplicative one leads to a Fokker-Planck equation with linear drift and quadratic diffusion coefficients. In this talk we provide a full description of these processes in terms of their moments, allowing for a quite general time dependence for both coefficients. This class of processes has been proven to be very successful in describing the time evolution of stochastic volatility in the context of financial time series modeling. It is also extremely convenient from a computational point of view; indeed, the quadratic diffusion can be formally manipulated to reduce it in a suitable form for computing integrals in functional space by means of fast algorithms. In this respect it is known that one of the relevant tasks when dealing with stochastic processes consists in reconstructing efficiently conditional probability density functions. In this talk we present numerical evidences of the advantages provided by fast Fourier algorithms applied to the class of processes under consideration. Eventually, we draw some perspectives concerning the pricing of financial derivatives.

### Anomalous price impact and the critical nature of liquidity in financial markets

J.P. Bouchaud*

*Capital Fund Management, Paris, France*

We propose a dynamical theory of market liquidity that predicts that the average supply/demand profile is V-shaped and vanishes around the current price. This result is generic, and only relies on mild assumptions about the order flow and on the fact that prices are (to a first approximation) diffusive. This naturally accounts for two striking stylized facts: first, large metaorders have to be fragmented in order to be digested by the liquidity funnel, leading to long-memory in the sign of the order flow. Second, the anomalously small local liquidity induces a breakdown of linear response and a diverging impact of small orders, explaining the square-root impact law, for which we provide additional empirical support. Finally, we test our arguments quantitatively using a numerical model of order flow based on the same minimal ingredients.

### Network analysis of countries' production

G. Caldarelli*, M. Cristelli, A. Gabrielli, L. Pietronero, A. Scala, A. Tacchella

*National Research Council of Italy, Roma, Italy*

Here we applied methods of graph theory to the analysis of the economic productions of countries. The information is available in the form of a rectangular matrix M of size Nc times Np, giving the different production of the Np goods for each country in the Nc list. This can be transformed with some linear algebra into a country-country and product-product network. In these latter forms, by using complex-networks analysis, we can attain an effective filtering of this information. We introduce here a new community coding algorithm that identify cliques of countries connected by their common production. As an unexpected result, this analysis shows that neighboring countries tend to compete over the same markets. We also show that a classification of goods based on such community detection provides a bottom up taxonomy that can be used

to determine countries activity.

### Evidence of Multifractality from CEE Exchange Rates against Euro

P. Caraiani*

*Romanian Academy, Bucharest, Romania*

I test for the presence of multifractality in the daily data on selected exchange rates from Central and Eastern European economies against euro. The approach is based on the Multifractal Detrended Fluctuation Analysis. I also assess the drivers of the multifractal spectrum strength, like temporal correlation or nonlinearity based on surrogate data. Another topic discussed is whether the entrance in the exchange rate mechanism ERM II influences the multifractality of the exchange rates.

### Dynamic aggregation in the times of heterogeneous interacting agents and network: an analytical solution for agent based models

C. Di Guilmi, M. Gallegati*, S. Landini, J.E. Stiglitz

*Universita Politecnica delle Marche, Ancona, Italy*

One of the consequences of the failure of mainstream theory in convincingly taking into account the heterogeneity of agents is the misrepresentation of markets with asymmetric information. In fact, the consideration of players with diverse information sets is at odd with the idea of the representative agent. The Global Financial Crisis spectacularly exposed this inconsistency, casting doubts on the core neoclassical assumptions for the representation of markets. Moreover, standard modelling techniques leave no or little room for agents inter-action, which is the most intriguing and relevant corollary of the heterogeneity. In this paper we propose a model with heterogeneous and interacting firms and banks, which is solved analytically. Methodologically, the economy is modelled as a network, a theoretical structure which is particularly suitable to represent the interactions among different individuals. In this credit network firms interact directly with banks and, indirectly, among themselves. The main novelty is the use of the master equation to perform the aggregation over a population of heterogeneous firms and to describe the endogenous evolution of the network. The asymptotic solution of the master equation provides a system of coupled equations, governing the dynamics of growth and fluctuations of the network degree.

### Is the gravity model able to predict the topological properties of the international-trade network?

M. Duenas*, G. Fagiolo

*Sant'Anna School of Advanced Studies, Pisa, Italy*

Complex-network approaches offer an appropriated framework for understanding the International-Trade Network (ITN), defined as the graph of import/export relationships between world countries. In this paper, we ask whether the workhorse economic theoretical and econometric model of international trade, i.e. the gravity model (GM), is able to satisfactorily reproduce and explain the observed ITN topology and weighted-network structure. The term "gravity" recalls the Newton's formula, where the magnitude of aggregated trade flows between a pair of countries is proportional to the product of country sizes (e.g. the masses, as proxied by GDPs) and inversely proportional to their geographic distance, interpreted as proxies of trade-resistance factors, e.g. tariffs. We fit bilateral trade flows, based on the GM, using three procedures: standard OLS, Poisson pseudo-maximum likelihood (PPML), and two-stage zero-inflated Poisson (ZIP). In particular, the ZIP model, as opposed to standard OLS, explicitly estimates the probability of observing zero flows, which is extremely high in trade data and can severely bias estimates, but modifying the network's binary structure. We use GM predictions of trade flows with OLS, PPML and ZIP to build predicted binary (adjacency) and weighted trade matrices. We then compute standard network statistics (e.g. node-degree and strength distributions, clustering, assortativity coefficients, etc.) on both observed and predicted networks to study whether predicted ones match over the years observed patterns, i.e. to ask whether the GM satisfactorily explains the ITN architecture and its evolution over time. We also perform extensive Monte Carlo simulations to estimate confidence intervals around predicted network statistics. Our main conclusion is that most of

weighted-network properties strongly depend on the binary structure. Nonetheless, GM fits quite well, on average, the observed first-order (local) properties, like node strengths or observed disassortativity. However, higher-order statistics such as weighted node-clustering can hardly be reproduced.

### Globalization and international integration in the world trade web

G. Fagiolo, R. Mastrandrea*

*Sant'Anna School of Advanced Studies, Pisa, Italy*

The issues of globalization and international integration have received a great deal of attention in the last decade. However, we are still far from reaching a consensus on fundamental questions such as: (i) what do we exactly mean by globalization? (ii) how can one measure globalization? (iii) what level of globalization did we attain? (iv) do we live in a fully globalized world, or can we expect some further increase of the globalization level in the future? In this paper we try to address these questions by proposing a series of statistical indicators measuring globalization and international integration from a complex-network perspective. We employ data on international trade bilateral flows(1948-2000) to build a sequence of weighted-directed networks in order to study network-based distances between countries. We study globalization by exploring the evolution of binary and weighted country-country distances, under the assumption that shorter distances and more concentrated distance distributions implies an increasing integration and world globalization. We also ask whether country average distance is correlated with country per-capita GDP and GDP growth to study the relationship between integration and country size and income. Finally, we compare network-based measures of globalization and integration with more traditional ones (e.g., trade openness), to understand if the former better capture the complexity of the ITN and its non-trivial evolution. Preliminary analyses show that both from a binary and weighted perspective distance distributions have been shifting to the left, hinting to an increasing integration and globalization of trade. Distributions are strongly bimodal, suggesting the presence of two groups of countries in world trade, one belonging to a core characterized by very short bilateral distances, and a fringe or periphery composed of countries that are far from every other in the network.

### An analysis for firm size distributions classified by sector of industry

S. Fujimoto*, A. Ishikawa, T. Mizuno, T. Watanabe

*Kanazawa Gakuin University, Kanazawa, Japan*

We analyze for firm size distributions such as sales, assets, number of employees and total factor productivity by using the database of Bureau van Dijk's ORBIS. This database contains comprehensive information on 63,000,000 firms worldwide for the years 1999-2009. Differences of the distributions classified by country have been reported in our previous study. In this presentation, we emphasize differences of distributions classified by sector of industry. Four-digits standard industrial classification (SIC) code is attached to firms in the database. We clarify differences among firm size distributions by sector of industry. In addition, by using SIC code, firms can be aggregated in various levels such as minor, middle or major classification. We investigate firm distributions in three different aggregation levels.

### The Behaviour of the Electronic European Interbank Market to the Financial Turmoil

G. Gabbi, G. Germano, V. Hatzopoulos, G. Iori*, M. Politi

*City University London, London, UK*

We present an empirical analysis of the European electronic interbank market of overnight lending (e-MID) during the years 1999-2009. The main goal of the paper is to explain the observed changes before, during and after the 2007-2008 financial crisis, of the cross-sectional dispersion of lending/borrowing conditions. Unlike previous contributions, focusing on banks' dependent and macro information as explanatory variables, we address the role of market microstructure as a determinant of the credit spreads. Combining econometrics and network analysis techniques we investigate if banks who experience better credit condition, both as lender

and borrower, play strategically and exploit market opportunities.

### Self-organized model of cascade spreading

S. Gualdi, M. Medo*, Y.-C. Zhang

*Fribourg University, Fribourg, Switzerland*

We study simultaneous price drops of real stocks and show that for high drop thresholds they follow a power-law distribution. To reproduce these collective downturns, we propose a minimal self-organized model of cascade spreading based on a probabilistic response of the system elements to stress conditions. This model is solvable using the theory of branching processes and the mean-field approximation. For a wide range of parameters, the system is in a critical state and displays a power-law cascade-size distribution similar to the empirically observed one. We further generalize the model to reproduce volatility clustering and other observed properties of real stocks.

### Derivatives and Credit Contagion in Interconnected Networks

S. Heise, R. Kuehn*

*King's College London, London, UK*

The importance of adequately modeling credit risk has once again been highlighted in the recent financial crisis. Defaults tend to cluster around times of economic stress, both because the profitability of firms tends to suffer in poor macro-economic conditions, but importantly also by defaults directly triggering each other through contagion. In the last two decades, the dynamics of contagion has been radically altered by credit default swaps which have created pervasive new forms of financial dependencies. Models quantifying the consequences for systemic risk are, however, still missing. Here we examine contagion through credit default swaps in a stylized economic system composed of networks of corporates and financial institutions. We show that credit default swaps, when used to expand banks' loan books, can have destabilizing effects on the entire network. This can result in considerably enhanced probabilities for the occurrence of large losses and high default rates in the system. Our approach adds a new dimension to research on credit contagion, and could feed into a rational underpinning of an improved regulatory framework for credit derivative markets.

### Hurst exponent decomposition and crashes on the financial markets

L. Kristoufek*

*Charles University, Prague, Czech Republic*

The idea of using local Hurst exponent for predictions of upcoming market crashes has already been applied in several research papers. In our research, we try to get more information from the scaling represented in Hurst exponent of the series. As local Hurst exponent is usually estimated on rather short series, we cannot really talk about long-range dependence in the series, but rather a scaling of variance (measures in various manners represented by different methods of the exponent estimations). To decompose the Hurst exponent, we analyze the behavior of variances at different scales to get additional information. In our analysis, we study the behavior of variances at the lowest and the highest scale as well as their ratio (appropriately rescaled). By doing so, we can compare the trading activity of different investors groups with different horizons. Similarly, we use the intercept from the Hurst exponent regression as a proxy of an investment horizon close to zero and thus a proxy of trading activity of traders with a very short investment horizon. These measures are taken as indicators of an upcoming crash or turning point on the market. The logic is quite simple when investors anticipate that a current trend is about to change, they start selling and thus they switch from long-term investors to short-term investors. Other indicators, which could be measured from the variance scaling, are as follows standard error of the Hurst exponent estimate (a measure of stability of scaling), standard deviation of variances at the lowest and the highest scale (for significance reasons of their differences) and a sum of variances at all scales (as a measure of total variance). To show a usefulness of the method, we analyze the recent crashes on the stock markets as well as FX markets and bond markets.the correlations between the

performances of the names into our studies.

### How efficiency shapes market impact

F. Lillo*

*Scuola Normale Superiore di Pisa, Pisa, Italy*

We develop a theory for the market impact of large trading orders, which we call metaorders because they are typically split into small pieces and executed incrementally. Market impact is empirically observed to be a concave function of metaorder size, i.e. the impact per share of large metaorders is smaller than that of small metaorders. Within a framework in which informed traders are competitive we derive a fair pricing condition, which says that the average transaction price of the metaorder is equal to the price after trading is completed. We show that at equilibrium the distribution of trading volume adjusts to reflect information, and dictates the shape of the impact function. The resulting theory makes empirically testable predictions for the functional form of both the temporary and permanent components of market impact. Based on a commonly observed asymptotic distribution for the volume of large trades, it says that market impact should increase asymptotically roughly as the square root of size, with average permanent impact relaxing to about two thirds of peak impact.

### Do interest rate changes affect stock market volatility?: The European Union experience

R. Menezes*, S. Bentes

*ISCTE-IUL and UNIDE-IUL, Lisboa, Portugal*

This paper analyzes the impact of interest rate changes on the volatility of stock market returns using daily data collected from Datastream over a period of more than 20 years. Since the time period under analysis spans from 1990 to 2011, two periods of high volatility in stock markets are covered by this study: the beginning of the current decade and the recent subprime crisis. Of special interest is the analysis of the impact of interest rate changes on stock returns over the most recent crisis and whether high stock returns volatility is likely to persist as long as interest rates remain at high levels or, otherwise, the volatility of stock returns will tend to behave independently of the level of interest rates as time passes. In the latter case, one would observe that, for instance, the volatility of stock returns will become rapidly lower even if interest rates remain at high levels or that the volatility will remain at high levels although interest rates may decay significantly. In the former case, one would observe a systematic co-movement of both series. In this study we adopted a mean-variance multivariate framework to model both the mean effects of interest rate changes on stock returns and the asymmetric and nonlinear effects of the former on stock returns volatility (the variance equation). Asymmetric effects caused by bad news are captured by an EGARCH variance equation while persistence or long-memory is modeled by a FIGARCH variance equation. Both models account for volatility clusters and fat tails as well as other typical characteristics of stock market returns data. We apply this methodology to 15 countries including 14 EU countries belonging to the Euro zone plus the US. Since there has been plenty evidence that the US usually drives the behavior of worldwide stock markets it is important to add this data series to our analysis. The results show that interest rate changes affected significantly the volatility of all stock market returns since 2008 but in most cases this effect declined sharply (and almost to the pre-2008 levels) towards 2010 and 2011. The exception was, perhaps not surprisingly, the PIGS countries where such effects lasted over time until now. At the same time, persistence increased quite significantly for most countries and only Austria, Denmark, Finland, Ireland and Portugal report persistence coefficients lower than 0.5 during the crisis and post-crisis period. For Ireland and Portugal this seems to mean that after the initial impact, interest rates will no longer affect the volatility of stock markets. For the UK and the US, high volatility persistence appears to cohabit with lower interest rates towards the end of the period but for all other countries there is some evidence that stock returns and interest rate changes co-move over time. The percent increase in persistence for the crisis period versus the pre-crisis period was, on average for these 15 countries, 25% for short-term maturities and 21% for long-term maturities.

### Analysis of high frequency news using the Reuters NewsScope database

T. Mizuno*, K. Takei, T. Ohnishi, T. Watanabe

*Fribourg University, Fribourg, Switzerland*

We study the impact of news in New York Stock Exchange. We first focus on the occurrence frequency of the news for each company, and next investigate the relationship between the number of news and the

realized volatility. We analyze historical dataset of transaction price and news that is published by Thomson Reuters from 2003 to 2009. We extract the news concerning about 100 companies, which are composed of top 50 companies in global market capitalization and 50 companies randomly chosen from rank 500 to 1000 in global market capitalization, and count up the number of those companies' news individually. We investigate relationship between the mean and the standard deviation of frequency of news for each company. If the frequency of news follows Poissonian proses, the standard deviation is proportionate to a square root of the mean. However, such characteristic is not observed. Therefore, the frequency does not follow Poissonian proses. Next, we investigate market impacts of news. By the influence of the Lehman shock in 2008, the stock price fluctuated violently and a lot of news was made. We can find a liner function on the relationship between number of news and volatility. In this presentation, we will also show the relationship between news and transaction volume.

### Two Different Types of Scaling for Analyzing Financial Markets Crisis

R. Morales, R. Gramatica*, T. Di Matteo, T. Aste

*King's College London, London, UK*

The aim of this work is to have deeper insights in how financial crisis can be studied and forecasted by using tools which look at the scaling behaviour of financial time series. There are two types of scaling behaviour studied in the finance literature: the behaviour of some forms of volatility measure as a function of the time interval on which the returns are measured and the behaviour of the tails of the distribution of returns as a function of the size of the movement by keeping the time interval of the returns constant [1,2]. The recent unfolding of the 2008-2009 'credit crunch' financial crisis has made all of us aware that in real markets very large fluctuations can happen with finite probability. By looking at the tails of the distributions of prices of 395 stocks traded in the US equity market in the time period between 1 January 1996 and 30 Aprl 2009 [3], we have studied how the inclusion of the crisis affects the tail index values. Reliability and robustness of the results have been tested by means of different statistical tests. We have then looked at the scaling behaviour by means of the generalized Hurst exponent (GHE) that has been proved to be relevant in characterizing the different degree of development of the market [2]. The dynamics of the GHE shows some interesting trends that cluster stocks in the market sectors they belong to. The dynamics is also conveying interesting information as far as the crisis is concerned. In particular, it is observed that stocks belonging to the financial sector exhibit a tendency in increasing their scaling exponent in correspondence to the unfolding of the crisis.

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### Bootstrapping the economy – a non-parametric method of generating consistent future scenarios for the world economy

U.A. Muller, P. Blum, M.M. Dacorogna*, A. Wallin

*SCOR Switzerland, Zurich, Switzerland*

The fortune and the risk of almost every business venture depends on the future course of the economy. There is a strong demand for economic forecasts and scenarios that can be applied to planning and modeling. We present here a method to simulate the future of the world economy. The economy is represented by key variables such as interest rates (yield curves), inflation, GDP and equity indices, all of these for several currency zones, plus the foreign exchange rates between the currencies. The ambitious goal is to generate a set of consistent stochastic scenarios that represent the space of likely future developments. This goal is pursued by resampling historical values in a sophisticated manner. While there is an ongoing debate on modeling economic scenarios, the bootstrapping (or resampling) approach has several advantages. As a non-parametric method, it relies on past market behaviors rather than debatable assumptions on models and parameters. Empirical distributions and dependencies between economic variables are automatically captured. Historical innovation vectors (deviations of actual variable values from their prior market expectations) are sampled and used for simulated scenarios. Several straightforward extensions of the method help to overcome some limitations of the original bootstrapping method. The limited historical data used for resampling may not contain extreme innovations, but a well-defined modification makes sure that return distributions can have

fat tails, and a small number of simulated scenarios will have an extreme behavior. This is important for a realistic modeling of risks due to shocks. While the original method disrupts serial dependencies, another extension re-establishes clusters of volatility through a GARCH model of innovations. Long- term trends and long-term mean reversion effects such as purchasing power parity are introduced as small correction terms in the market expectations. Thus the method becomes suitable for long-term simulations over many years, as tests and applications have shown. More economic variables and currency zones can be added due to the modularity and flexibility of the method. In their main application, the authors compute simulated values for asset classes such as equities, bonds, mortgage-backed securities, hedge funds and real estate, for six currency zones: US Dollar, Euro, Yen, Sterling, Swiss Franc and Australian Dollar.

### A Computational Model of Market Share Instability

T. Onozaki*, T. Yanagita

*Rissho University, Tokyo, Japan*

We study a simple model of market share dynamics with boundedly rational consumers and firms interacting with each other. As the number of consumers is large, we employ a statistical description to represent firms' distribution of consumer share, which is characterized by a single parameter representing how rationally the mass of consumers pursue higher utility. Firms with various strategies compete with each other by differentiating their products in order to avoid price competition. Simulation results show that (1) market share is relatively unstable at the early stage of the industry life-cycle and is relatively stable at the mature stage, (2) three phases of market structure, i.e. the uniform share phase, the oligopolistic phase, and the monopolistic phase, appear depending upon how rational consumers are and how heterogeneous firms' strategies are, (3) in an oligopolistic phase, the market share distribution of firms follows Zipf's law, and (4) an oligopolistic phase is the best state of market in terms of consumers' utility and firms' profit in the long run.

### The economic complexity of countries and products

L. Pietronero*

*ISC-CNR, Univ. Sapienza, Roma, Italy*

We discuss a recent new approach to the complexity of countries and products in the spirit of the recent papers by Hidalgo and Hausmann (PNAS 2009). The basic information is represented by the matrix of countries and exported products. The standard economic analysis is essentially based on the GDP but the diversification of this into a series of different products provides an additional element of fitness in the spirit of biodiversification in a fluctuating enviroment. In fact the idea that specialization of countries towards certain specific products is considered as optimal in the standard analysis, but this could only be valid in a static situation. The strongly dynamical situation of the world market suggests that flexibility and adaptability are also important elements. The basic idea is to introduce a Fitness parameter for each country which is able to take into consideration this effect. Such an analysis, selfconsistently also leads to a ranking of the Quality of the products. These concepts are implemented with the use of statistical concepts inspired to the page rank (Google) problem may lead to a novel classification for the fitness of the countries and the quality of products which adds new information with respect to the standard economic analysis. This information can be used in various ways. The direct comparison of the Fitness with the country GDP gives an assessment of the non expressed potential of the country. Also for each country it is possible to define the quality of the products exported and how competitive is this country with respect to the other countries which produce the same product. Finally it is possible to make a planning for the optimal development of a country by considering its potential for adding a new product.

### Exploring the SABR volatility model

A. Pogudin*, D. Brigo, T. Di Matteo

*King's College London, London, UK*

The Black-Scholes model was the first widespread universally accepted approach in the theoretical modelling of prices of options on financial securities [1]. One of the drawbacks of the approach is that it does not explain

some of the important empirical facts observable in financial markets such as the volatility smile/skew in option markets [2]. A significant number of models were proposed to account for this empirical fact. One of the models which gained particular popularity recently is the Stochastic Alpha Beta Rho model (SABR) [3]. The SABR model is de facto the most widespread framework for pricing and modelling the volatility skew in interest rates markets for all expiries and tenors [4] and [5]. There are several reasons for its popularity. One of them is that the calibration of the model using the approximate Hagan's formula to market prices/implied volatilities is easy and straightforward. Another reason is a transparent effect of the parameters on the skew/smile. Also, the model suggests the correct dynamics of the smile, consistently with market experience. We discuss advantages and disadvantages of the model. We look in depth into the mechanics of this model and compare its theoretical implications with actual market dynamics. We also explore different specifications of the model including Markovian projections [6]. We investigate implications of our results for pricing of deep out of the money options. Overall, the results highlight benefits and drawbacks of the model and suggest new directions for further research.

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### Switching Point Analysis of Financial Markets

T. Preis*

*Artemis Capital Asset Management GmbH, Holzheim, Germany*

Financial market fluctuations are characterized by many abrupt switchings creating upward trends and downward trends, on time scales ranging from macroscopic trends persisting for hundreds of days to microscopic trends persisting for a few minutes. The question arises whether these ubiquitous switching processes have quantifiable features independent of the time horizon studied [1,2]. We find striking scale-free behavior of the transaction volume before and after each switching. We test the possible universality of our result by performing a parallel analysis of fluctuations in time intervals between transactions. We suggest that catastrophic bubbles that occur on large time scales - such as the most recent financial crisis - may not be outliers but single dramatic representatives caused by the formation of increasing and decreasing trends on time scales varying over nine orders of magnitude from very large down to very small.

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### House prices in London and Dublin: An update

P. Richmond*

*CASL University College Dublin, Dublin, Ireland*

A few years ago (2006) we analysed data for house prices in both London and Dublin. An outcome of the analysis was that the then level of house prices would not be sustained and a fall in prices was imminent. How have prices fared since that time? How good was our prediction? In this presentation we review recent developments and update our analysis. It will be suggested that so-called fundamental traders dominate the dynamics of the price movements. Additional insight into the influence of interest rates will also be presented.

### Combining Random Matrix Theory and Information Theory methods to highlight relevant information from Financial Data

J. M. R. T. Salgado*, J. A. O. Matos

*University Porto, Porto, Portugal*

In the study of multivariate time series, Information Theory and Random Matrix Theory methods are complementary methods. Entropy, a special case of Kullback-Leibler divergence, is one of the key measures of

Information Theory. Random Matrix Theory deals with matrix-valued random variables and is of interest to filter the relevant information over statistical fluctuations in cross correlation matrices. Random Matrix Theory and Information Theory have a wide range of applicability, like, for example, multivariate statistics, computer science, nuclear physics, signal processing, cryptography, quantum computing and number theory. The main objective of this work is to present our latest results in this effort to combine Information and Random Matrix Theories in the study of the most relevant worldwide stock market indices in a multivariate scenario. We study the system dynamics taking into account the time dependency of the most significant eigenvalues extracted from the covariance matrices. The joint use of Information and Random Matrix Theories in finance gives a complementary view of the data in order to search for early warning information and for signs of information transfer between time series.

### Monte Carlo Portfolio Optimization

W.T. Shaw*

*University College London, London, UK*

We develop the idea of using Monte Carlo sampling of random portfolios to solve portfolio investment problems. We explore the need for more general optimization tools, and consider the means by which constrained random portfolios may be generated. DeVroye's approach to sampling the interior of a simplex (a collection of non-negative random variables adding to unity) is already available for interior solutions of simple fully-invested long-only systems, and we extend this to treat, lower bound constraints, bounded short positions and to sample non-interior points by the method of Face-Edge-Vertex-biased sampling. A practical scheme for long-only and bounded short problems is developed and tested. Non-convex and disconnected regions can be treated by applying rejection for other constraints. The advantage of Monte Carlo methods is that they may be extended to risk functions that are more complicated functions of the return distribution, without explicit gradients, and that the underlying return distribution may be modeled parametrically or empirically based on general distributions. The optimization of expected utility, Omega, Sortino ratios may be handled in a similar manner to quadratic risk, VaR and CVaR, irrespective of whether a reduction to LP or QP form is available. Robustification is also possible, and a Monte Carlo approach allows the possibility of relaxing the general maximin approach to one of varying degrees of conservatism. Grid computing technology is an excellent platform for the development of such computations due to the intrinsically parallel nature of the computation. Good comparisons with established results in Mean-Variance and CVaR optimization are obtained, and we give some applications to Omega and expected Utility optimization. Extensions to deploy Sobol and Niederreiter quasi-random methods for random weights are also proposed. Extensions to the value functions of prospect theory are possible. The method proposed is a two-stage process. First we have an initial global search which produces a good feasible solution for any number of assets with any risk function and return distribution. This solution is already close to optimal in lower dimensions based on an investigation of several test problems. Further precision, and solutions in 10-100 dimensions, are obtained by invoking a second stage in which the solution is iterated based on Monte-Carlo simulation based on a series of contracting hypercubes.

### Economic fluctuations and statistical physics: quantifying extremely rare events with applications to the present worldwide crisis

H.E. Stanley*

*Boston University, Boston, USA*

Recent analysis of truly huge quantities of empirical data suggests that classic economic theories not only fail for a few outliers, but that there occur similar outliers of every possible size. In fact, if one analyzes only a small data set, then outliers appear to occur as "rare events." However, when we analyze orders of magnitude more data (200 million data points!), we find orders of magnitude more outliers–so ignoring them is not a responsible option, and studying their properties becomes a realistic goal. We find that the statistical properties of these "outliers" are identical to the statistical properties of everyday fluctuations. For an intriguing variety of switching processes in nature, the underlying complex system abruptly changes at a specific "phase transition" point from one state to another in a highly discontinuous fashion. Examples of phase transitions range from magnetism in statistical physics to physiology and macroscopic social phenomena. Financial market fluctuations are characterized by many abrupt switchings on very short time scales from increasing "microtrends" to decreasing "microtrends"–and vice versa. We ask whether these ubiquitous switching processes have quantifiable features analogous to those present in phase transitions, and surprisingly we find striking scale-free

behavior not only after, but also before the switching occurs. Moreover, we find that the same laws govern the formation and bursting of large bubbles as tiny bubbles, over a factor of 1,000,000,000 in time scale. We interpret our findings as being consistent with time-dependent collective behavior of financial market participants This work was carried out in collaboration with a number of colleagues, chief among whom are T. Preis, J.J. Schneider, S. Havlin, R. Parshani, S.V. Buldyrev and G. Paul.

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### The dynamics of CDOs

M. Stipplinger, E. Racz, B. Vetö, B. Toth, Z. Bihary, J. Kertész*

*Institute of Physics, Budapest, Hungary*

Collateralized debt obligations (CDO-s) consist of credit default spreads (CDS-s) and serve as a hedging tool against bankruptcy of sets of companies (names). They are one of the complex financial products, which have been considered to be responsible for the last global crisis. In spite of the severe criticism against them, their trading has been continued and raises questions interesting both for science and practice. We have developed a compound Poisson model of efficient pricing of CDO-s. We use Monte Carlo simulation and verify the results for a simple and analytically solvable model. We apply weighted Monte Carlo method to increase the speed of the calculations and an automated optimization to find the best values of the parameters. We also make an attempt to incorporate the correlations between the performances of the names into our studies.

### Trend-extraction of Stock Market by Means of RMT-PCA Applied on Daily and Intra-day Price Time Series

M. Tanaka-Yamawaki*, T. Kido

*Tottori University, Tottori, Japan*

We apply the method of RMT-based PCA [1, 2] to extract the temporal trends in the stock market, on wider sets of American/Japanese Stocks and compare the results of different markets, different time intervals as well as different time periods [3]. For example, the trends of 8-years from 1994 to 2001 and another 8-years from 2002 to 2009 extracted from the daily close price data of S&P500 stock prices have been compared, showing the fraction of business sectors (A-J) of the 20 eminent +/- components of the 2nd to the 5th principal eigenvectors. The corresponding eigenvalues have been computed, namely all the 20 eminent, positive-signed components of the 2nd principal eigenvector of the data 1994-2001 belong to J (Utility business) and the negative-signed parts of the same data belong to H (IT business), which are replaced by A (Energy) and G (Financial) in the term 2002-2009.

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### Chemical Picture of Extreme Dynamics in the Singapore Stock Exchange

B. K. The, W. G. Ong, Y. W. Goo, T. W. Lian, S. A. Cheong*

*Nanyang Technological University, Singapore, Republic of Singapore*

Market crashes are as abrupt and unpredictable as earthquakes. There is, however, an important distinct between the two. Whereas earth scientists are starting to get high-resolution data on a small number of important seismological variables, the financial markets have for a long time been blessed with large volumes of high-frequency data at the individual stock level. Drawing upon the much-lower-quality data of Tycho Brahe, Newton discovered the Three Laws of Motion. Why then have we not formulated the Three Laws of Market Dynamics? We believe the sheer volume of financial data available to us is as much a curse as

a blessing, and that various forms of coarse graining is necessary before the human mind can grasp what goes on during market crashes. In this talk, we will report a time series clustering study of the Singapore Stock Exchange over various violent periods in recent history. We will explain how the price time series of different stocks can be clustered based on their Pearson correlations in a series of sliding windows. We then explain how the slow time evolution of the abundance and compositions of these clusters allow us to develop a chemical picture, involving the reaction and subsequent dissociation of various clusters, of market crashes in the Singapore Stock Exchange.

### The role of leverage in a world of perfect hedging

S. Thurner*, S. Poledna, J.D. Farmer

*Medical University of Vienna, Vienna, Austria*

We use a toy model of the financial market to test the efficiency and dangers of credit regulation schemes. We find that Basle-type regulations work fine in situations of low leverage levels in the financial system, however they become destabilizing in scenarios with realistic leverage levels. We further design an 'ideal world', where all leverage-induced risk is hedged with options. Even by assuming that option writers never default, we see that introducing the heavy requirement of complete hedging does not make the system systemically more secure.

### Financial extreme events, risk, and stratification in the income - Connection to nonextensive statistical mechanics

C. Tsallis*

*Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil*

First we briefly review some central concepts and recent applications of nonextensive statistical mechanics. Then we focus on two recent econophysical applications, namely (i) Ludescher et al consider 16 representative financial records (stocks, indices, commodities, and exchange rates) and study the distribution of the inter-occurrence times $r$ between daily losses below negative thresholds, for fixed mean inter-occurrence time. We find that, in all cases, this distribution follows the $q$-exponential form where the index $q$ depends (in a simple form) on the mean time, but not on a specific asset. Also we analytically estimate the risk function; (ii) Ferrero analyzes the USA 2001 income distributions and identifies a stratification in two main components, both of the $q$-exponential form, one of them with $q = 1$ and the other one with $q = 1.28$.

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### Extracting similarity information from word association networks

M. Tumminello, F. Lillo, J. Piilo, R.N. Mantegna*

*Universita di Palermo, Palerno, Italy*

We use statistically validated networks [1], a recently introduced method to validate links in a bipartite system, to identify clusters of investors trading in a financial market. Specifically, we investigate a special database allowing to track the trading activity of individual investors of the stock Nokia. We find [2] that many statistically detected clusters of investors show a very high degree of synchronization in the time when they decide to trade and in the trading action taken. We investigate the composition of these clusters with respect to the attributes characterizing the investors with a method allowing to estimate the over-expression and under-expression of heterogeneous attributes [3] and we find that several clusters of investors show over-expressions and under-expressions of specific categories of investors, specific combinations of co-occurrence of trading actions, and specific attributes.

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**Collaboration and innovation performance in industrial cluster: a comparison between emergent and efficient innovation networks**

X. Zhuang, W. Huang*, X. Jin, Y. Gao

*Northeastern University, Shenyang, China*

Innovation networks are those linked organizations in industrial cluster (e.g., firms, research institutions, financial institutions, government agencies) that collaborate with each other and acquire the diverse knowledge to innovate. In this paper, we present a model of collaboration and innovation built on the innovation networks which are self organized and evolved. In our model, organizations have different innovation-required knowledge endowments. They benefit from knowledge flows from other organizations with whom they are directly or indirectly connected. Such knowledge flows depend on the strength of the externalities and relational distances between organizations. Meanwhile, they support costs for direct connections which are linearly increasing with knowledge distance. Organizations decide whether to collaborate with others according to the profits that is the difference between revenues from knowledge-innovation process and costs from direct collaborations. The collaborations between organizations make the dynamic process of innovation network formation exhibits preferential meeting for close organizations (in the relational network and in the knowledge space metrics). We make use of network dynamic evolution simulations to compute the emergent innovation networks which are stochastically stable in the long run. As the network structure being fixed, its efficiency, that is, the collaboration and innovation performance in industrial cluster (the sum profits of organizations) is also constant. So the emergent innovation networks do not necessarily have the highest efficiency. However, searching for efficient network structures which maximize the collaboration and innovation performance turns out to be a very difficult analytical problem as well as a huge computational task, even for a relatively small number of organizations. So we use genetic algorithms to find the efficient networks based on the collaboration and innovation model. We then compare the structural properties of emergent and efficient networks by relying upon several indexes (including their corrected ratios) such as average degree, average path length, average clustering coefficient and so on. We find that the network topologies of both emergent and efficient networks are significantly affected by the strength of the externalities. We find critical values of this parameter for which small world emergent networks dynamically appear, while the efficient networks are more close to the stochastic network. We also find the inefficiency sources in innovation networks formation from the network structure view such as the insufficient connections, lack of costly distance connections, too localized connections, asymmetries connections between organizations and so on. Such problems are especially significant when the strength of externalities is weak. At last, we bring up some mechanisms be mobilized to try to overcome such inefficiencies and to promote the collaboration and innovation performance in industrial cluster.

# Frontiers in the Theory of Evolution

**Organizers: H. Meyer-Ortmanns**

### Selection mechanisms in the cultural evolutionary dynamics of language

R. Blythe*

*University of Edinburgh, Edinburgh, United Kingdom*

Evolution is a process of change through replication of DNA in biological evolution, and of human behaviour in cultural evolution. Selection is said to take place when one replicator systematically outperforms another. In this talk I will argue that in the case of linguistic behaviour, one can identify a hierarchy of selection mechanisms that can be directly related to theories of language change of fundamentally different types. In turn, these can be related to models of evolution in population genetics, some of which are traditionally regarded as 'neutral' (i.e., lacking selection) and some not. A closer inspection of these processes reveals that the relevant property governing the time course of change is the presence or otherwise of symmetries between human social roles or between different linguistic behaviours. We argue that only when the latter symmetry is broken (which can be achieved through the classical notion of fitness) does one see the trajectories of change that are widely observed in sociohistorical linguistics. The question of where the asymmetry comes from, however, remains open.

### Ancestor tree in a branching random walk with simple selection

E. Brunet*

*Ecole Normale Superieure, Paris, France*

A branching random walk can be seen as the simplest model of evolution with mutation: each individual at each generation has a certain number of offspring, and each of these offspring inherits the fitness of its parent plus a random number representing the mutation. If, at each generation, the population is kept at a fixed size by choosing $N$ surviving individuals at random (no selection), we recover a Wright-Fisher model with an ancestor tree described by the Kingman coalescent. I will discuss in this talk the radical changes in the ancestor tree when a simple scheme of selection is added.

### Modeling of dynein-mediated microtubule reorganization in cellular morphogenesis

T. Mazel, A. Biesemann, J. Nowald, M. Krejczy, O. Müller, L. Dehmelt*

*Max-Planck-Institute of Molecular Physiology and Dortmund University of Technology, Dortmund, Germany*

Microtubules close to the plasma membrane are pushed by cortically associated dynein motors. Here, we directly observed fluorescence-labeled cortical dynein speckles and microtubule fragments simultaneously in living cells. We find that the dynein heavy chain forms spatially resolved, dynamic speckles at the cell cortex, which are preferentially associated with microtubules. Measurements of bleaching and dissociation kinetics at the cell cortex reveal that these speckles often contain multiple labeled dynein heavy chain molecules and turn over rapidly within seconds. Dynamic behavior of microtubules, including forward movement, bending or rotation, are influenced by association to dynein speckles, suggesting direct physical and functional interaction. A computational model based on known and measured biophysical properties of dynein recapitulates the key properties of microtubule transport and suggests that rapid turnover of cell cortex associated dynein complexes facilitates their search to efficiently capture and push microtubules. Similar mechanisms might be used to organize microtubules during cellular morphogenesis.

### Thermodynamics and kinetics of protocells – toward a quantitative theory of early life

H. Fellermann*, B. Corominas Murtra, R. Solé, S. Rasmussen

*University of Southern Denmark, Odense, Denmark*

The emergence of self-replicating and evolving chemical systems remains a poorly understood event in the history of life. In recent years, several model systems have been proposed in order to study possible transitions

from non-living to living matter [1]. To serve as a model for early life, so-called protocells should be able to perform an entire life cycle, i.e. they must reproduce their components as well as replicate their structure as a whole. They should possess inheritable information that somehow affects their metabolism. Here, we present a thermodynamic framework and stochastic simulation results of a particularly simple protocell design proposed by Rasmussen and co-workers [2-3]. This design features *i)* a cell container composed of fatty acids and fatty acid precursors, *ii)* a metabolism that converts precursors into functional fatty acids, and *iii)* short replicable nucleobase strands that regulate the metabolic turnover rate according to their sequence information. All functional molecules are attached to the outside of the container, thereby nullifying the need for complex nutrient uptake and waste disposal mechanisms. In our approach, protocells appear naturally as thermodynamic engines that drive a metabolism which powers the acquisition of information during evolutionary search [4]. As a consequence, we can quantitatively characterize properties such as work, power, and energetic efficiency of the evolutionary search. This allows us to quantitatively explore the feasibility of microemulsion compartments to serve as containers for these minimal protocells and to analyze the uptake of information in evolution from an energetical perspective.

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### A Computational Model for the Evolution of Metabolic Networks

P. F. Stadler, A. Ullrich, H. Ekker, M. Mann, C. Flamm*

*University of Vienna, Vienna, Austria*

In the literature several competing hypotheses for the evolutionary mechanisms that shape metabolic pathways and the architecture of metabolic networks have been discussed, each of which finds support from comparative analysis of genomes. Alternatively, direct simulation studies on the the principles of metabolic evolution are rare because of the demanding pre-requisites. A central component of such a computational model is an algebraic chemistry model which acts as a substrate on which a metabolism can be selected. This component must be sufficiently involved to mimic the complexity of a modern metabolic network, without restricting the possible chemistry to the "known" extant end results. Furthermore, a genetic system that expresses catalysts and a non-trivial map from sequence and structure features of the catalysts to their respective functions within the metabolic network is necessary. The sequence to function map itself must be evolvable to allow the system to escape constraints set by the initial conditions. Finally, a fitness function that can be selected for and which evaluates metabolic efficiency is crucial. I will give a brief overview of the dominating mechanisms that govern metabolic pathway evolution and the architecture of modern metabolism, followed by an in-depth discuss of the various components that comprise our simulation framework. Finally results from large-scale evolutionary simulations will be presented.

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### Bacterial Games

E. Frey*

*Ludwig-Maximilians-Universität München, Germany*

Microbial laboratory communities have become model systems for studying the complex interplay between evolutionary selection forces, stochastic fluctuations, and spatial organization. Two fundamental questions that challenge our understanding of evolution and ecology are the origin of cooperation and biodiversity. Both are ubiquitous phenomena yet conspicuously difficult to explain since the fitness of an individual or the whole

community depends in an intricate way on a plethora of factors, such as spatial distribution and mobility of individuals, secretion and detection of signaling molecules, toxin secretion leading to inter-strain competition and changes in environmental conditions. We discuss two possible solutions to these questions employing concepts from evolutionary game theory, nonlinear dynamics, and the theory of stochastic processes. Our work provides insights into some minimal requirements for the evolution of cooperation and biodiversity in simple microbial communities. It further makes predictions to be tested by new microbial experiments.

### Evolution of cooperation and punishment in non-anonymous societies

C. Hilbe*

*University of Vienna, Vienna, Austria*

Empirical evidence suggests that the mere opportunity to punish others can act as catalyst for cooperative behaviour. It has been argued that humans are equipped with a taste for punishment, but what is the evolutionary cause for such a taste? Moreover, recent experiments reveal a problematic side of retribution. A non-negligible fraction of subjects abuse sanctioning opportunities to engage in spiteful acts (which can harm cooperators, or everyone) or in revenge (as a response to being punished). Most evolutionary models neglect these issues, but recently it has been shown that the co-evolution of punishment and cooperation is dampened, or fully suppressed, if spiteful actions are available. Here we present a simple game-theoretic approach to show that these negative results hinge on the unrealistic yet common assumption of anonymous interactions. In our model, individuals adapt to the reputation of their co-players and learn to behave opportunistically, by cooperating against players who punish defectors but saving the cooperation costs otherwise. This in turn provides an incentive to engage in costly punishment without being spiteful. To unfold this positive effect, sanctions must neither be too soft nor too severe. Between these two extremes, punishment is targeted at noncooperators only, and leads to stable cooperation. These findings are in line with theories that emphasize the strategic role of emotions: In non-anonymous societies, anger or vengefulness may partly have evolved to serve as a credible signal to bystanders.

### Schumpeterian economic dynamics as a quantifiable minimum model of evolution

P. Klimek*, S. Thurner

*Medical University of Vienna, Vienna, Austria*

We discuss a simple quantitative network model of Schumpeterian economic dynamics. Novel products and services are endogenously created through recombinations of already existing goods. These new products enter the market and compete with other goods which may be driven out from the market and thereby trigger cascades of defects. The model's generic dynamics is characterized by alternating between phases of relative economic stability and phases of massive restructuring of marketplaces. Model time-series of economic productivity and the number of defects reproduces a series of stylized facts of economic time-series such as GDP, business failures, or invention rates – including fat-tailed statistics and volatility clustering. We show that it is possible to understand Schumpeterian economic change as either self-organized criticality. It can be quantitatively controlled by an eigenvalue analysis of the dynamic production networks.

### Evolution on neutral networks: On the topology of RNA sequence space and quasispecies adaptation

S.C. Manrubia*

*Centro de Astrobiologia, Madrid, Spain*

High replication error rates strongly limit the length of sequences that can transmit reliable genetic information. However, this restriction is alleviated when considering that selection acts on the phenotype: the extremely large degeneracy between genotype and phenotype spaces confers robustness (in the form of increased molecular neutrality) to RNA populations. Sets of sequences folding into the same secondary structure form neutral networks in genome space: A population of sequences can move on such networks without seeing its functionality affected, as far as the secondary structure is concerned. The adjacency matrix Aij states whether sequence i can be accessed from sequence j, thus fully describing the structure of the neutral network. The topological

properties of neutral networks determine (i) the time Tn required to attain maximally neutral states and (ii) the diversity of sequences in the population at that state. When information on the energy associated to each sequence is included, topology also affects (iii) survivability of the populations under temperature fluctuations. The position of the maximally neutral region and the diversity of the population once that region has been attained can be analytically obtained through the principal eigenvalue and the corresponding eigenvector of Aij. The relaxation time to that state is obtained from non-principal eigenvalues of Aij. Changes in the strength of selection towards maximally neutral or maximally stable states cause fast transitions in the genomic composition of the population. The complex dynamical behavior of quasispecies on neutral networks will be illustrated through evolution with selection on RNA secondary structure. The topological properties of those networks and the abundance of different phenotypes provide important hints on the navigability of the space of sequences and on the relevance of entropic effects in adaptation.

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### Reconstitution of essential biological processes in the test tube: minimal bacterial divisomes

A. Martos*, M. Loose, M. Vicente, M. Jimenez, G. Rivas, P. Schwille

*TU Dresden, Dresden, Germany*

The bacterial cell division machinery assembles at mid-cell to form a dynamic ring towards the end of the cell cycle [1]. We aim to reconstitute the minimal functional protein set needed to initiate division [2] and the two main positioning mechanisms [3] in minimal systems that reproduce the conditions found in the cell. This bottom-up strategy involves the confinement of the components in a cell-like environment under well-defined and controlled conditions [4]. Consistently, we combine complementary biophysical, biochemical and imaging methodologies to study the biochemical activities, interactions and assembly of division ring elements. Such detailed information would be otherwise difficult to obtain from in vivo measurements. This challenging strategy will provide not only information to understand the factors that modulate the formation of the ring at the mid-cell but also a synthetic procedure to reconstruct the initial events of bacterial division in the test tube. This novel approach is of general application to the construction of minimal assemblies from other biologically relevant systems.

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### Effective spatial organization from simple cytoskeletal elements

F. Nedelec*

*Cell Biology Unit, EMBL, Heidelberg, Germany*

Living cells have a system of fibers and associated proteins, called the cytoskeleton, that provides an essential mechanical support during migration, polarization, division, etc. Cytoskeletal fibers form spontaneously by self-assembly of monomers, and multiple fibers can further self-organize into assemblies of cellular scale. In this talk, we will introduce our simulation approach with the aim to study systems of many fibers. We will illustrate simple collective effects that have the potential to organize the cellular space. We will also illustrate how artificial evolution can be used to systematically explore the possibilities embedded in a cytoskeletal system.

# Hierarchy: From the Definition to the Characterization of Complex Systems

**Organizers: B. Corominas-Mutra, C. Rodriguez-Caso, J. Goni**

### Dynamic and static analysis of transcriptional regulatory networks in a hierarchical context

N. Bhardwaj*, M. Gerstein

*Yale University, New Haven, Connecticut USA*

Gene regulatory networks have been shown to share some common aspects with commonplace social governance structures such as hierarchies. Thus, we can get some intuition into their organization by arranging them into well-known hierarchical layouts. Here we study a wide range of regulatory networks (transcriptional, modification and phosphorylation) in a hierarchical context for five evolutionarily diverse species. We specify three levels of regulators – top, middle and bottom – which collectively regulate the non-regulator targets lying in the lowest fourth level, and we define quantities for nodes, levels and entire networks that measure their degree of collaboration and autocratic or democratic character. Overall we show that in all the networks studied, the middle level has the highest collaborative propensity and that co-regulatory partnerships occur most frequently amongst mid-level regulators, an observation that has parallels in efficient corporate settings where middle managers need to interact most to ensure organizational effectiveness. Then to study dynamic effects, we superimpose the phenotypic effects of tampering with nodes and edges directly onto the hierarchies. We reconstruct modified hierarchies reflecting changes in the level of regulators within the hierarchy upon deletions or insertions of nodes or edges. Overall, we find that rewiring events that affect upper levels have a more dramatic effect on cell proliferation rate and survival than do those involving lower levels. We also investigate other features connected to the importance of upper-level regulators: expression divergence, back-up copies and expression level.

### Hierarchy in transcriptional regulation within and across genomes

M. Cosentino-Lagomarsino*

*Université Pierre et Marie Curie, Paris, France*

From the coarse viewpoint, and from the eye of a physicist, a genome may be seen as a repository of genes and other elements having functional and evolutionary roles. Both its content and its architecture are shaped by a number of constraints and optimization principles of physico-chemical, biological or evolutionary nature. Some of these constraints have an intrinsically hierarchical nature. As an example, I will consider the large-scale regulation of transcription, a topic that I approached from different viewpoints over the past years. At the level of a single genome, this functional module has the scope of activating the correct genes in response to a set of stimuli and environments. It can be represented as a network whose topology (available experimentally for a few microorganisms) has a prominently hierarchical organization, which can be traced back to the evolutionary history of the genome. On the other hand, this hierarchy has complex feedback with the physical organization of the genome as a giant nucleoprotein complex. At the level of many genomes, the size of the transcriptional regulatory network is conditioned hierarchically by the classes of metabolic processes the cell participates into, and by the evolutionary growth of the genome by horizontal transfer and gene duplication/loss. I will describe a quantitative statistical physics approach to this problem guided by data on all sequenced genomes.

### Complex study of complex urban systems

P. Em*

*Russian Academy of Sciences, Moscow, Russia*

The basics in studying of urban systems established in the first part of XX. The first principle which allowed researching of hierarchy in urban systems was rank-size distribution. It was opened by F. Auerbach, and than, regardless rediscovered by G. Zipf. W. Christaller published the theory of central places in 1932. In this theory he tried to detect regularities in distribution of communities. All communities were located on the

different hierarchical levels depending on their size and central functions. Christaller instituted K. It means numerous of central places on lower hierarchical level which subordinated to one center extended for 1. This research is generally focused on complex studying of urban hierarchical systems. As one result we made a recipe of construction anamorphic crystalline grid with determination of modification of grids edges. The main index here is density of the population. In the course of studying of settlement systems of different regions and countries we demonstrated the mechanism of falling out of communities which should be on the various hierarchical levels. At that we found possibility of falling out the main central place and communities which should be on the 2nd and 3rd levels. In this case functions of falling out communities were taken by main center. In case of falling out of the main center, like in Vietnam, communities on the second hierarchical level became the main centers each for its minisystem. In such a way bicentric system was appeared. At that its ability to live was proved contrary to assertions of many researchers. Presence of two competitive centers makes good effect for economic development. We proved possibility of existence of transitional form of K. Central places on different hierarchical levels with economic development often raise their levels. Gradual rise of central functions we denote with fractional K. It will help explain the development of urban systems in detail. One more perspective method to study hierarchies in urban settlement system is theory of categories. We use it now and hope to present new results and methods to analyze development of hierarchies in urban systems.

### The Evolutionary Growth of Complexity through Systematization of Decisions in Natural and Social Systems

C. Henning-Reschke*

*Institute for Management Research, Cologne, Germany*

This paper explores how a systemic evolutionary view, which argues that evolution is a knowl- edge generating process, and conceptually or mathematically related perspectives can contribute to an integrated perspective on the evolution of information organization by linking perspectives from biology and the social sciences. The paper uses the illustrative example of punctuation patterns in pharmaceutical innovations as a starting point for discussing a number of theoretical models and perspectives with respect to their suitability for such an integrated perspective. These models, if sufficiently correct representations of the characteristics of and tools for research into evolutionary development processes should play a role in explaining the molecular make-up of human organisms. Thus they also must find a reflection in the history and characteristics of pharmaceutical research as well as the more general characteristics of knowledge processes. The implied circularity of scientific concepts used for analysis and processes operating in the evolution of biological organisms and of knowledge indicates the relativity and reflexitivity of knowledge which is seen as expression of evolutionary processes of knowledge growth in the social domain being 'eigenprocesses' of evolutionary development from inanimate matter to the social domain.

### The emergence of hierarchy through competition in social organisations

N. Perony, B. König*, F. Schweitzer

*ETH Zurich and University of Zurich, Switzerland*

Social, or dominance, hierarchies are observed in many social organisations, most notably in animal groups. Dominance hierarchies have a crucial evolutionary value as they give the dominant individuals privileged and sometimes exclusive access to resources and mating with other group members. Here we discuss the conditions for emergence of a dominance hierarchy in a simplified social system based on competition for social capital, defined as an agent-wise reputation level. The social dynamics of this simplified model are based on pairwise agonistic interactions between agents. The outcome of these interactions is determined from both individual history (reinforcement dynamics) and stochastic factors, and has a direct impact on the reputation level of the agents. We observe that a stable multi-layered social structure can emerge from this simple model, and we solve analytically the number and population of each stable social state. We then proceed to include spatial dynamics in this model, by allowing individuals (i) to compete preferentially with others near them, and (ii) to move away from a position where they are sub- ordinated by another individual. We show that the inclusion of these spatial dynamics allows for the transition of the social system from a linear hierarchy, where each individual dominates only those beneath her, towards a localised despotic hierarchy, with one individual subordinating all others within a certain area. We observe that dominant individuals can coexist in the same system, provided their ranges of dominance do not overlap. Finally, we embed our results in a social network

context and compare the simulated social structure with the real social network of associations in a population of wild house mice (Mus domesticus). We find that our simple model can adequately reproduce some features of the real social network, such as its stable community structure. This work is relevant to the understanding of both the origin and the consequences of hierarchy in animal societies and social organisations in general.

**Emergence of hierarchical structures in urban systems: From Christaller to complexity science.**

P. Viejo*

*European Institute for Energy Research, Köln, Germany*

Urban planning and urban management lacks today of methodologies that take into account the complexity and diversity of urban systems. One of the research questions without concluding answer regards the emergence of the first human settlements and its evolution on complex urban systems. This paper aims to present a discussion about the emergence of hierarchical structures on different domains of urban systems, regarding urban form, urban infrastructure and systems of cities. Through an historical overview of the different urban models regarding hierarchical systems (i.e. Christaller or Zipf), the author argues about the use of complex systems modeling and simulation to validate different theories related to urban growth and urban planning. Several cases studies are presented in order to illustrate the emergent hierarchical structures: health systems, educational infrastructure and social networks. Furthermore, several methodological approaches are presented, which should help to recognize, quantify, analyze, model and simulate hierarchical urban systems. The paper concludes with a discussion about research challenges and opportunities.

# Emergent Properties in Natural and Artificial Complex Systems

**Organizers: M.A. Aziz-Alaoui, A. Banos, C. Bertelle**

### Towards a Swarm Optimization Algorithm with Logistic Agents

R. Charrier*

*University of Le Havre, Le Havre, France*

Adaptation and self-organization are two main aspects of swarm mechanisms and collective intelligence. We adress here the global question of controlling the coordination of groups of mobile agents in order to achieve optimization processings. We study in this paper a simple case involving logistic agents - whose internal decision is governed by a logistic map, that is a discrete parametrized quadratic map - slaved to a stochastic environment through their control parameter. The proposed algorithm enables agents to find local minima in the environment. We show that the adaptation process on the control parameter leads to this local optimization. Applications may be envisaged for multi-objective problems.

### Burst Synchronization of Coupled Oscillators: Towards Understanding the Influence of the Network Topology

N. Corson*, S. Balev, M.A. Aziz-Alaoui

*University of Le Havre, Le Havre, France*

This paper addresses the question of burst synchronization in networks of chemically coupled Hindmarsh-Rose neurons. After a brief description of the model and of an algorithm of numerical detection of burst synchronization, we present numerical experiments designed to give an insight on the influence of the network topology on the minimal coupling strength needed to obtain burst synchronization in the network. Two topological characteristics are studied: the network diameter and the in-degrees of the nodes. Our numerical simulations show that when the diameter grows, the network becomes more difficult to synchronize, while networks with bigger in-degrees of the nodes synchronize more easily.

### What make a system complex?

M. Cotsaftis*

*ECE, Paris, France*

The fast changing reality in technical and natural domains perceived by always more accurate observations has drawn the attention on a new and very broad class of systems mainly characterized by specific behavior which has been entered under the common wording “complexity”. Based on elementary system graph representation with components as nodes and interactions as vertices, it is shown that systems belong to only three states: simple, complicated, and complex, the main properties of which are discussed. The first two states have been studied at length over past centuries, and the last one finds its origin in the elementary fact that when system performance is pushed up, there exists a threshold above which interaction between components overtake outside interaction. At the same time, system self-organizes and filters corresponding outer action, making it more robust to outer effect, with emergence of a new behavior which was not predictable from only components study. Examples in Physics and Biology are given, and three main classes of “complexity” behavior are distinguished corresponding to different levels of difficulty to handle the problem of their dynamics. The great interest of using complex state properties in man-made systems is stressed and important issues are discussed. They mainly concentrate on the difficult balance to be established between the relative system isolation when becoming complex and the delegation of corresponding new capability from (outside) operator. This implies giving the system some “intelligence” in an adequate frame between the new augmented system state and supervising operator, with consequences on the canonical system triplet {effector-sensor-controller} which has to be reorganized in this new setting. Moreover, it is observed that entering complexity state opens the possibility for the function to feedback onto the structure, ie to mimic at technical level the invention of

Nature over Her very long history.

### New Alternate Lozi Function for Random Number Generation

A. Espinel*, I. Taralov, R. Lozi

*Ecole Centrale, Nantes, France*

An improved Lozi function with alternate coefficients has been proposed. The modifications in the model allow to remove the holes in the attractor which are not desirable, but appeared in the previous Lozi function; in this way, an everywhere dense attractor can be obtained. Moreover, the strong sensitivity to the type of binarisation (conversion of real values to 0 and 1) has been demonstrated; this conversion to binary numbers is instrumental to apply the NIST tests for randomness. The results have been validated and compared via NIST tests, for the different methods of quantization. Finally, is has been verified that the random properties of the output signal have been improved thanks to the following strategies: under-sampling of the output signal, and the system order increasing.

### Rouants Simulation Platform to Model Service-user Dynamics of Cultural Sites within Urban Area

R. Ghnemat*, F. Lucchini, C. Bertelle

*German-Jordanian University, Amman, Jordan*

Rouants simulation platform concerns spatial analysis of urban dynamics described here by services development and their practice by users. A study case allow to analyse cultural sites development applied to the French urban area of Rouen.

### An Estimation of the Shortest and Largest Average Path Length in Graphs of Given Density

L. Gulyás*, G. Horváth, T. Cséri, G. Kampis

*Eötvös Loránd University, Budapest, Hungary*

Many real world networks (graphs) are observed to be 'small worlds', i.e., the average path length among nodes is small. On the other hand, it is somewhat unclear what other average path length values networks can produce. In particular, it is not known what the maximum and the minimum average path length values are. In this paper we provide a lower estimation for the shortest average path length (l) values in connected networks, and the largest possible average path length values in networks with given size and density. To the latter end, we construct a special family of graphs and calculate their average path lengths. We also demonstrate the correctness of our estimation by simulations.

### Improving Chaotic Optimization Algorithm Using a New Global Locally Averaged Strategy

T. Hamaizia*, R. Lozi

*University of Constantine, Constantine, Algeria*

Recently chaotic optimization algorithms as an emergent method of global optimization have attracted much attention in engineering applications. Their good performances have been emphasized. In the frame of evolutionary algorithms, the use of chaotic sequences instead of random ones has been introduced by Caponetto et al. Since their original work, the literature on chaotic optimisation is flourishing. They are used in the scope of tuning method for determining the parameters of PID control for an automatic regulator voltage, or in order to solve economic dispatch problems, or also for engineering design optimization and in many others physical, economical and biological problems. Different chaotic mapping have been considered, combined with several working strategies. The assessments of the algorithms have been done with respect to numerous objective functions in 1, 2 or 3- dimension. In this paper we present an improvement of the COLM (Chaotic Optimization based on Lozi Map) which is based on a new global locally averaged strategy. The simulation results are done with a 2-D objective function possessing hundreds of local minima, in order to test this new

method vs. the previous one in very tough conditions. We emphasize an improvement of the optimisation.

### Effects of Time-Dependent Edge Dynamics on Properties of Cumulative Networks

R.O. Legendi*, L. Gulyás

*Eötvös Loránd University, Budapest, Hungary*

Inspecting the dynamics of networks opens a new dimension in understanding the interactions among the components of complex systems. Our goal is to understand the baseline properties to be expected from elementary random changes over time, in order to be able to assess the effects found in longitudinal data. In our earlier work, we created elementary dynamic models from classic random and preferential networks. Focusing on edge dynamics, we defined several processes changing networks of fixed size. We applied simple rules, including random, preferential or assortative modification of existing edges - or a combination of these. Starting from initial Erdos-Renyi or Barabasi-Albert networks, we examined various basic network properties (e.g., density, clustering, average path length, number of components, degree distribution) of both snapshot and cumulative networks (of various lengths of aggregation time windows). In the current paper, we extend this line of research by applying time-dependent edge creation and deletion algorithms. I.e., we model processes where edge dynamics is defined as a function of time. Our results provide a baseline for changes to be expected in dynamic networks. Also, they suggest that certain network properties have a strong, non-trivial dependence on the length of the sampling window.

### Exploratory Analysis of Web Data: Methods, Tools and Geographical Distribution

F. Pfaender*, N. Esposito, M. Jacobi

*University of Technology, Compiène, France*

We propose a methodology for the exploration of Web data, built on the principles of exploratory data analysis and analytical visualisation of information. Our approach aims at combining these two approaches in order to benefit from both of them. This allows us to explore heterogeneous complex dynamic systems such as the Web, and to construct emergent structures and indicators without getting lost. By studying the geographical dimension for a specific Web locality, which is exemplary in many ways, we were able to test our methodology and various visualisation tools, thus validating our theoretical proposals.

### Emergent Human Behaviour During a Disaster: Thematic Versus Complex Systems Approaches

D. Provitolo*, E. Dubos-Paillard, J.-P. Müller

*Géoazur CNRS, Sophia Antipolis, France*

Disasters or catastrophes engender social and spatial disorganization of the territories affected by these events and specific human behaviour. In this paper, we look both at the responses of societies in terms of specific human behaviour in times of disaster or catastrophe, which may be either a form of vulnerability or on the contrary of social resilience, and at the forms of emergence associated with such exceptional events. The first part proposes a typology of behaviours observed at times of catastrophe and identifies properties common to all such behaviours. Parts two and three ask whether behaviours observed at times of disaster or catastrophe (behaviours that stand apart from everyday behaviours and that can be observed both individually and collectively) can be characterized as emergent behaviours. Answering this involves weighing up inputs from the science of risk and the science of complexity. We present the different properties for characterizing emergent human behaviour, in order to recombine the disciplinary approach of scientific communities. This knowledge of the conditions underlying the emergence of behaviours points the way to how the phenomenon might be modelled.

### Centroids: a Decentralized Approach

A. Dutot, D. Olivier, G. Savin*

*University of Le Havre, Le Havre, France*

The centroid of a graph is a structure composed of nodes closest from all others. This suggests the presence of center of mass average of all edges, weighted by the local density or specific weight. To compute this centroid

in a classic way needs a global view of the graph environment. In this paper, we propose an algorithm using ant colony is proposed to compute an approximate solution of the centroid using a local view of the graph. This allows to study the centroids of complex networks such as protein-protein interaction networks and also those generated by social interactions or Internet, for example.

### From Complex Networks to Urban Mobility Modeling: the Reticular Model for Urban Simulation (REMUS)

D. B. Tran*, R. Frigui, D. Moreno, A. Piombini, D. Badariotti

*University of Strasbourg, Strasbourg, France*

The REMUS model is based on the concept of graph theory which allows modeling the network accessibility of time/distance-dependent multimodal transport and urban pattern. The urban graph is represented by buildings and transportation network. The REMUS model allows the extraction of neighborhood proximity of complex networks which represent the accessibility in terms of network-time-distances between buildings, according to a given modal choice and a given time/distance. It visualizes the neighborhood of each spatial unit (building), and calculates topological graph-based indicators characterizing the real distribution of spatial units, depending on the local urban pattern. The REMUS indicators are comparative and could be used to compare the topological properties of different urban patterns (quarters or whole cities). They have been applied to cities and urban quarters, demonstrating that the real distribution of buildings and the introduction of network accessibility in urban metrics induce an important anisotropy in urban space at local scales, which is obviously impacting mobility and modal choice. In a second step, these topological indicators, summarizing the morphological properties of local urban patterns, are compared to mobility indicators extracted from surveys. The main objective is to respond how and why urban mobility is influenced by the local urban pattern.

### Effects of Partner Selection on the Emergence of Cultural Divides in Mixed Populations

E. Tzafestas*

*University of Le Havre, Le Havre, France*

In this work, we are exploring spatial dynamics and clashes in cultural simulations involving multicultural populations with partner selection. We are using as basis an Axelrod model extended with a Moore neighborhood, heterogeneous sets of cultural features per agent and a number of psychologically realistic, basic and more advanced, conceptual models of cultural affinity perception and imitation. Elsewhere we have shown that in many cases the population stabilizes to multi-cultural configurations and that in cases of population clashes where two or more culturally contiguous populations meet the cultural divide may persist, albeit in a relatively weaker form. In this paper we repeat our previous experiments to investigate the effects of partner selection on these configurations.

### Topology Identification of Complex Dynamical Network with Hindmarsh-Rose Neurons

J. Zhao*, N. Corson, M.A. Aziz-Alaoui, C. Bertelle

*Textile University, Wuhan, China*

The topology identification is a significant issue in the study of complex networks. For example, if a major malfunction occurs in a communication network, power network or the Internet, it is very important to quickly detect the location of the faulty line. Topology identification of complex dynamical networks has received more and more attention from the systems science community. Generally speaking, two methods are used to study the identification problem. One is based on the classic adaptive control. Considering the complex dynamical network with unknown topology as a drive system, some researchers built a response system and adaptive controls to estimate the unknown topology. The other mainly used method consists on solving large scale linear equation. Driving the complex dynamical network to an equilibrium state by a control law, the identification problem can be transformed to solve the large linear equation. It is worth remarking that the earlier results neglected a crucial condition: persistent excitation (PE) condition. The condition is so important that the topology cannot be identified successfully without it. In 1952, two neurophysiologists proposed a mathematical model that describes neuron activity. This model have been modified

into different other models. In this study, we focus on one of them, the Hindmarsh-Rose model (HR), which can exhibit most of biological neuron behavior, such as spiking, bursting. Meanwhile, it is also important to investigate the group action when they are coupled each other. In this paper, we estimate these unknown parameters in an asymptotic manner and discuss the important of PE condition on the process of identification in such neuron networks. Pinning control is used to drive the response system synchronize with the drive system because it is difficult to control all the nodes of the large network. Additionally, we consider the topology identification of complex network with noise as many real systems will be subject to perturbation.

# PhD Research-in-Progress Workshop - from Lab to Society

**Organizers: D. Rodrigues, L. Mihoreanu, I. Kusel**

## Transportation system before, during and after natural disaster in a complex city environment

F. Atun*

*Politecnico di Milano, Milano, Italy*

When the effects of a natural hazard combine with a complex city system which is consisted of numerous and diverse variables affected by each other, it turns into a disaster which creates serious human causalities, physical damages, economic and moral losses. The disaster risk depends on both the severity of hazard and pre-existing vulnerabilities in the area. Without making any changes on the ratio to hazard, risk could raise due to an increase in the physical, social, economic and organizational systems vulnerabilities. Which means that when a city is hit by a disaster, having damages on the transportation system could serve to exacerbate the pre-existing conditions of vulnerability by being connected and interdependent to other sub-systems, such as economy, built environment, water, gas, sewage, electricity, communication and fuel supply. How ideas of complexity can be applied to transportation system to increase the resilience of the entire city system is the starting question of this research. The hypothesis of this study is that with an understanding of the complex nature of transportation system and interdependent character to its own components and to other sub-systems in time (disaster phases: pre-disaster/emergency/post-disaster) and spatial scales (such as local and regional), a stronger and more sustainable transportation system could be achieved. The latter could significantly contribute to resilient of a city. By aiming to prove the hypothesis, this study focused on quite many case studies to understand the effects of natural disasters on transportation system. In the complex environment of a city, there are some reasons which make transportation system so attractive to study. First of all, transportation system is large, complex and strongly interdependent system which covers the entire city. All the lifeline systems depend on the transportation system at different levels. On the other hand, components of the transportation system, such as roads and railroads, are strongly depended on the other systems. Secondly, transportation system often requires longer repair times than other lifeline systems, and this situation leads to long term economic impacts depending on loss of competitiveness, decreasing number of jobs and changes on the spatial pattern. Finally, the importance and the function of the transportation system are changing depending on the disaster phase and scale, although in every phase transportation system enables vehicular movement, flow of people and goods. What is the main reason behind the damage after a disaster? Is it complexity? In the disaster risk management literature failures as a result of a complex environment are described by many theorists from different point of views. All those theories constitute a framework to investigate the reasons behind cities breakdown after a disaster (see White, 1936; Beck, 1992; Schneider, 1995; Balamir, 2001). However, even complex physical, economic and social networks are the factors amplifying the effects of a disaster, they also provide the opportunities to decrease the risk and increase the resilience of each system and the city. The overall aim of this study is to reveal these opportunities by focusing on the reasons of the transportation system failures which are conditional on the complex nature of the city, and to provide solutions by introducing a methodology. The problems that need to be achieved during this study are threefold. First of all, the literature study states that the solutions are provided for single problems in the transportation system, such as strengthening a bridge, without considering its relation within the entire transportation network. Secondly, dealing with transportation system without considering its interdependent nature with other sub-systems and environments is another problematic issue which is considered during this study. Moreover, it can be said that the most problematic issue is not having interaction between the research community and society. The latter could lead to problems while trying to implement the achieving results of the study. Chang and Nojima (2001) state that while much attention has been paid to understanding and predicting the performance of individual bridge structures under seismic loading, only recently have researchers begun to evaluate the performance of the transportation system as a whole. There are studies focusing on bridge's damage modelling (Rojahn et al. 1997; Werner et al. 1997), the costs associated with travel times (Werner et al. 1997), network traffic flows (Werner et al. 1997; Nojima, 1997; Wakabayaski and Kameda, 1992), transport cost, cost of operation the projects (Ponti, 2006), regional production losses (Shinozuka et al. 1998). However, there is a need to study more natural hazards to the transportation system by considering the relation of an individual transportation network with the entire transportation system. To be clear, it can be said that not considering the complex nature of the system while providing solutions and policies leads to new problems while trying to solve the existing point-shaped ones. Within the overall aim of turning the complexity into an advantage instead of being a weakness for the transportation system to increase the resilience of a city,

the research identifies the following specific aims. The first aim is to determine the needs of transportation system during diverse disaster phases (pre-, emergency and past-) and depending on the diverse disaster types (flood, earthquake, landslide etc.). The literature review starts with some case studies to understand nature and structure of transportation system with particular emphasis on vulnerabilities in diverse disaster phases and types. The second aim is to investigate failures on other systems due to the failures on transportation system and vice-versa by defining the internal and external components that interact and influence each other. Last but not least, the aim in this study has been to introduce complexity theory by using some insights of it for providing a way forward to deal with uncertain behaviour of the system due to interconnectedness of the existing components. In particular this study provides a way forward to handle the complex problems in the transportation system between the components existing in a city on the one hand and decision makers on the other hand. Thus, for engineers and urban planners the question is what should be the methodology to solve the problems in the transportation system due to being hit by a disaster before its occurrence. For decision makers, or governmental authorities, the questions of how to use the expert knowledge and implement it without being affected from the complex nature of governance how to provide funds for implementation of the policies and from where do a governmental authority start spending the provided funds can be answered more easily by using the complexity theory which helps to identify the hidden connections in the system between single vulnerable parts which affect the whole system. To conclude, this study proves that cities are dynamic complex systems, and providing solutions to their problems as they are static in their nature does not help to ensure their safety and security when a natural disaster is in the question. Moreover the results of the study comes up with a positive answer to the research question and introduces a way to prove the hypothesis. As a final statement, one more time it would be said that with an understanding of the complex nature of transportation system, a strong and sustainable transportation system could contribute to resilient of a city.

### Evolution of retirement: inter-generational cooperation and strong reciprocity

S. Bacelar*

*ISCTE, Lisbon University Institute, Lisbon, Portugal*

Retirement is a special case of intergenerational cooperation, where young workers agree to pay the pension of retired people in return for the promise that the next generation of workers pays for their pension. Retirement pensions (PAYG) are a stream of payments that redistribute income between total strangers, from the younger generation to the older, with the approval of the electorate. Mainstream Economics, based on the assumption of a selfish human motivation, has some difficulty to explain the reason why people vote for that redistribution. The reason why people support welfare state and intergenerational cooperation is because it conforms to the behavioral schema of strong reciprocity, that differs from self-interested forms of cooperation. Experimental evidence proves that strong reciprocity is a better explanation for the motivations to support welfare state than homo economicus or altruism. Strong reciprocators adopt strategies of conditional cooperation and conditional punishment. They evaluate the fairness of retirement related behavior of other players, from the same generation or from the older generation and adjust their propensity to support redistributive policies. Low or non-contributors are punished, even if that implies a cost to retaliators. We want to build an overlapping generations agent-based model to show the aggregate behavior of individuals that generalizes the lifecycle model. Using a game-theoretic framework, preferences for reciprocity can be modeled based on the assumption that utility of player i depends both on own payoff and on the payoffs of other players. Reciprocal behavior consists of the reward of kind actions and the punishment of unkind ones. Retirement is usually regarded as a formal norm that is imposed top down by the State to the individuals. Our bottom-up approach will try to grow the retirement norm, from a set of attributes and behaviors of interacting agents.

### A mathematical approach to medical complexity

M. Barons*, F. Griffiths, N. Parsons, M. Thorogood

*University of Warwick, UK*

Healthcare is a complex interaction of individual characteristics, treatment characteristics and organisational characteristics. Tailoring treatments to patients has potential to improve patients quality of life and reduce resource consumption. In the UK, lower back pain has an annual period prevalence of 37% and costs the economy an estimated 1632 million ( 2000 million), not including the cost of treatment. A clinical trial of a new, complex intervention for low back pain, which included a cognitive behavioural element, was shown to be clinically effective on average and cost effective. [Lamb et al, 2010] The power of mathematics is used to

drive efficient and provably robust machine learning, which has the capacity to predict outcomes in the case of complex interactions, such as in healthcare. Using individual characteristics relevant to the intervention, latent class analysis produces models which cluster patients into subgroups. The choice of model is guided by statistical validation and comparison with qualitative descriptions of medically meaningful subgroups. Group membership has a significant association with clinical outcome suggesting potential for tailoring treatments to patients. Another approach, which captures nonlinear interactions between input variables, is to use an artificial neural network. A multi-layer perceptron with a single layer of hidden units is trained, tested and optimized, and used to categorize the patients attendance, compliance and recovery. This is compared to the approach of a classification tree, more familiar to clinicians, and showed that the same input variables gave the best models.

**Emergency Management Concepts: A network approach**

N. Caseiro*, P. Trigo

*ISCTE/FCUL, Instituto Politecnico de Castelo Branco, Portugal*

The socio-technical systems that make part of our lives are subject to disturbances through disasters that can have serious consequences (at the limit, completely destabilizing the basis system). To deal with this situation modern societies have developed structures, tools and mechanisms that aim to reduce the probability of occurrence of these negative situations. Good decision making is critical and information is needed when analyzing the environment for risks, when defining emergency plans, when training agents and society to deal with the foreseen accidents. All elements and people involved in the emergency cycle need to have a common mental structure to deal with information issues. Our research goal is to identify and build a semantic base underlying the mental model from experts by using a collaborative web tool. Mental models, underlie how people structure concepts; how they relate them; which are the similarities and differences of these structures; what concepts they recall first and which concepts they associate with them. The approach we propose merges both the power of collaborative web-based techniques and the use of social sciences methods to obtain the data, through questionnaire, that will allow to build a network of concepts. We expect that, by aggregating all the answers, will allow us to deepen the analysis of the resulting network, to understand connections and main group concepts in this domain. Some of the research questions we want to address are: (i) concepts with more commonalities/dissimilarities among participating subjects and from subjects with specific profiles; (ii) type and intensity of the relations defined; (iii) network coherence, by searching missing key nodes or relations. Finally, an ontology will be developed based on the information gathered and applied in a real context to test the suitability of the application.

**The social transformation and your role in it**

D. Hales*

*Open University, United Kingdom*

Modern social systems have always been in a state of transformation. Today is no different. Indeed, recent events indicate that major social and economic transitions are in progress globally. What can complexity science offer in the way of increased understanding and practical application during turbulent times? What is the role of complexity scientists in these transitions? I will discuss these questions with reference to some of my own work and interests involving the interplay of centralised (top) versus decentralised (bottom-up) control in social and technological systems. I'll include reference to a) recent interlinked events such as the Wikileaks project, the financial crisis and the Arab Spring uprisings; b) technologies such as peer-to-peer systems, cloud computing and social software; c) social theory and models.

**Should we cooperate of defect? Polarization of strategies in social games.**

A. Jarynowski*, K. Kulakowski

*Jagiellonian University, Cracow, Poland*

A simple model of the Prisoner Dilemma, which can imitate a mechanism of rapid norm change, is proposed. The setting is described by players acquiring reputation and evolving altruism, which in turn determine their

choice of strategy. The probability of cooperation depends linearly, both on the player's altruism and the co-player's reputation. Collective behavior is introduced by altruistic optimism (punishment) and reputation reciprocity (fail). Agents can establish the best strategy in repeated games. The final, stationary probability of cooperation can vary sharply with the initial conditions and jumps to zero or one for some critical values. Specification of the rules as initial conditions have impact on final states as well as on dynamics of the system. If only the reputation could vary one would observe coexisting strategies but with altruism change all players choose only one strategy. In both approaches, payoffs are not relevant and only mutual interaction between players are significant. We also observe, that the transition state close to the boarder between the two regimes can be described as Gaussian cumulative distribution function.

### The Effects of Yoga Breathing Techniques on Heart Rate Variability

M. Kovacs*, A. Schaefer, K. Kratky

*University of Vienna, Vienna, Austria*

The human organism is a highly complex system of intertwined variables, their mutual dependence being not fully understood yet. To determine the impact of controlled breathing on some of these variables, our group has done research on the effects of specific yoga breathing techniques (Pranayama). For this purpose we recorded the electrocardiogram (ECG), blood volume pulse, thoracic and abdominal breathing amplitude, skin conductance and oxygen saturation during periods of rest, as well as during the performance of breathing exercises. Some of the 24 probands were yoga teachers with different levels of experience, others were students. One focus of our analysis up until now is the heart rate variability (HRV) derived from ECG data, the most notable results being a significant decrease in heart rate after the application of breathing techniques, a stronger decrease of heart rate variance for higher adeptness levels of yoga and several differences regarding sex. Further analysis will include the thorough assessment of breathing activity: breathing rate variability (BRV) will be examined as well as possible correlations between HRV and BRV. Additional results concerning the evaluation of breathing data and skin conductance levels will be discussed at the conference. We feel confident that this kind of interdisciplinary and intercultural research is crucial when it comes to exploring new ways of enhancing as well as preserving well-being and health.

### Conflict is Complex

B. Hassani-Mahmooi*

*Medical University of Vienna, Vienna, Austria*

In economic analyses, conflict, as an alternative to productive behavior, had been neglected until almost forty years ago when researchers started to develop special frameworks to include unproductive activities and artificial transfers in their economic models. These frameworks are usually studied as the theory of production and conflict (P&C) where each agent allocates its resources between production and fighting and have been applied to study diverse issues ranging from matters in defence economics to topics about crime, piracy and terrorism. In this research, firstly I would review the current equation-based P&C models and then highlight their limitations in dealing with real world complexities. Later, a modular agent-based model is introduced with bounded-rational agents who can allocate a fraction of their effort to predatory behavior. The agents are capable of learning and optimizing their decisions using a genetic framework to select the best combination of allocation strategies. A Cobb-Douglas production function and a standard contest-success function are embedded in each agent with heterogenous attributes. The basic model is tested and the agents emergent behavior has been shown to be adaptive. Then, I have enriched the model with different subjects of conflict, separate product and resource appropriation procedures, private and common resources and capacity for collaboration among agents to study the relations between resource scarcity and security. The model is run under different population, resource degradation and social network structure scenarios with different sets of initial conditions; both individual and Monte Carlo outputs are reported. The results show a high level of complexity in agents allocation behavior with outputs ranging from no statistically significant allocation changes to widespread conflict in the environment supporting previous empirical findings that the main link between climate change and conflict is through changes in the distribution of resources rather than their overall

availability.

### Organizational Crisis Preparedness and Response: from a Complex Network Model to a Complex Networked World

J. V. Matos*

*ISCTE, Lisbon University Institute, Lisbon, Portugal*

The present research work in progress is focused on the impact of organizational design and business networking on organizational crisis preparedness and response. For this purpose an integrated approach making use of agent-based computer simulation, complex network theory and dynamic modelling is adopted and developed based on a complex adaptive system (CAS) paradigm perspective. A pervasive research theme lies in the tension between organizational efficiency-gain initiatives, frequently implemented at the expense of vulnerabilities that remain dormant until a crisis appears, and organizational resiliency, implying the allocation of resources often seen as diverted from their possible contribution to the firm short-term competitive position improvement. Conceived as a preliminary study at the intersection of a subsequent three-phase research process, the current initial research stage involves an agent-based model with interacting grid spaces of competing organizations, customers, and suppliers. Translating management theory concepts, like Porter five competitive forces, to CAS properties and mechanisms, the model is used to assess firms ability to avoid and handle crises under different market turbulence conditions. The following research phases focus specifically on a multilayer organization performance perspective, on a supply chain and alliances network resiliency perspective, and on organizational dynamic crisis response from a business fitness landscape perspective. Aiming to help closing the gap between management theory development and real-world business decision-making needs, the significant contribution that the present research may provide to a more sustainable business environment is addressed, specifically in the impacts resulting from organizations improved capability to: (1) more adequately value the drivers of organizational resiliency and particularly the impact of crisis preparedness and response measures; (2) make a more insightful assessment of their available options considering the corresponding ordered-complex-chaotic transition context and competition-cooperation co-evolutionary dynamics; and (3) gain a better understanding of the short term benefits expected versus long term potential consequences faced.

### Three and more heads deciding: models of information-sharing and aggregation for two-choice discriminative tasks

P. Migdal*, M. Denkiewicz, J. Rsczaszek-Leonardi, D. Plewczynski

*Department of Psychology, University of Warsaw, Warsaw, Poland*

Everyone who ever took part in a group decision making or problem solving, probably asked oneself whether it actually made any sense - wouldn't it be better if simply the most competent person made the choice? Put differently, the question is whether a group can outperform its most capable member. We investigate mathematical models for estimating performance of a group solving a two-choice task. In these models each trial is characterised by a single, continuous parameter, determining the difficulty of the trial. For a given participant or group we can then fit a psychometric function that describes his/hers/its performance. The models describe a relationship between group and individual functions. We also consider if data is collected all-at-once or as a dynamical process, when only small subgroups can communicate at a time. Our research follows Bahrami et al. (2010, Science), who provided deep introduction and model foundation for describing experimental data gathered from dyads (a pairs) of people solving difficult perceptual task. It turns out that in most models a groups outperform the most skilled member, as long as the performance difference is small. Furthermore, the hierarchical decision-making process decreases the performance only little, for the most realistic models. For every model we investigated the group performance is a product of a scaling factor depending of the group size (e.g. constant, square root, linear) and an average (arithmetic mean, quadratic mean or maximum) member performance. The paper is an invitation for an experiment, as it proposes how to distinguish different models of information-sharing and decision making in terms of simple and easily measurable quantities. By investigate the properties of the models one can determine, which group size and/or

composition is most promising, prior to designing an experiment.

### Complexity of Built Environment in Public Realm

A. Patil*, A. Dongre

*VNIT, Nagpur, India*

Approximately 50,000 years of man's existence has undergone drastic transformation and is continuing in an exponential manner. Urbanisation of the commumnity is one of the most spectacular changes of our times. The rapid pace of urbanization is posing one of the greatest challenges of designing and managing our fast growing cities. The modernist approach of Architects and urban planners of the early 20th century came under criticism through the work of Jane Jacobs. The transformation in elements and disciplines of the city is much faster than the advancement in the process of urban design. The major effect of this is on public realm in urban areas which remains every ones responsibility and hence, no ones responsibility. This has resulted in declining quality of public realm primarily due to the disturbed equilibrium of use, user and used. The public realm is the best representation of urban chaos in Indian context. The quest is to know how to design, manage, build and control public realm as it increases in size and connectivity. The concepts from complexity science have potential of addressing this issue. Can complexity science aid urban designers in generation of coherence at smallest and most important scale of public realm in urban areas? These concepts can be systematically explored for analyzing complexity of built environment in public realm and identifying their potentials to harness the same. Varied concepts from complexity science and urban design explored simultaneously have substantial potential to equip urban designers with processes, which will ensure efficient predictability in public realm. Although the research will draw a lot of inputs from the peripheral fields the interest strictly remains in the field of urban design (built environment) and intends to develop model for addressing physical design issues related to the public realm. This complexity science based new approach is presently dominated by mathematical instruments and computational techniques which act as barrier for architects and urban designers. The need is to overcome this barrier. Any progress in this regard will enable us to develop appropriate public realm which is essentially used by urban population and enhance their experience. Adopting such developed models in practice in due course of time would be instrumental in improving the quality of urban life at large.

# Policy Modelling

**Organizers: P. Ahrweiler, D. Payne, B. Edmonds, S. Occelli**

### Using network analysis and agent-based simulation for FP8 ex ante evaluation

P. Ahrweiler*, M. Schilperoord, N. Gilbert, A. Pyka

*University College Dublin, Ireland*

In the Europe 2020 initiative for smart, sustainable and inclusive growth designed as the successor to the Lisbon Strategy, the Digital Agenda is a centrepiece: Information and Communication Technologies (ICT) research and innovation are considered to be crucial for achieving its ambitious policy goals, as drivers of inclusion and quality of life, and as enabling an open and competitive digital economy (see also i2010 strategy). ICT is an enabling pervasive technology providing wide business and social benefits particularly from investment in network and infrastructure technologies. Opportunity and social cohesion will be enhanced in a world where innovation makes the difference in both products and processes, harnessing the potential of education, research and of the digital economy (EU Commission Working Document: Consultation on the Future EU 2020 Strategy, November 2009). In particular, as this policy paper points out, the digital economy will provide many opportunities for SMEs in the production and service sectors. ICT R&D networks have the largest share of the Framework Programme budget across all thematic areas. In the current 7th Framework Programme, ICT research is mainly organised within the area Cooperation: The main bulk of ICT research is implemented by consortia with participants from different countries through a range of collaborative funding schemes (Tender Specifications: 2). The CIP programme, which is more directed to deployment activities, is also concerned with funding collaborative arrangements and networks. Policy design and evaluation methods in this area are challenged by the imponderability of research and innovation, which are characterised by true uncertainty and are exposed to risks and failures. However, recent studies of network architectures and their dynamics indicate that the success of innovation networks is related to specific network structures as well as mechanisms of network evolution. From this it follows that there may be scope for the improvement of the policy instruments used to create and to support research and innovation networks. Informed by large FP6 and FP7 datasets on EU-funded ICT R&D networks, the paper uses methods from network analysis and agent-based simulation to understand the relation between research funding and the realisation of the goals of EU policy programmes. It provides insights for the ex post evaluation of FP7 and for the impact assessment / ex ante evaluation of FP8. A new model is presented, which implements the agents and behaviours of EU-funded ICT research networks. Calibrated by FP7 network data and measures, the model is used for some policy experiments to test the effects of Commission interventions on network evolution.

### The communicative aspect of modern policy modeling. The role of metaphors in bridging the gap between the world of figures and the world of feelings

B. Bielenia-Grajewska*

*University of Gdansk, Gdansk, Poland*

In this paper the author wants to research the issue of modern policy modeling from the communicative perspective. The aim of the investigation is to show the methods of bridging the gap between the pure and objective world of figures, data and modeling and the cognitive sphere, encompassing effective communication, both verbal and nonverbal. Thus, the author wants to discuss the best, in her opinion, ways of policy modeling communication taking place between scientists, governors and the broadly understood stakeholders. This line of investigation follows the modern approaches in the discussion on policy modeling, stressing the issues of complexity in shaping modeling. In principle, the structural-cognitive shift in modeling is stressed, treating modeling as the way to check, explore, create and communicate knowledge (e.g. Occelli, 2001). The author of the present study treats modeling as a communicative tool, drawing the attention of the audience to the role of linguistic tools in making connections between the approaches which, when perceived only in the epidermal way, seem to be very different, if not even contradictory. However, the author wants to show that by using proper communicative solutions these two worlds (the world of figures and the world of feelings) can not only meet but be reciprocally beneficial. Due to the limitations imposed on the paper resulting from the multifactorality of linguistic tools, the author concentrates on the issue of metaphors and how

they serve as effective messengers of scientific and organizational communication on policy modeling. The metaphor is treated broadly in that case, encompassing both verbal and nonverbal (pictorial) metaphors. The metaphors have been chosen for different reasons. The first reason is the nature of metaphors themselves which help to grasp new concepts by taking into account well-known domains. This allows for effective and quick communication. Secondly, the topic of metaphors and their role in communicative policy modeling has not been studied so far. As far as the way of studying the policy modeling is concerned, the theoretical investigations are backed by several selected examples of empirical studies which aim to show both the effective as well as ineffective methods imposing metaphorical terms and expressions. In her investigation the author also wants to take into account the intercultural component, thus the study covers materials in Polish, English, German, Spanish and Italian. The participants in the policy modeling communication (scientists, governors, stakeholders) and their communicative strategies have been studied by implementing the network perspective. Moreover, this analysis entails the role of modern technology in conducting the dialogue, by showing how discussion lists, blogs, facebook determine the scientists-stakeholder interaction. To add, the topic of this research is connected with the authors postdoctoral thesis which is devoted to the corporate identity from the linguistic perspective. The author, being a linguist and an economist, tries to combine these two areas in her research project. What is more, authors interest in sociology and network studies (especially SNA and ANT) results in paying attention to the role of networks in creating and sustaining corporate linguistic identity. This aspect involves the study on policy modeling and its implication for creating effective corporate personae.

**Simulating the impacts of future European ICT research intervention policies**

F. Cunningham*

*European Commission, DG Information Society & Media, Brussels, Belgium*

Traditional approaches to evaluate research and deployment programmes have mainly focused on inputs, outputs and outcomes and have left relatively untouched the dynamics (i.e. the processes involved in generating innovation outcomes from a systems point of view is non-linear, networked and with multiple feedback loops) of research, deployment and innovation. New methodologies and tools are needed to better understand the impacts of EU, National and Regional funding on collaboration networks within the 'eco-system' of research and innovation. DG Information Society and Media has been at the forefront in recent years in developing methodologies and tools to assess the 'behaviour additionality' of the EU RTD intervention in terms of linkages within the EU ICT RTD community, with the global ICT innovation processes and with regional innovation systems. So far almost all of this work has been 'ex-post' and was very suitable for evaluation and impact analysis of current and past EU-level research and innovation programmes. The evaluative work (based significantly on social network analysis) has contributed towards better understanding the links between research, deployment and regional innovation systems, and thus improving the assessment of the impact of EU level interventions in research and deployment on regional eco-systems of innovation. There is a growing need within the services of the European Commission dealing with Research and Innovation policies and programmes to be able to deduce what could and should be changed in EU level interventions to improve (potential) impacts. It is proposed to employ 'ex-ante network analysis' to simulate the impacts of EU research intervention policies. This paper sets out the both the background and experience gained in building up knowledge and expertise in systemic analysis of European ICT research programmes and present effort to evolve and transform this into a sound and theoretical conceptual framework for simulating (a-priori) impacts of future policy interventions.

**Four different views of a policy model: an analysis and some suggestions**

B. Edmonds*

*Manchester Metropolitan University Business School, Manchester, UK*

A policy model has (at least) four different interpretations: (a) intention: the intention/interpretation of the simulation designer/programmer, (b) validation: the meaning established by the validation of the model in terms of the mapping(s) to sets of evidence, (c) use: the meaning established as a result of the use of a model in a policy making/advice context and (d) interpretation: the narrative interpretation of the policy maker/advisor when justifying decisions made where this refers to a policy model. These four different interpretations are loosely connected via social processes. The relation between intention and validation is relatively well discussed in the context of scientific model specification and development. The relation between use and interpretation has been discussed in a number of specific contexts. However when and how a relationship between the

scientific world of intention/validation and the policy world of use/interpretation are established in practice is an area with little active research. Both personal experience and philosophical considerations suggest that these two worlds are very different in terms of both purpose and method. However this does not mean that there cannot be any well-founded connection between them. The key question is understanding the social processes of how this can happen, what are the conditions that facilitate it happening and what is the nature of the relationship between the four views when it does happen. Interestingly these issues have been faced and extensively discussed in the field of Artificial Intelligence, which has confronted the distinction between meaning of internal models (loosely, the beliefs of an agent about its environment) in these four ways. The field of AI has not come up with a final solution to these problems, and is itself divided into those that inhabit separate approaches that adopt a subset of these approaches to model meaning. However it is suggestive of some ways forward, namely: a recognition of the problem that there are these different ways of attributing meaning to a policy model (and hence avoid some common errors derived from conflating these four views); symbol grounding in the sense of learning meanings through repeated use and adjustment (either in response to validation or interpretation views or both); and the observation of scientific-policy interaction as it actually occurs (e.g. an ethnographic study of scientist/policy advisor interaction). Some developments in the area of participatory policy modelling can be seen as forays into this arena, albeit without structured assessment.

### Modelling renewable energy innovation networks – the ocean energy network in Ireland

C. Gao*

*University College Dublin, Dublin, Ireland*

For knowledge intensive industries, with complex and expanding knowledge base and widely dispersed source of expertise, innovation takes place in networks of learning. As part of the EU project Managing Emergent Technologies for Economic Impact, my research aims to investigate renewable energy innovation networks in Ireland, and explore the impacts of the emergent technology on reconfiguring existing industry architectures, as well as economic and social impacts. This concerns research on national and sectoral innovation system, knowledge dynamics in innovation network, and evolution of technology policy. A sub-study has been done on ocean energy. Ocean energy has great importance in fulfilling long-term goals in Ireland. It has been calculated that Europeans accessible wave power resource is about 320,000MW with the highest resource available near the west of Ireland. The potential of wave energy market is estimated to be 70,000 MW by 2020.

### Lack of scarcity and missing markets for waste resources

O. D. Kalkan*

*University of Surrey, Guildford, UK*

Market failure is the general name of inadequacies of markets in providing economically efficient or socially desirable allocations of scarce resources. The case of a missing market is a particular type of market failure, in which the system of institutions that are needed for shaping and facilitating the exchanges of an economic good has failed to emerge. In environmental economics, missing markets argument is frequently raised in the context of pollution abatement (Ayres, 2008), demand management of scarce resources such as water (Kumar and Singh, 2001) and value assessments of ecosystem services and natural capital (Constanza et al, 1997). This paper addresses yet another environmental concern; the substitution of virgin resources used in industrial processes with by-products that would otherwise be regarded as waste (waste resource hereafter) and questions why some waste resources markets fail to emerge. It proposes a hypothesis that focuses on supplier incentives in the face of a lack of scarcity. More specifically, the paper argues that in some industrial settings, waste resources are not scarce and so their supply curve in the classical market plot are way at right, far from the demand curve. Hence, even though the waste resource has some positive use-value, a positive price level cannot be established in the market. Lack of scarcity as defined here for the industrial waste resources context is different from abundance of free goods such as air in that waste resources are not non-appropriable, there is a clear ownership or responsibility involved with these resources. The way incentives and expectations of suppliers shape a missing market with lack of scarcity in this hypothesis can be compared to the way expectations of a supplier with market power affect its pricing strategy in contestable markets theory. The paper first illustrates the concept with market plots, elaborating on possible ways the lack of scarcity condition can be changed. It then employs agent-based simulations with zero-intelligence traders to illustrate that when agents are unable to learn, transactions do occur but when agents have simple adaptive capabilities the market fails to emerge. Thereby, the paper employs the zero-intelligence traders for an unusual purpose; whereas the

literature on zero-intelligence traders aim to show markets can emerge even when agents lack rationality and learning skills, this paper illustrates that markets can fail to emerge when agents have these abilities. Finally, the paper provides several examples of waste resource exchanges between UK firms, where a landfill tax on discarded resources enabled establishment of a negative price.

### The impact of public research funding in biotechnology: an agent-based simulation

M. Korber*, M. Paier

*Austrian Institute of Technology, Vienna, Austria*

This paper presents an agent-based model of a localized biotech cluster and its socio-economic dynamics, with a special focus on the influence of public research funding on its innovation performance. It accounts for organizationsfirms, universities, public research and other relevant organizationsas heterogeneous agents that are able to make investment decisions about conducting research, to exchange assets with other agents in geographical space, and to produce innovative output for generating revenues they need to survive. Agents receive feedback from the system level and may receive different types of public funding. The credibility of the model in the context of regional policy is strengthened by a transparent calibration and validation strategy based on own qualitative and quantitative empirical research, as well as secondary data from Vienna, Austria, in the period of 1999 to 2009. Thus, the presented model expands existing agent-based models of innovation in the biotech sector that focus primarily on qualitative aspects of agent behavior.

### Issues pertaining to Policy Assessment and Simulation Modelling

P. Lucas*

*Manchester Metropolitan University, Manchester, UK*

This paper address issues that evidence-driven modellers confront when developing agent-based models supposed to be useful for policy-makers. Simulation models, regardless of how detailed, represent phenomena in a more formal and synthesised way than descriptive accounts, and the methods and techniques employed in their implementation are often alien to stakeholders. Various emergent socio-economic outcomes are increasingly being analysed through the surrogate reasoning provided by computational simulations. Yet meaningfully informing policy changes with results obtained in such models is not straightforward. That entails difficulties of communicating how techniques and technologies are employed and the limitations of assessing the usefulness of simulation results. Some of these barriers can be minimised by the time-consuming endeavour of involving stakeholders directly in the modelling process, providing them with a sense of ownership over the newly generated knowledge whilst resolving unintentional misunderstandings. Case studies can be helpful to credibly introduce the worthiness of adopting new research methods that engage policy-makers to at least consider changing policies, particularly if these are tied to tight budgetary constraints. Albeit there is no a priori guarantee that commissioned fieldwork will produce relevant findings for policy-making, currently this approach usually informs policy-makers more clearly than simulation models. That is due to focus of discussing still-observable states of a particular phenomenon, both in terms of intervention time and scale. Policy-makers recognise the value and implications of such detailed reports, and usually find harder to evaluate the potential inaccuracies of simulation results because of their hypothetical time scales. Yet to pursue an appropriate policy change, reliable means of evaluating possible interventions are necessary in light of an in-depth understanding of the current relevant circumstances. There has been methodological progress in interpreting models processes and results, but relevance is still largely theoretical and reliability of validation procedures is incipient. Thus validating outputs that have no comparable datasets is an eminent issue, and this seems only clarified by comparing simulation results with further data. Simulation is perhaps best understood nowadays as a complementary approach to describe in detail – along with traditional quantitative and qualitative research methodologies

### Bridging expert and lay knowledge in policy making activities: which role(s) for models?

S. Occelli*, F. Semboloni

*Istituto di Ricerche Economico Sociali del Piemonte, Turin, Italy and Florence University, Florence, Italy*

As other societal organizations, governmental systems are currently exposed to social, economic geo-political and institutional pressures which call for adaptations and major changes. Since the last decade, in particular,

a number of processes are at work in concocting a radically different policy background, also popularized as the e-government and e-governance transformations. In particular, the transformations associated with the responsibility enhancement are of utmost relevance. They in fact urge public administration to improve, also by means of ICTs, its overall production processes, while designing, managing and accounting policy actions in innovative ways. Actually, no matter how policy and governmental change processes are viewed, they turn out to be increasingly knowledge demanding. This requirement should not come unexpected since in the current debate knowledge and learning are widely acknowledged as being foundational to the very features of tomorrow society. So far, science has been the unwarranted champion in knowledge processes, and its role in supporting a knowledge society of tomorrow is expected to be further enhanced. Scientific thinking, however, has not been immune to the effects of societal changes. The transformations occurring in the field are by no means less deep than those observed in society. They herald in fact something different from the kind of paradigm shift, advocated by Kuhn whenever novel theories are consolidated. Uncertainty, urgencies, ethical values and the societal relevance of the issues at stake often make (policy) situations not solvable by means of neat scientific expertise. In many cases, an extended peer community is called for in which scientific experts and stakeholders (including decision makers and citizens) would engage into dialogue and leverage their own knowledge in order to cope with the policy problems at hand. Whether the goals of this community would be locally based, being set by specific population needs such as those related to the delivery of education or health services, or motivated by wider societal concerns, such as those caused by climate changes, is an open question. A related and even more thorny one is how the expert and lay knowledge would be shared and whether their mutual understanding be beneficial for supporting better policy processes. In this context, a main questioning of this paper is how and to which extent, in the current increasingly ICT mediated human organizations, models might be effective vehicles for that. The functional and cognitive mediator roles models have conventionally played in policy making are briefly recalled. The former mainly concerns the syntactic, semantic and project components of a modeling activity. The latter deals with the linking between the process of abstraction involved in model building and the general, socioeconomic, cultural and institutional context in which, a model activity takes place. Building upon the experience gained in the model based policy studies carried out in Piedmont and Tuscany over the last decade, these roles are re-appraised and the main pitfalls in model usage reviewed. The discussion also suggests that in order to overcome them, novel model requirements should be acknowledged which, in addition, turn out to be relevant in supporting policy extended peer community. In this regard, a twofold argument is offered. First, it is argued that by providing an epistemology for making sense of social processes among the members of that community, models (and namely the many applications of model functional and cognitive roles) would play a novel and to some extent unanticipated role in leveraging the organizational capability of that community. Second, it is also realized that in order to successfully instantiate that organizational capability, co-evolutionary changes should take place in: a) the encoding-decoding processes underlying model activities, on the one hand, and b) the ways policymaking activities are implemented in real governmental systems.

### Modelling policy making in a group: empirical applications and challenges for the future

D. Payne*

*University College Dublin, Dublin, Ireland*

There are a wide range of approaches in the research literature for examining policy making in groups. This paper focuses on rational choice institutionalist approach, which allows us to pay particular attention to the mechanisms by which groups of policy agents reach collective agreements, even where they hold very different policy preferences for the policy issues being negotiated. In most applications in this field, the rational choice, institutionalist perspective is combined with a formal deductive modelling approach. Moreover, within the rational choice field, it is cooperative game theory, and in particular the focus on bargaining and vote-trading, which provide key theoretical basis for the assumptions of collective decision models. Combining the deductive modelling approach with real decision data allows contrasting model assumptions about the collective decision process to be set out explicitly, as well as carefully tested as to their veracity in predicting real decision outcomes. By way of example, this paper will discuss various empirical applications of this modelling approach to prospective and retrospective decision making. Moreover, the decision models are implemented as computer simulations of the actual negotiations. This enables us to examine what might be the impact on the model predicted collective outcomes, given alternative distributions of resources and salience across the policy agents, as well as the likely decision outcomes under alternative negotiations strategies implemented in the various computer simulations tested. To date, there have been a number of empirical applications of these computer simulation collective decision models and across a range of different decision arenas. This paper will discuss the key successes and new challenges of this approach to collective decision modelling, as well as identify the

limitations of this approach and how these limitations might be overcome by enhanced research collaboration.

### Intelligent Policy Automation for Open Networks and Smarter Infrastructure

J. Pitt*

*Imperial College London, London, UK*

We are interested in the design, specification, implementation and run-time operation of open embedded systems for network and infrastructure management. Our approach is to combine aspects of social networking, complex systems and multi-agent systems to ensure such systems exhibit self (-regulating, -organising, etc.) qualities in the context of an effective operational policy, thereby demonstrating both timely adaptation and 'fair' decision-making, in response to recognised events, prevailing environmental conditions, or anti-social (illegal, or invalid) behaviour of other components. We will present a framework which inter-leaves aspects of norm-governed specification from distributed multi-agent systems, opinion formation from social networks, and voting procedures from computational social choice, to develop a self-regulating network. We propose to extend this idea to include dynamic specification, modular argumentation, and richer opinion formation models for infrastructure management, where the problem is compounded by making policy in the context of a policy hierarchy, the uncertain impact of policy decisions on policy subjects' behaviour, and the role of policy subjects in policy-making itself. Our ambition is to create a general computational framework which uses evidence-based policy making to encapsulate socio-economic principles for creating enduring institutions for smart infrastructure management.

### Language of professional, language of scientist: can complexity science make each other understandable?

G. Rabino*

*Polytechnic of Milan, Milan, Italy*

Language, the explicit one (interpersonal communication) or the tacit one (messages conveyed by behaviours), reveals our innermost way of thinking. In this meaning, language of scientists and language of professionals seem to be very different, because they give often rise to misunderstandings or at least to incommunicabilities. These facts are really evident for example in the field of spatial planning and policy.Working for many years at the edge of these two activities (science and profession), analysing the differences and digging deep into their roots, three levels of divergence drew (my) attention: (i) in epistemology. A forma mentis rooted in a holistic humanist culture or in a reductionist naturalist science;(ii) in methodology. A preference for abstract and specialistic thinking or for a real generalist knowledge; (iii) in practice. A mind orientation to scientific discovery or to exploitation of professional expertise. These divergences are fully detailed and argued in the conference presentation. Then it is suggested that, instead of an opposition, there is a possibility for a fruitful integration within the science of complexity paradigm (as much as the paradigm spreads and becomes the usual way of thinking of a professional and scientist, more or less oriented to science or profession).In this view, starting from a personal interpretation of complex science (a widely distribute knowledge in the context of a global multi-level consciousness, on the subject side; an augmented and at the same time naturalized knowledge, on the object side), some features of this emergent new scientific-professional activity are sketched.

### ICT support to policy modelling: the IPTS experience on managing policy making complexity

J. J. A. Sanchez*, L. Minghini, G. Misuraca

*European Commission, Institute for Prospective Technological Studies, Seville, Spain*

The main activities of the Institute for Prospective Technological Studies (JRC-IPTS) relate to providing strategic support for the conception and development of European Union policies, working at the intersection between the socio-economic aspects of an issue and the science and technology involved (http://ipts.jrc.ec.europa.eu/activities/). To do so, JRC-IPTS researchers make use of both, sector-oriented models and models integrated across policy domains such as economic dimensions, energy, environment, climate change, transport, agriculture and others. Running model scenarios requires in many cases highly intensive computational resources and the use of very large databases. Moreover, the policy making process imposes tight deadlines on

deliverables and high degrees of flexibility for deployment of models and platforms, including offering these as a service to different communities. To respond to these needs, the supporting computing infrastructure has had to move from a mere personal computer based environment to an innovative, virtualised data centre oriented architecture, where features like performance and flexibility can be managed and delivered more efficiently, while enabling a more optimal use of resources (capital and human) and energy. The regular introduction in the market by different manufacturers of highly performing and scalable processors and storage solutions at near commodity prices, together with improvements in communications (local and wide area networks, cloud computing) have made possible the said shift of the computing paradigm in support of modelling. The current work focuses on the innovative use of state of the art technologies as enabler to boost researcher's productivity in fields that hitherto looked incompatible to support modelling, namely virtualisation and high performance computing. At the same time, it demonstrates that inter-departmental, multidisciplinary approaches are key factors to achieve the expected results.

### Satellite Workshop: Policy Modelling

B. Schrempf*

*University College Dublin, Dublin, Ireland*

Investigating the Management of Emerging Technologies for Economic Impact is the purpose of the ManETEI project. By analysing the nanotechnology industry and innovation networks in Ireland and their influence on different local industries, effects of different behaviour of actors as well as policy measures in nanotechnology in particular as well as in emerging technologies in general are revealed. Analysing innovation networks by applying ABM mainly relies on the fact that agents of an ABM interact autonomously, react on their environment and show the properties of local interacting as well as path dependencies and dynamic returns. The decisive feature of ABM is that very different actors with bounded rationality can be modelled, and emergent phenomena can be observed (Pyka, Scharnhorst, 2009; Dawid, 2006; Axelrod, Tesfatsion, 2006). Social Network Analyses of these networks provides the data to build an Agent Based Model (ABM). The ManETEI-ABM is based on the SKIN model, which consists of heterogeneous agents, acting in a changing environment (Ahrweiler, Pyka, Gilbert, 2004). The SKIN model is adopted to fit the purpose of modelling the nanotechnology network and the already existing industry architecture. In the baseline model of the PhD project, the aim is to reproduce basic network patterns, network statistics and dynamics. In a first step towards this goal it is necessary to calibrate the ABM with empirical data (Windrum, Fagiolo, Moneta, 2007), which contains a social network analysis of the respective innovation network and a qualitative investigation. Data needed include the number and types of actors (SMEs, universities, financial institutions) active in the network, network statistics like degree distribution and cliquishness and e.g. of collaboration rules, partner choice behaviour as well as policy instruments promoting innovation. A first SNA of the EUs Framework Programme 6 in Nanotechnology already provides results for a calibration of the model. The artificial networks produced by the ABM will be compared to the real world nanotech innovation networks. A comparison will be possible on the level of network structures and statistics. Network dynamics like the emergence of small world and scale-free properties, will be reproduced by the model. In the simulation it will be then possible to identify behaviour, decision making processes, knowledge dynamics and promotional instruments which influence the development of innovation networks in different industries most. Numerous simulation runs with the same settings using a Monte-Carlo simulation of outcomes. Changed settings will then lead to a different distribution, making it possible to compare the effect of alternative policy measures – even though only on a nominal scale. Analysing and understanding the artificial world and investigating the effects of changing endowments, rules of interaction and environmental settings on the artificial world conclusions from the simulation can be drawn on the structure and behaviour of the nanotech innovation networks, giving policy makers a tool to act appropriately.

### Science of computational socio-genomics

J. Sutcliffe-Braithwaite*

*University of Westminster, London, UK*

This paper proposes a new science-based method and toolkit to support Policy modelling; we will argue current methods are increasingly ineffective in the modern, global, complex world being encountered and likely to increase in severity. We will argue that the answer requires a radical reappraisal of every facet of what Policy modelling is about  a root and branch 9W investigation1; BAU is not an option. Furthermore

the underlying issue is what is the complex adaptive system called Society; the fundamental answer called computational socio-geonomics, and its tool-kit called Metaloger, are correct because they are symbiotic with the perceived dimensions of society and its needs2. They will be a foundational component of the FuturICT Living earth simulator; this workshop starts the serious consideration of this new science. Policy modelling concerns design and implementation of a game-plan for any domain of life; as in sport, the team, its coach, its manager, the ruling-body, study other teams game-plans. This paper proposes that a new life science of computational socio-geonomics will be a fundamental contribution to the domain of Policy Modelling involving all the focus themes listed and additionally change in society at a paradigmatic level. SOCIONOME is the coded structure of human designed society and socio-geonomics is its evolving enactment, past, present, and future. The session will therefore outline what the new science is and examine how this new paradigm maps onto Policy modelling. It will also touch on the scale of change involved in its take-up across society. It will take as starting point that Policy Modelling is a sub-type within a continuous spectrum of modelling that is pervasive to all of human activity. You could add strategic planners, managers and leaders, and actually all of us when we take any life-decision, at however humble a level. We are the CAS called society; our perspective of both a new science and practice of computational society puts in the hands of everyone a tool to do it better. We will show this leap forward is to render the fundamentals of human social existence computable we are beginning to enter a world of On Computable Society; it is about intervention based on a joined-up science of human purpose. The human perturbations that trigger these derive from the unfolding of complex purposes. We will focus particularly on why this is the key bridging aspect: it is in vivo computational modelling of human purpose. Policy modelling will become an in vivo as well as in silico experiment with real-life ICT the in vitro dimension. It is a constructivist model, fashioned and enacted in the living lab of life itself. The most novel component of the technological solution is called Metaloger which is a means to process the components of the CAS discussed above. It yields the dynamics that generate futures, and, for this workshop, are the raw material of policy determination. We will try to show that the new affordance of real-time Meta-modelling will enable a new science and practical basis for Policy modelling. We think this is possibly the generic societal process of governance (not Government!). SOCIONOME AND METALOGER are a new kind of computing. Figure 1 is a schematic of Metaloger, the toolset of computational socio-geonomics. A hypothetical initial schema and basis is therefore that: 1. the sum total of the means whereby the Human Race discourses on life, its purpose, direction, action and change to this, is the foundation of computational socio-geonomics, and the basic principle of Metaloger design, construction, and deployment 2. Meta-modelling enables a working-reconciliation of this multi-faceted phenomena, that is now practically summed up as multi-disciplinary research, e.g. apparently conflicting MetaFoRs; it also explains and enables the phenomenon of the sum is greater than the parts 3. The Complex Adaptive System called society is the living working out of the above, and whilst natural science, mathematics, the life sciences, the biological sciences, etc all contribute to specific useful models, the reality is they are all subservient to (subjective) human will and wilfulness: that is the Final Cause of everything societal, its creativity (aka innovation) and also all the opposites of this as well 4. Hence Policy modelling concerns the engagement, empowerment and enablement of the human race in all its myriad activities to deploy its unique intellectual capabilities towards the well-being of (wo)mankind and the entire ecosystem we inhabit and depend on; this extends from every enterprise up to the GAIA imperative specifically S-GAIA; this is the deliverable of Metaloger Labs 5. The divide discussed in this workshop may be the chimera. The challenge is in the construction of meta models and the translation between them that enables meaningful discourse that is a combination of both. 6. Actually Policy Modelling is life itself. We need a new tool to do this better.

### Technology space, landscapes and units of knowledge: the issues presented by a core component to simulation models of innovation

C. J. Watts*

*University of Surrey, Guildford, UK*

Computer simulation models of technological evolution, academic science publication, and knowledge dynamics and the emergence of innovation networks of firms can each serve as tools for thinking about innovation. The models are introduced to explain stylised facts about innovation, such as the emergence of macro-level patterns from micro-level behaviour or social and economic interactions. In cases where experimenting with real-world systems is impractical or unethical, these simulation models can support policy makers, including on R&D policy between firms and within firms, and on the organisation of academic researchers. To be convincing to policy makers, however, simulation models must address issues of validation. This presentation will draw attention to analogous validation problems of validating in various simulation models and invite discussion of possible solutions. In each case the validation problem concerns a core component to that model, generally some sort of network or structure of interdependencies.

# Social Energy: A Useful Notion for Analysing Complex Socio-ecological Systems?

**Organizers: S. Wolf, A. Mandel, I. Chabay, C. Jaeger, I. Kondor**

### From individual energy to collective social behaviour in animal populations

N. Perony*, C. J. Tessone, B. König, F. Schweitzer

*ETH Zurich, Zurich, Switzerland*

We study the relation between animal motion on an individual scale and complex collective behaviour arising at the level of an animal population. We use a simple energy-based approach to model micro-level spatial patterns and apply it in a multi-agent context to reproduce macro-level socio-spatial patterns. We first start from the general comparison between animals on the move and random particles endowed with a certain energy. We detail how discrete sampling of the individuals position allows us to recreate a landscape of potential in which the motion of freely-moving particles mimics that of the animals. We then further the comparison by employing this approach in the study of the collective behaviour of a population of wild house mice, individually equipped with RFID tags to track their spatiotemporal behaviour. We extend the ecological concept of "landscape of fear", which represents the way in which the movement of individuals and populations is influenced by their environment (notably their predators), by introducing a more general perceptual landscape. This landscape is built by establishing a parallel between the motion of mice across their natural environment and the motion of Brownian particles in a (i) purely diffusive context when a mouse is nesting, and (ii) advective-diffusive context when a mouse is travelling between two nestboxes. We show how this comparison allows us to map a landscape shaped by all socio-spatial constraints that apply to the behaviour of the mice, and compare this resulting perceptual landscape to traditional ways of studying the environment of animal groups. We conclude on the utility of simple energy-based approaches to animal behaviour in the study of complex phenomena at the population level.

### Energy – a missing dimension of evolutionary models of industry dynamics

K. Safarzyńska*

*University of Economics and Business, Vienna, Austria*

A transition to sustainable economy is unimaginable without restructuring energy system, in the context of its fossil-fuel dependency. Neoclassical models are too abstract to deal with changing structure of the economy because of their focus on equilibrium conditions and rationality of market participants (Ayres and van den Bergh, 2005). As a consequence, the theoretical and empirical evidence on how improvements in energy intensity can lead to higher energy consumption, referred to as rebound effect, remains partial and inconsistent (Sorrell, 2009) and lacking behavioural foundations. On the other hand, evolutionary modelling provides tools and concepts to frame complex dynamics, dissipative structures, self-organisation processes, and bounded rationality of heterogeneous agents beyond the scope of neoclassical economics. Still, the energy dimension of economic growth and industry dynamics is largely ignored in relevant evolutionary-economic modelling and theorising (Foster, 2010). As a consequence, there is little understanding of specific channels through which demand and supply can affect the use of, quality and composition of energy sources in production. So far, only few evolutionary models have explicitly accounted for an environmental dimension of economic dynamics either by specifying energy as an input in production (Nannen and van den Bergh, 2010) or by introducing an environmental component into utility functions of consumers (Janssen and Jagger, 2002; Oltra and Saint-Jean, 2005; Windrum et al. 2009a,b). The main message from such models is that consumers are key drivers of sustainability: environmentally conscious consumers, who attach high weights to environmental features (service characteristics) of products, can be an important source of technological change and adoption of environmental products. However, focusing on the demand side alone overlooks symptoms of, instead of focusing on causes of, environmental harm. Transition to sustainability may require changes not only in preferences of consumers but also in the composition of inputs in production, in particular a shift towards less energy-intense and less polluting energy technologies. Because of feedback mechanisms and rebound effects underlying interactions between various types of heterogeneous agents, it is not clear which polices can be the most effective in guiding successful transitions here. To our knowledge there is no single evolutionary model

that explores complex linkages between different fuel source in production, technological change, evolving consumer preferences and demand side dynamics. This is quite surprising given urgency of tackling climate change and the need for transitions to a low carbon economy. To address this gap, we propose an agent-based model, where technological change results from interactions on three markets: heterogeneous power plants, producers of finals goods and consumers. The model builds upon Safarzyńska and van den Bergh (2010) coevolutionary framework of demand and supply dynamics, and it extends its by adding market of heterogeneous power plants producing electricity from diverse energy sources (nuclear, coal, gas). Electricity is subsequently introduced as important input in production of final (consumer) products. This approach is motivated by the fact that electricity is an important input in manufacturing. Empirical evidence indicates that plants utilising more advanced manufacturing technologies (AMT) are less energy-intensive and more electricity-intense (Doms, and Dunne,1995). Many of manufacturing activities rely on electricity as a major energy source, which can reach up to 95 percent, while there is little substitution between fuels in manufacturing sector (Steinbucks, 2010). In our model, electricity market is composed of heterogeneous plants employing different energy technology to produce electricity. Electricity production in each plant is described by a fuelspecific Cobb-Douglass function that accounts for substitution of fuel, labour and capital in electricity generation. Unlike in most models of electricity markets, long-term investment decisions over size and fuel type of a new plant (coal, gas and nuclear) are endogenous, while the productivity of incumbent plants can change over time due to innovation and learning-by-doing. Electricity is an input in production of consumer goods. On the market for final products, a technological trajectory arises from the interplay of incremental innovation, search for a new product design and marketing activities by heterogeneous firms. On the demand side, we focus attention on the interdependence of consumer preferences. Two disequilibrating forces influence evolving preferences of consumers, namely: a desire for distinction and imitation of other consumers within the social network. The model provides insights into technological change, substitution of energy sources in electricity production, and statusdriven consumption. A number of policy measures (tax on coal, gas; tax on energy-intensive products; subsidies for research; public procurement) for altering path of market development towards a low carbon economy are examined and compared.

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### Human energy concepts in the social sciences and how to model them

C. J. Watts*

*University of Surrey Guildford, Surrey, UK*

Everyday applications of the word "energy", to human beings who are showing signs of vitality, confidence or high motivation, raise the question whether there might be useful analogies to be drawn between the human or social phenomena behind these applications, and energy concepts in the physical sciences. Ideally an energy concept would be identified in the behavioural and social sciences that was easy to communicate, practical to measure and allowed the use of mathematical tools, as the concept in physics did, or at least some sort of abstract, rigorous, calculative tools, such as computer simulation. In this paper pointers are given to several research fields where candidate concepts may be found, ranging from psychology to sociology, and including positive organisational studies. Approaches to modelling energy concepts are described, including statistical

modelling, social network analysis, system dynamics modelling, and agent-based simulations. Finally, some objectives are given for social energy studies, especially in application to larger-scale social organisation.

**Social energy – Workshop introduction**

I. Chabay, C. Jaeger, I. Kondor, S. Wolf*

*Potsdam Institute for Climate Impact Research, Potsdam, Germany*

The purpose of the workshop is to discuss a social energy concept that should facilitate the study of complex socio-ecological systems. We present different aspects as input to the discussion. (i) In the context of climate change economics, the study of transitions from one equilibrium to another one is of interest to analyse win-win options for climate and the economic system. Simple stochastic models may be one tool to think about such equilibrium transitions. Borrowing from the theory of randomly perturbed stochastic dynamical systems, several meta-stable states may represent the different equilibria and the variation between agents' actions may be the "perturbation" that enables transitions from one of these states to another one. Then, a potential function could be interpreted, in a broadly metaphorical sense, as describing a form of "social energy" present in the system. We are interested in the opportunity that may derive from the notion of a social energy surface or landscape in considering transitions between social system states. We aim to understand the possibilities for using the fuzzy notion of social energy and the diagram suggestive of a slice through a potential energy surface to guide development of models of transitions between social-ecological-economic system states. How can the rather different notions from natural science be applied metaphorically to social systems, including hysteresis and tipping points, fluctuation dissipation, free energy, entropy, etc? – in particular in the cases in which the community is subjected to shocks or perturbations large relative to the coping capacity of the system. What is needed to better understand and model how a society or community undergoes or may undergo a transition from one "state" to another? The state of the system, in this case a community of interacting people within a defined spatial, ecological, and economic domain, must be sufficiently stable to allow for its relevant descriptors to be specified. If stable, the system must be in a local minimum in the function landscape. What kind of descriptors could be used to form the basis for different models of the system under perturbations leading to changes or transitions to another state involving all or some subset of the characteristics of the community? The components of the social system to consider include the economic, physical infrastructure, information resources, social (and political) affiliations and enmities. The economic dimension can be treated, for example, as a stochastic dynamic model described by Wyart and Bouchaud. The stability of an ensemble of triadic social configurations is described in the energy landscape of social balance of Marvel, Strogatz, and Kleinberg. Can the network analysis meaningfully incorporate measures of social capital and social energy to assess probabilities of transitions to a different social structure? Are there other metrics from social psychology that could lead us further in this? What about changes in the organizational, informational, and physical infrastructure in the event of an external shock (e.g. earthquake, armed conflict) to the community? Can a system of models explore the parameters for transition of states of the community state in separate components or must it be fully integrated to be useful, e.g., for policy decision makers? We are looking forward to learning with the group in our session in Vienna so that we understand better and can make good use of the virtues and limits of this direction of inquiry. (ii) Some cautionary remarks on the use of the social energy metaphor (Imre Kondor) It is tempting to use the picture of an energy landscape to interpret some social phenomena such as revolutions and other changes in social, institutional or economic arrangements of human society. If, however, what we wish to apply in a social context has anything to do with what is called energy in physics, we have to exercise extreme caution and keep constantly in mind that the extended use is highly metaphorical and easily misleading. There are (at least) two important aspects in which physical energy differs from its any possible extension to the social domain. 1) The energy of a closed system is conserved which is deeply related to time translation invariance, that is to the fact that the rules of the game are constant. This is certainly not the case in human society where agents compete and cooperate, have interests, emotions, intentions, can learn and adapt, etc., so that they continuously change their interactions. 2) If a physical system is not closed but interacts with its surroundings, its energy is not conserved, there is a constant exchange of energy with the surrounding heat bath and the system will progress toward equilibrium by minimizing its free energy. So we have an objective function to be minimized here, a goal as it were, a distinguished direction of time, and a final arrival in the Nirvana of equilibrium where all the preceding history is forgotten and, for a large system, the relative fluctuations are very small. This picture has greatly (and most unfortunately) influenced economic theory, but, in a wider context, fantasies of an ideal society as a goal of history keep recurring time and again. In some respects the picture of fitness landscape in evolutionary biology is somewhat more adequate to conceptualize the dynamics of human society, but, of course, it is still far from grasping the most essential specificities of social dynamics: Humans are strategic agents, they reflect upon their situation, their

interactions depend on their goals and how they perceive their chances of achieving them, etc. The concept of energy has to be stretched very far indeed if it is to accommodate this kind of agents. If we manage to avoid mistaking a metaphor for a theory, however, models of heterogeneous physical systems with competing interactions (spin glasses) can become an extremely rich source of ideas and their astonishing complexity can serve as a (very crude) lower bound for the complexity of any social theory. (iii) Remarks on Emotional Energy (Carlo Jaeger) For Aristotle, a virtue is the disposition to do something well, while actually doing it well is an energy. He coined the term "energeia" to talk about events where something fulfills a characteristic disposition. The Roman rhetoric teacher Quintilian spoke of the energy of the spoken word: words have a disposition to affect a listener, well-spoken words actually do so. In the Middle Ages and the Renaissance, energy was an important rhetorical concept, especially when discussing how spoken words can generate vivid images in the minds of the listeners. In his influential book "Shakespearean Negotiations: The Circulation of Social Energy in Renaissance England" (1988) Stephen Greenblatt argues that the rhetorical energy of Shakespeares plays is in fact a social energy: "What then is the social energy that is being circulated? Power, charisma, sexual excitement, collective dreams, wonder, desire, anxiety, religious awe, free-floating intensities of experience". It was an English physician, Thomas Young, who in 1807 introduced the word "energy" in physics by writing: "The product of the mass of a body into the square of its velocity may properly be termed its energy." Since then, the physical concept of energy has shaped the use of the word in ordinary language to a large extent, not only in the realm of science and technology, but also when talking about mental and social events. An interesting proposal to develop a useful concept of energy in the social sciences has been made by Randall Collins (Interaction Ritual Chains, 2004). He introduces a notion of emotional energy (EE) as follows: "EE is the emotional feeling of strength, confidence, and initiative, at the high end of the continuum; at the low end, it is a feeling of weakness, passivity, expectation of failure, depression." The key idea then is that EE is strengthened or weakened through face-to-face encounters called interaction rituals. Interaction rituals form chains through two separate mechanisms. On one hand, people tend to repeat encounters that have enhanced their emotional energy and to avoid those that have impaired it. On the other hand, the opportunities for interaction change for all sorts of reasons, requiring people to engage in encounters they would rather like to avoid. EE can be used to study how persons choose to interact, across whatever range of situations they may encounter. There is no need for conscious comparisons and deliberations: "since EE can be felt, as an emotional attraction or lack of attraction (or at the extreme, repulsion) individuals make emotionally-oriented 'choices' even unconsciously". The embedding of EE dynamics in interaction ritual chains makes evolutionary game theory a promising candidate for their study. Often, EE is enhanced by successful coordination among people, as in dancing. Therefore, iterated coordination games should be expected to play an important role in models of EE dynamics.

# Unraveling and Controlling Discrete Dynamical Systems

**Organizers: J.M. Baetens, F. Bagnoli, B. de Baets**

### Symbolic dynamics for studying complex systems

F.M. Atay*

*Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany*

Symbolic dynamics provides a natural bridge between discrete- and continuous-state systems by coarse-graining continuous state variables into discrete ones. Although some information is presumably lost in the process, it may often be possible to gain useful knowledge that is otherwise difficult to obtain. In this talk we report on our recent work where we study dynamics on networks based on methods from symbolic dynamics, particularly focusing on networks with communication delays. We develop the concept of forbidden symbol sequences for delayed systems and apply it to detect network synchronization, or conversely, to determine unknown delay values in a synchronized network. Furthermore, the symbolic approach unravels nontrivial transition patterns as the network approaches synchrony.

### The stability of cellular automata revisited

J.M. Baetens*, B. De Baets

*Ghent University, Ghent, Belgium*

Despite the efforts spent on an elucidation of the dynamics of cellular automata (CA), *i.e.* simple mathematical models that are discrete in all senses, it is not yet clarified to what extent the specificities of the simulations affect their dynamical properties. Indeed, many papers have been written on the intriguing spatio-temporal patterns these utter discrete dynamical systems can bring forth, but - aside from the imposed initial condition - it is not yet clear how their dynamics is affected by the decisions that have to be made prior to the actual model simulation. By means of meticulously formalized non-directional (topological) Lyapunov exponents and Jacobians, we first outline the methodology that allows for a sound quantification of the dynamical properties of CA after which we give an overview of our recently obtained results with regard to the interference that can exist between the employed update method and the characteristics of the underlying tessellation, on the one hand, and the stability of CA, on the other hand.

### Can we understand the full Lyapunov spectra of cellular automata?

J.M. Baetens*, B. De Baets

*Ghent University, Ghent, Belgium*

Ever since the postulation of cellular automata (CA), numerous studies have been conducted to gain insight into the dynamical properties of these uttermost discrete dynamical systems. Mostly, these studies were motivated by the fact that CA turned out capable of evolving intriguing spatio-temporal dynamics notwithstanding their intrinsically simple nature. Though many measures have been proposed for gaining insight into CA dynamics, the use of Lyapunov exponents that measure how their phase space trajectories evolve with respect to each other has proved particularly fruitful. Strangely, to this day, studies have been confined to the so-called maximum Lyapunov exponent (MLE), even though a CA is characterized by a full Lyapunov spectrum since CA may be regarded as high-dimensional dynamical systems. Motivated by its usefulness in elucidating the dynamics of continuous dynamical systems, we outline a procedure that allows for the determination of a CA's full Lyapunov spectrum and we show that the highest Lyapunov exponent in these spectra agrees with the one retrieved using numerical methods for assessing the MLE of CA. Further, we discuss the meaning and use of the other exponents of which the Lyapunov spectra are composed.

### Chaotic bifurcations induced by topology in a cellular automaton opinion model

F. Bagnoli*, R. Rechtman

*Universita di Firenze, Firenze, Italy*

We study a cellular automaton opinion formation model of Ising type, with antiferromagnetic pair interactions, modeling anticonformism, and ferromagnetic plaquette terms, modeling the social norm constraints. For a

sufficiently large connectivity, the mean-field equation for the average magnetization (opinion density) is chaotic. This "chaoticity" would imply irregular coherent oscillations of the whole society, that may eventually lead to a sudden jump into an absorbing state, if present. By varying the log-range rewiring of links, we trigger a small-world effect. We observe a bifurcation diagram for the magnetization, with period doubling cascades ending in a chaotic phase. Similar and richer phenomena appears in scale-free networks, which are more representative of a social system.

### Synchronization and control of disordered cellular automata

F. Bagnoli, R. Rechtman*

*Centro de Investigacion en Energia UNAM, Temixco, Mexico*

We study the chaotic properties of cellular of cellular automata, *i.e.*, systems which are not chaotic in the usual sense, but are unpredictable for finite perturbations, in the case of non-regular lattices. We relate the Lyapunov maximal exponent to the synchronization threshold, and apply this result to the problem of optimal synchronization (control) of a replica with a master copy. We show that it is possible to exploit the characteristics of the system in order to reduce the distance between two replicas with less control.

### Controlling self-organized criticality in sandpile models

D.O. Cajueiro*, R.F.S Andrade

*National Institute of Science and Technology for Complex Systems, Distrito Federal, Brazil*

Self-organized criticality (SOC) is a characteristic of systems that are driven by a slowly acting external force and organize themselves through energy dissipating avalanches of all sizes. Examples of these events of dissipation of energy in nature and society are avalanches that arise in snow hills, bubbles that explode in financial markets, earthquakes and the spread of forest fires. Although it is not possible to intervene in events such as earthquakes, in some sense we can intervene in the process that generates large snow avalanches, the explosion of stock bubbles and the spread of forest fires. In order to consider the problem of controlling self-organized criticality in sandpile models, we introduce an external control to reduce the size of avalanches in some sandpile models exhibiting self organized criticality in lattices and complex networks. The control action, which amounts to triggering avalanches in sites that are near to become critical, reduces the probability of very large events, so that energy dissipation occurs most locally. The proposed control seeks a tradeoff between control cost and large event risk. Furthermore, to study the optimality of these strategies, we also propose a dynamic programming approach to deal with this problem in tiny systems. First, the optimal solution of the problem is characterized by numerical solutions of the Bellman equation. Second, the solution is used as a benchmark to value how far from the optimum other heuristics that can be applied to larger systems are.

### Emergence of synchronicity in phasic sensitive cellular automata with stochastic topology

D. Makowiec*

*Gdansk University, Gdansk, Poland*

The presented problem is inspired by the first heart pacemaker (the sinoatrial node): how simple operating units, rather poorly connected, self-organize themselves into a state which oscillates regularly. Our solution relates to Greenberg-Hastings cellular automata for modeling excitable medium. Each cellular automaton circles according to a fixed sequence of states: firing, refractory and activity. Time steps spent in each state can be changed by interactions with neighbouring cells. The activity state can be shortened and the refractory state can be elongated. The rare intercellular organization of interacting oscillating units is represented by diluted square lattice which additionally is stochastically rewired. The resulting stationary states are oscillatory with robustly fixed frequencies. It appears that sustained spiral waves of cells in firing state develop only at the certain model parameters. Depending on interaction parameters these spirals can be expanding or collapsing. The autonomous nervous system controls the sinoatrial node oscillations to adjust the heart rhythm to actual needs of the human body. This aim is achieved by sending neural impulses to shorten or elongate the activity state. During presentation we discuss the influence of external fields on oscillatory properties of the discussed

system.

### Information Codimension and Persistent Mutual Information

R. C. Ball, M. Diakonova*, R. S. MacKay

*University of Warwick, Coventry, United Kingdom*

We propose to use the Persistent Mutual Information (PMI), the Shannon information about the infinitely separated future stored in the past, to quantify strong emergent behaviour. We test this approach on data from the logistic map, and find that PMI captures the global periodicities of the system independent of whether the attractor is chaotic or not. In the area-preserving Standard Map PMI is found to grow indefinitely with resolution. We use information dimensions of the underlying spaces to interpret the scaling behaviour. The scaling index is the information codimension (IC), a function of resolution and time separation. We find that for the fully-integrable case curves of IC at different resolutions collapse onto a single time separation plot. The well-defined rescaling for which this happens is related to the specific manner in which apparent causality is lost with time. We also investigate the effects of increasing non-linearity and see that the breakup of the last surviving KAM torus is associated with a qualitative change in behaviour.

### Entropy as an indication of the runtime of terminating discrete dynamical processes

J.J. Joosten*, H. Zenil, F. Soler-Toscano

*University of Barcelona, Barcelona, Spain*

Various hard problems in computer science are related to the asymptotical runtime of terminating processes. Most prominent among these problems is the question whether $\mathsf{P} = \mathsf{NP}$, that is, whether problems whose solutions can be checked in polynomial time to be solutions can actually be solved in polynomial time. In this paper we make a first experimental study on how a certain notion of entropy can be an indication of the runtime of processes. To this extend we have programmed and ran all Turing machines with two symbols and either two or three states. For a space-time representation of the tape-evolution of these machines we defined a notion of entropy. For all the machines with 2 states and 2 colors we have verified that the entropy is 1 if and only if the process terminates in linear time, it is 2 if and only if it takes super-polynomial time and strictly between 1 and 2 for all asymptotic runtimes that are slower than linear but faster than super-polynomial. Ongoing work aims at testing whether this strong correlation can be extended to a more general setting.

### Excitable nodes on random graphs: Structure and Dynamics

K. Manchanda*, R. Ramaswamy

*Jawaharlal Nehru University, New Delhi, India*

We study neuronal cellular automata on quenched random networks and examine the interplay between topology and nodal dynamics. Each node in the network has $r$ states of which $k$ are active, one is silent, and $(r-k-1)$ are refractory. The dynamics on each node changes according to well–defined evolution rules. We address the question of whether a particular network design pattern favors the generation of rhythmic activity and whether this design can sustain such activity. The effect of the heterogeneity and variation in network growth mechanism on the network dynamics is also examined. We introduce heterogeneity in the system in two ways, (a) by allowing the nodes to have different values of $r$ i.e. the size of the state space at each node is different and (b) at a fixed value of $r$, by having different values of activity period ($k$) and refractory period $(r-k-1)$. For small networks, precise mathematical conditions for sustained activity are derived whereas for large networks numerical results are presented.

### The behavior of the dynamic system of electric arcs in a laboratory scale vacuum arc-remelting furnace

C.S. Mucsi*, J.L. Rossi

*Instituto de Pesquisas Energeticas e Nucleares, Sao Paulo, Brazil*

The vacuum arc remelting (VAR) furnaces are used to produce high quality metals and alloys, used in the aerospatial and nuclear industries. The electric arc in a VAR furnace is disturbed by the continuous dripping

of melted metal falling down from the electrode. The consequence is a well-known source for metallurgical defects and electric transients inserted into electric power lines. This work presents results obtained during the study of the disturbed electric arc dynamics for the operation period of a laboratory scale VAR furnace. Experimental arrangements were set up to allow long electric arcs appearing between the electrodes so the electric signal would be disturbed by only one drop at a time. Electric voltages between electrodes during long arc gaps were digitally recorded together with digital filming and further, data analysis were performed. The correlation dimension was first evaluated indicating a chaotic behavior in the evolution of the dynamical system. The behavior of the largest Lyapunov exponent was analyzed and compared to the disturbed electric signals showing a cyclic oscillation since the non-disturbed electric arc, increasing disturbed arc due to the melt of the electrode until the metal drop which precedes the non-disturbed electric arc. It was found that the behavior of the largest Lyapunov exponent during the melting process might be used as a viable tool for an automatic control of the VAR furnace.

### The chronic conflict & system dynamics

M. Round*

*Center for Autosocratic Excellence, Overland Park, Kansas USA*

Despite massive resources to solve societal issues, the perpetuation of system undesirable effects continues. The penal system, math education, poverty, crime, and similar issues often share a common feature: agreement there is a problem, but disagreement on how to fundamentally address the problem. The inability to reconcile 'constraint management' and 'core problem' approaches can manifest itself in a chronic conflict, resulting in the continuation and exasperation of undesirable effects. This presentation provides a process to visually integrate the chronic conflict dilemma with the continued undesirable effects, metaphorically via the Lorenz Attractor, as a starting point for proper systems improvement, now and in the future.

### Towards a "Complexity Theory": Theoretical Foundations and Practical Applications

A. Sanayei*

*Sahand University of Technology, Tabriz, Iran*

In spite of different definitions of "complex systems" (that some of them give rise to contrary results), it is ordinary to ask: "how complex is a particular complex system?" This question inspires that it is significant to say, for example, system X is more complex than system Y, or equivalently, the complexity degree of X is more than the complexity degree of Y. Strictly speaking, the class of "complex systems" contains complex systems with a continuum of grades of membership. Thus, the set of complex systems is fuzzy rather than crisp. Accordingly, the concept of "complexity" is a fuzzy concept ("fuzzy complexity" idea), and that is why we are able to compare the complexity of some given complex systems with each other. In this work, first, I explain precisely the advantages of fuzziness in complex systems and also the pivotal role of "fuzzy logic" to establish a "complexity theory". More precisely, the "fuzzy complexity" notion leads us to investigate complexity by natural language and computing with words. Second, I demonstrate that how we can apply the novel concepts of Z-numbers, Z-information, and Z-rules to decision analysis, modeling of complex systems, complexity measurement, and also establish a "complexity theory" unlike the scientists who believe that "there is no complexity theory". Finally, as an important application, I try to employ this achievement to compute the complexity degree of chaotic systems, and accordingly, explain how it can be applied to control chaotic dynamical systems. In this regard, the control of a given chaotic dynamical system can be carried out by varying the complexity degree of the system.

# Urban Social Dynamics: Segregation and Criminality

**Organizers: M.B. Gordon, J.P. Nadal, A. Tseloni, A. Vignes**

### Formalising Schelling's Bounded Neighbourhood Model

A. Afshar Dodson*, S. Stepney, E. Uprichard, L. Caves

*University of York, York, UK*

Schelling's models of segregation have been the focus of a number of studies using a range of different techniques. Whilst there has been a number of papers discussing and extending Schelling's Spatial Proximity Model, there is less work on his Bounded Neighbourhood Model, a situation that Schelling himself found "suprising". A major difficulty towards developing an implementation of the model is the ambiguity of the language Schelling uses to describe it. Although the population within the bounded neighbourhood is well defined, it is less clear how one should treat the population outside the neighbourhood. Additionally the dynamics of movement of the populations can be interpreted in a number of ways. Here we present a formalisation of Schelling's Bounded Neighbourhood Model that allows us to identify and resolve ambiguities in the original model and provides for the implementation and exploration of various model variants. These variants can then be used to test the robustness of the underlying model through computer simulation.

### Social dynamics for structured populations

M. Primicerio, S. Barontini*, J.C. Nuño

*University of Florence, Florence, Italy*

We present a model of evolution of a population in which age and social structure are taken into account. The model considers age groups and social classes and the evolution matrix is assumed to be dependent on the solution itself. Some special cases are discussed and some simulations are presented.

### Exploring intelligent agents and spatial heterogeneity in an agent-based model of civil violence.

P.J. Baudains*, S.D. Johnson, A. Braithwaite

*University College London, London, UK*

There is on-going debate as to the role of social media in recent protests worldwide. With this motivation in mind, we present an extension to Epsteins agent-based model of civil violence (Epstein, 2002) by incorporating factors observed in recent conflicts and uprisings, namely the consideration of a spatially heterogeneous environment, and the addition of purposive movement for the agents. Epstein proposed a simple agent-based model of civil violence in which two classes of agents, civilians and cops, interact within an environment. At any point in time, civilian agents can be in one of three states: quiescent, active or jailed. Being active may involve participating in protests or acts of violence. Civilian agents change their state as a function of the number of cops and active civilian agents in their local neighbourhood, their perceived hardship, their level of risk aversion and their perception of the legitimacy of the government (which, for the current models, is constant across agents). At initialization, agents of both classes are randomly distributed. They subsequently move according to a random walk (Brownian-like motion). The environment in which they move is homogeneous. Epstein shows that, despite very simplistic agent behaviour, macroscopic properties emerge. We consider how social media might influence outcomes by providing a fraction of civilian agents with global knowledge of civilian protests. Once a civilian agent with access to global information becomes active, their movement is biased towards areas of high activity. Levels of activity at each location are dynamic and a consequence of the complex interactions between civilian and cop agents. This extension leads to a consideration of spatial heterogeneity. On the one hand, agents who are protesting move towards a focal point for maximum visibility. On the other, new policing strategies are considered. Results show that the macro-scale dynamics of the model can drastically change when spatial heterogeneity, and awareness of it, is considered in this way. Policy implications for both protesters and the police will be discussed.

Epstein, J. M. (2002). Modeling civil violence: An agent-based computational approach, Proceedings of the National Academy of Sciences of the United States of America. 99:7243-7250.

### An inspection game with two different crimes

L. Andreozzi, C. Bruni*

*University of Florence, Florence, Italy*

The inspection game has been widely used as a model for crime deterrence. In the classic version, an agent A (named *public*) must decide whether violate or not a given law, knowing that a second agent B (named *inspector*) could decide to inspect him. The inspection game cannot answer to some kind of questions. For example, in the classic version of the game it is assumed that the inspector has to prevent just one type of crime, while in many real situations he has to use his scarce resources to fight more crimes. It seems interesting to understand how the increase of money for the prevention of a crime influences that one of other categories of crime: we could aspect that, if the police intensifies its efforts in the fight against prostitution, drug dealers can act more freely, but that if the police becomes more active against the drug market then the prostitution level could increase. Our aim is to generalize the classic inspection game by the introduction of $N$ possible laws to violate (or places where laws can be violated). We study how the inspector distributes his resources among their protection and how the equilibrium values of the game change with the parameters; in particular, we shall analyze the consequences of an increase in the severity of punishment or in the incentives to the inspector in one or more sites.

### Simulation: the point of view of a 'traditional' criminologist

F. Caccavale*

*University of Naples Federico II, Naples, Italy*

Under the methodological profile, the computational aged-based approach can represent a development of remarkable interest for legal and criminological sciences: the quantitative data for the elaboration of statistics in crime has allowed an ex post overview of the crime. In fact, the traced mapping crime has allowed a static crime photography sic stantibus rebus; it can serve in prevention key, but in concrete terms it does not offer a dynamic and articulated vision of the society and of crimes that in it are taken place. Computational aged-based science, with the possibility of a simulative approach - taking advantage of the data collected in a definite historical moment and dynamically joined with other environmental factors, to obtain a temporal projection extended to the future - succeeds instead rendering live the social dynamics, concurring to an interpretation of the prevention that can take advantage of the acquaintance in real time of the action-reaction nexuses between the several human behaviors and between these and what encircles around them. In the field of Criminology, it is often quite difficult to perform experiments that involve changes in the real world. Simulation can help to answer what-if questions and to verify theories about the relation between different processes about the development of criminal behavior. Not only. The evidence provided by simulation models is already considered as useful knowledge about the relevance of criminological theories (such as the differential association theory). On this way, the talk will aim to stimulate the discussion if traditional criminologists could utilize this technique to test and refine theory, to anticipate consequences accruing from different intervention choices, and to provide informed policy guidance to crime control agencies.

### Minorities and their normalization – a statistical mechanics approach

C. Contucci*

*Universita di Bologna, Bologna, Italy*

The talk will illustrate a statistical physics theory about minorities normalization and how it matches the statistical data. By identifying a few basic assumptions, and using the statistical mechanics of complex systems, we propose a novel quantitative approach that provides a minimal theory for minority normalization phenomena. We show that the competitive interactions in decision making among a minority of $P$ individuals and a host population of $N$ people, a bi-partite spin-glass, give rise to a "social consciousness" inside the host community in the sense of the associative memory of neural networks.

A. Barra and P. Contucci, Europhysics Letters 89, 68001-68007, (2010)

**Urban insecurity and crime in post-disaster context: Back analysis of Katrinas aftermath in New Orleans**

P. Cotelle*, F. Leone, E. Velasquez

*Universite Paul Valery, Montpellier, France*

This research is an attempt to establish the link between 'natural disasters and urban insecurity using New Orleans post-Katrina as our case study. Crime, fear of crime and responses to urban insecurity are analyzed. The 2005 storm has indeed brought significant changes for the New Orleans urban dynamics and still has and will have durable impacts on the citys demography, geography, organization, urban dynamics, etc. New Orleans has always been characterized by high crime rates, especially homicides, and perceived as a violent city. Considering the historical and present contexts of the city, the key question this document is dealing with is: what impacts can Katrina and all the territorial changes have on crime, the perception of crime and the response to insecurity? This study attempts to show how the disaster and its consequences can shape urban insecurity, but also how urban insecurity shapes the post-disaster recovery and so contribute to the production of space. After a major disaster, the need to feel safe and protected intensifies and people respond differently to it according to the means they can dispose, increasing the social divide regarding the differentiated access those different communities can have, what tends to aggravate segregation. Some case studies presented below support arguments to explain evolutions in crime concentration, spatial location and responses. The analysis attempts to look at the impacts of Katrina on each dimension of space for a given community. Considerations are made on a horizontal dimension (structural organization, physical environment), a vertical dimension (representation, perceptions, and common values) and a historical dimension as well (space and cultural heritages). In addition, the importance of social networks is underlined. Indeed, according to social disorganization theory, the greater the density of friendship networks among persons in a community, the greater the constraint on deviant behavior within the purview of the social network. Some neighborhoods cases will illustrate the impact of Katrina on insecurity. It is argued here that Katrina has exacerbated and accelerated the disorganization of already disorganized communities and positively impacted fear of crime since the storm has aggravated the lack of collective efficacy and amplified the erosion of social cohesion by impacting the different dimensions of space (cf. Sampson et al. 1997). The feedback dynamic of disorganization and crime will be analyzed through the examples of some neighborhoods still negatively impacted by Katrina and characterized by high crime rates, especially violent crimes. Secondly, the study analyzes the impacts of Katrina on communities that developed new modalities to defend their territory and interests, relying more on private security for instance. Gentrifying and revitalized areas that used, or not, to be prone to crime and disorder are elaborating strategies to promote security. Spatial inequalities regarding access to protection are investigated. Also, Katrina has constituted a wake up call leading to more civic engagement, self-reliance but less confidence in public services like the police. Indeed, Katrina has put a light on the long lasting dysfunctions in the police department and worsens citizen distrust in the police. This empowerment of the citizens leads, in some communities, to an increase in the practices of spatial control but well see that those NIMBYs practices creates in the same time an increase of social divides and aggravates the dynamics of socio-spatial segregation. Finally, the study aims to show the changes Katrina brought in public housing projects that concentrate poverty and that are generally characterized as socially disorganized. Those places have always been associated with violent crime, fear of crime, delinquency and the lack of collective efficacy and informal social norms (cf. Coleman, 1990). According to Jane Jacobs, public housing complexes destroyed the traditional mixed-use communities that produce a social stability and a vibrant street life. Well see that post-Katrina recovery led to a total change in the public housing since they have all turned into mixed income communities designed according to the principles of New Urbanism and defendable space. This focus allows the authors, through a geographical approach, to establish the link between Katrina and urban insecurity by confronting evidences from the field with environmental crime theories. Using a large scale of data both qualitative and quantitative, the paper intents to find out to what extent a major disaster does impact urban insecurity. Katrina case shows that a disaster can shape urban insecurity by impacting all the dimensions of the urban system, but also that insecurity can shape the post-disaster dynamics and recovery. Evidences from the field will allow us to argue that the disaster had accelerated urban dynamics already existing before Katrina and increased socio-spatial segregation. The papers goal is to contribute to a better understanding of the relations between crime and place in post-crisis contexts.

R.J. Sampson (1989). The impacts of housing policies on community social disorganization and crime. S. Roche (1998). Expliquer le sentiment dinsecurite: pression, exposition, vulnrabilit et acceptabilite. J. Jacobs

(1961). The death and life of great American cities.

### The Dynamics of the Legal System

G. Dari-Mattiacci, B. Deffains*, C. Lovat

*CNRS and Universite Paris Ouest - Nanterre La Defense, France*

We present a dynamic model of noncontractual litigation in which the parties decision whether to litigate depends on information produced by courts and, vice versa, the courts involvement in the lawmaking process depends on the cases proposed by the parties. Thereby, we integrate in one model the two main functions of the judiciary (adjudication and law- making) and study their interplay. Our model offers a dynamic, cyclical perspective on the evolution of the legal system over time and sheds new light on the causes for high litigation rates and on judge-made law versus statutes.

### Modeling urban housing market dynamics: can the socio-spatial segregation preserve some social diversity?

L. Gauvin*, A. Vignes, J.-P. Nadal

*ENS, Paris, France*

"Don't buy the house, buy the neighborhood" (Russian proverb). This talk is concerned with issues related to social segregation in urban environments. Going beyond the simplest models such as the one introduced by T. C. Schelling in the 70's, we introduce a spatial model of real estate transactions between agents that are heterogeneous in their income and thus in their willingness to pay. The goal of the model is to see how the spatial income segregation depends on both economic constraints and social interactions. The housing market consists of assets differentiated by their location in the city and the agents choose according to these locations. A key feature of the model is the assumption that agents preferences for a location depend both on an intrinsic attractiveness of the location, and on the social characteristics of its neighborhood. The demand for an asset thus depends on the local attractiveness. An hypothesis of the model is that the price of an asset also depends on the local attractiveness. Non-trivial buying/settling patterns emerge from the resulting dynamics. We first focus on the case of a monocentric city, i.e. with a highly attractive center. The stationary state of the market dynamics is analytically characterized and yields the distribution of income over space. We then show how these results extend to more complex non-monocentric cities. The model is also studied through numerical agent-based simulations. The joint analytical and numerical analysis reveal that, even if socio-spatial segregation occurs, some social diversity is preserved at most locations. The analytical resolution of the model highlights the existence of a critical endogenous income threshold: agents with willingness to pay above this threshold can buy an asset wherever they demand. On the contrary, agents with a willingness to pay below the threshold can buy only in a restricted area. We then empirically verify the pertinence of these results through the analysis of a database of real-estate transactions in Paris. Some general trends are reproduced by the housing market model: the distribution of agents by income inside the city is characterized by a dissimilarity index that shows variations in the space comparable to those observed through the *arrondissements* of Paris. We distinguish arrondissements with a low level of social mix, both with a high average price and a low average price and less segregated arrondissements.

http://arxiv.org/abs/1012.2606

### Stylized facts in juvenile criminality: twenty years of data in Isere, France

M.B. Gordon*, S. Roche, M.A. Depuiset

*Laboratoire d'Informatique de Grenoble, Grenoble, France*

Literature on criminology reports - mainly based on data from USA, which are easily accessible - that the proportion of convicted individuals that belong to stigmatized minorities is much larger than the share of these minorities in the countrys population. There is also a long-standing discussion about the impartiality of justice. It has been argued that differential deployment of police and other criminal justice officials against Black and Latinos is the primary factor underlying minorities overrepresentation in US official crime statistics. Sentencing discrimination has also been found by many authors, as well as disparities in the judicial system

treatment of discriminated sub-populations. There are very few studies of this type in European countries. In this paper we consider individual characteristics and sentence outcomes of juveniles convicted of serious crimes in Isre (one of the 96 French Metropolitan Departments) in the 20-years period ranging from 1985 to 2005. Serious crimes (liable to imprisonment) have a higher elucidation rate than petty crimes, and are thus probably less biased by police differential selection. Since there are neither ethnic nor racial indications in French official documents, we classify the convicted juveniles as belonging to the majority or the (stigmatized) minority populations according to the parents' geographic origin. We find that the overrepresentation of minorities in our database is correlated with youth and poverty. Taking into account legal (the type of crime, the defendant's age and past recidivism) and extra-legal (the family composition, socio-economic status, etc.) variables, we find slight sentencing disparities, although not always to the detriment of the discriminated minorities. We discuss some possible explanations.

### Segregation: The role of race, income and the housing market

N. Hanaki, A. Kirman*, D. Viinkovic

*GREQAM, EHESS, Marseille, France*

Schellings basic argument in his famous segregation model was that a rather weak preference for ones own color is enough to generate total segregation. In Vinkovic and Kirman (2006) we developed a simple theoretical framework based on a physical analogy to analyze this problem. In this paper we will introduce two other features which have been mentioned as possible origins of discrimination, income levels and house prices, the two being clearly interrelated. A standard argument is that segregation is essentially due to the unequal income distribution between races. The basic idea would be that we would find clusters of housing by income levels and that these clusters would be racially mixed. However, since Blacks are poorer they would be in the majority in poor areas and whites would be dominant in richer areas. In our model we can see how clustering occurs and whether clusters mix across race and income. This enables us to understand how the forces derived from the utility functions involving considerations of race and income determine the nature of the clusters. We can examine, in particular, to what extent there is an important difference between the situation in which individuals wish to be with their own income group, or simply with people of the same or higher income. We then introduce house prices and can examine the extent to which prices are correlated with race and income. In particular we can analyze the prices at the frontiers of clusters and how they can act as a barrier between clusters. This can be compared with the evolution of house prices in Harlem during the twenties as the black community spread southwards.

### Understanding and managing crime dynamics

N. Lettieri*

*Institute of Cognitive Science and Technology, National Research Council, Rome, Italy and University of Sannio Law School, Benevento, Italy*

The integrated, interdisciplinary study of society through computational tools is leading a deep change in the way we relate to social dynamics. Computational social sciences (CSS), joining together simulation models, ICT, complexity, computer and social sciences, not only are driving a paradigm shift in the investigation of social matters, but are also enabling innovative ways to manage complex social issues from financial crisis to crime spread. The talk will take into account the developments of CSS related with crime emphasizing the perspectives disclosed in the field of policy and norm making. A promising research area is indeed represented by the applications of computational models in the regulatory impact analysis, a set of techniques, by now spread in many legal systems, devoted to provide a systematic appraisal of the potential impact of new regulations. After brief preliminary remarks about the opportunity of a more scientifically and empirically grounded law making, the issues so far mentioned will be addressed presenting the ongoing project of an interdisciplinary Crime Exploratory, a structure to be created within the FuturICT Flagship proposal. Details on the underlying vision will be provided in order to foster discussion and collaboration on this point.

### Methods for identifying organized criminal activity in reconnaissance-based information on criminal co-offending

F. Liljeros*, A. Rostami, C. Edling, P. Holme, X. Lu,

*Stockholm University, Sweden*

In this transdisciplinary research project we develop network analytical methods to estimate the degree of organization in criminal co-offending structures in Sweden during the past 15 years. Our data set contain

register-based dynamic contact structure data with information on all reported criminal collaborations between persons suspected for good reason, and police reconnaissance-based information of criminal gangs The main aim of the project is to develop various statistical measures to quantify the level of unionization in a dynamic network and to develop methods to identify individuals that are members, or are at risk of becoming members, of organized criminal groups.

### Spatial effects on fighting cheaters

L. Meacci, M. Primicerio, J.C. Nuño*

*Universidad Politecnica de Madrid, Madrid, Spain*

To fight cheaters is one of the most important challenges of modern societies. Despite the efforts made to enhance social participation, mainly by education and police repression, a stable percentage of tax-evaders exists in every developed country. It is evident that we face here a social dilemma since an excessive expenditure devoted to fight cheaters would deplete the common wealth even more than tax evasion does. In a previous paper [1], we presented a simple mathematical model, written in terms of Ordinary Differential Equations, that allows to find a good strategy to prevent tax evasion. Given a socioeconomical scenario, we found adequate values of the extra expenditure to be invested and how to share it between education and police repression to keep a low cheater population with a still large common wealth. It was also proven that different boundary conditions require alternative strategies to obtain this (sub)optimal situation. We address now how spatial inhomogeneties affect these (sub)optimal strategies. In particular, we study the consequences of implementing different strategies in neighbors countries. The extended system is modeled in terms of a two-dimensional cellular automata which is analyzed and compared with the homogeneous case. Finally, we discuss the implications that these results might have for associated countries that share economical but not political matters. [1] Nuno, J.C., M. A. Herrero and M. Primicerio. Fighting cheaters: How and how much to invest. European Journal of Applied Mathematics (2010), 21 459-478

### Urban complex growth on impact of spatial segregation

L. Özaydin*

*Mimar Sinan G. University, Turkey*

One in developing city can face the relationships between individual characteristics and the urban growth. They can be influenced by the actors who expect benefits of the urban growth and anticipate the effects of relationships derived from the segregation in individual neighborhoods during urban growth. In Turkey, many people have to deal with the changes of urban growth; spatial systems are complex and interconnected. The purpose of this paper is to present a framework of the complex growth with spatial segregation at the suburb of city. The complex dynamics of the growth can depend on ethnic population and interconnection amongst the other components of urban system. The study obtains a model in order to produce and sustain oscillations in quantitative variables of spatial growth that the social and economical dynamic system influences. The growth paths may appear in complex dynamics according to the values of spatial parameters of analytical model. The model system consists of an identical agent and this agent-based model aids decision making for the spatial growth. The originality of this paper is in the framework that I underline the role of nonlinearity of the growth for the agent desires spatial well being over an infinite time horizon.

### Mathematical theories and theories as artifacts: the case of other-damaging behaviours

D. Parisi*, N. Lettieri

*National Research Council, Rome, Italy*

Today the availability of computers with their very large memory and computing power and new theoretical developments based on viewing reality as a complex system induce many researchers to explore if and how mathematically expressed theories can be applied to cognitive and social phenomena. Although these attempts are interesting and they should be pursued, one has the impression that they tend to focus mainly on the regularities present in the available data overlooking the mechanisms and processes which underlie cognitive and social phenomena and explain them. A different approach is using the computer to construct

artifacts (agent-based simulations and robotic systems) that try to reproduce the observed regularities by incorporating in the artifact hypotheses about the mechanisms and processes underlying these regularities. Both types of theories may be needed but one does not substitute for the other, and an interesting question is why mathematical theories of physical phenomena appear to capture all which we need to know about physical phenomena while this is not true when mathematical theories are applied to the phenomena studied by cognitive and social scientists. We will discuss these questions with reference to modes of behaviour that damage others and that societies need to find ways to contain to avoid disintegration.

**Household burglary victimisation and protection measures: Who can afford security against burglary and in what context does it matter?**

A. Tseloni*

*Nottingham Trent University, Nottingham, UK*

Previous research on the link between security and burglary has offered mixed results to date: It has been found that enhanced security reduces burglary risk, especially for the poorest population segments, but also that visible protection measures, including neighborhood watch, are associated with more burglaries. This paper suggests that the link between security and burglary victimisation is not straightforward but mediated by household individual and contextual area characteristics. In this light the author argues that high quality security measures may thwart burglaries against those household types which are otherwise highly vulnerable due to exposure. By contrast, security should not affect burglary risks of non-vulnerable households or those which are targeted by highly professional burglars. The results are based on multivariate multilevel empirical models and employ data from the British Crime Survey.

# Complexity-Net Session

**Organizers: J. Johnson, L. Zandee**

### Resilience and interaction of networks in ecology and economics (RESINEE)

M. Baudena*

*Utrecht University, Utrecht, The Netherlands*

RESINEE is a project intended to make connections between issues related to the robustness of networks appearing in economics and ecology. In this talk, we will present the directions we have identified in trying to establish these connections and to allow each field to profit from the other, as well as the main difficulties we face. In particular, we will discuss work in progress about the application of ecosystem stability ideas to economic networks and about the evolution of countries' productive structures to the structure of ecological communities. Time permitting, we will also mention briefly other possible connections.

### Advances in Complex Matter Research

T. Bountis*

*University of Patras, Patras, Greece*

In this presentation we report on recent advances in critical phenomena and collective behaviour of multi-particle complex systems (Complex Matter for short) as they are pursued in a collaborative European research project joining 4 groups at the University of Patras, Greece, Free University of Brussels, Belgium, University of Manchester, UK, and University of Twente, The Netherlands (see http://complexmatter.wordpress.com). The main objectives of the project are: (a) to elucidate how the properties of individual particles, their interactions, and fluctuations at the small scale lead to spontaneous structure formation and collective dynamics at the large scale, (b) to develop a unified approach for systems whose constituents range from nano-particles to millimeter-sized grains, bridging the gap between quantum mechanics and the macroscopic world, and (c) to propose solutions for real-world problems such as the industrial processing of granular matter and the formation of traffic jams. In particular, the Patras team has been working on the phenomenon of clustering of granular matter. The spontaneous occurrence of dense clusters constitutes a major problem in industries around the world handling granular particles (mining, food production, pharmaceutical industry, construction works, chemical reactors, etc.) and also in vehicle traffic, where the clusters are known as jams. The Brussels team has obtained interesting results in phase transitions due to matter confinement in small cavities. The prediction of these properties is important in areas such as microfluidics, nano-scale technology and biomedical applications. The same issues arise in larger systems such as colloids and granular materials under conditions of confinement. The Manchester team has produced fascinating experimental results on self-organized segregation in bidisperse media. The transition from the mixed to the segregated state in a horizontally vibrated monolayer of a mixture of two kinds of granular particles is known experimentally to constitute a second-order phase transition. There have been many attempts to model this phenomenon numerically but to date the experimental findings have not yet been reproduced. Finally, the Twente team has been studying the Leidenfrost state a close-packed cluster of slow particles floating on top of a low-density gaseous layer of fast-moving particles , which was recently shown to undergo a transition to counter-rotating rolls similar to Rayleigh-Benard convection. A key difference between the above forms of multi-particle (granular) matter and continuous media is that in the granular case patterns typically emerge on the scale of several tens of particle diameters and fluctuations are not merely present but play a dominant role in the dynamics of these systems. To understand how fluctuations operate under these circumstances is crucial, not only for granular matter, but for all multi-particle systems far from equilibrium where statistical noise, dissipative interactions and fluctuations go hand in hand to produce spontaneously emerging structures.

### Simulating the Emergent Impact of Regulations Across Cultures (SEMIRA)

R. Conte*

*CNR Institute of Cognitive Sciences and Technologies, Rome, Italy*

The SEMIRA project studies the interaction between emerging normative behaviour and new regulations in different cultures and different countries. The goal is to support the preparation of new regulations of

different government bodies. Two types of agent-based simulation tools are being developed. One tool will validate the theoretical framework with actual people. The other will do large scale simulations based on emergent behaviour. The novelty in this approach is twofold. We will combine simulations with a few rich agents and simulations with many simple agents. Based on this rich (but computationally expensive) model we will build simulations with simple agents that will abstract away many of the details needed for the virtual environment simulation. The second novelty is that we will look at a combination of emergent patterns of behaviour that come from individual decisions in an environment with (new) imposed regulations and rules of behaviour that are inherent in the culture of the society. Hence, we simulate a combination of top down and bottom up changes of behavioural patterns. The new smoking legislation in bars and restaurants is our use case. So far, cultural influences on individual decision making have been modelled, linking dimensions of culture to normative behaviour. Secondly, the implementation of social norms has been linked to the OCC emotions model in the FAtiMA architecture, which is the virtual environment model that can (in)validate our behavioural assumptions with real people. Thirdly, the role of normative sanctions in contrast to a purely cost based enforcement mechanism has been investigated in a large-scale simulation of emergent behaviour.

### Multi-objective optimization for modeling developmental gene regulatory networks (MOPDEV)

C. Cronemberger*

*University of Amsterdam, Amsterdam, The Netherlands*

Gene regulatory networks underlying pattern formation in plants and animals have to reliably produce a specific output pattern in the presence of molecular fluctuations, genetic variability and environmental perturbations. Therefore, mathematical models of such processes not only need to reproduce observed experimental data, but need to do so robustly. An important issue with models of gene regulation is the large number of unknown parameters, which need to be estimated from experimental data. Traditionally, such parameters have been inferred based on simple cost functions such as the sum of squared differences between model and data. In this project, we propose to develop and apply new methods for multi-objective optimization, which are able to integrate different optimization criteria, such as robustness and accuracy of a fit. These methods will be used to estimate regulatory parameters for a variety of complex network models, some of which are spatially distributed and cover multiple levels of organization from gene networks to tissue mechanics. Models will be fit to available gene expression data (based on in situ hybridization, immunofluorescence or quantitative PCR) for three experimental models (the butterfly Bicyclus anynana, the cnidarian Nematostella vectensis, and the fruit fly Drosophila melanogaster). Solutions will be investigated in terms of their robustness/sensitivity, and the predictive behavior of the network. Specifically, we will test whether multi-objective optimization yields more biologically realistic solutions than parameters estimated based on a simple least-squares cost function alone. For the model systems used here, this can be achieved by model validation against published experimental evidence.

### Emergence and Evolution of Biological Symbol Systems (EvoSym)

J. de Beule*

*Vrije Universiteit Brussel, Brussels, Belgium*

EvoSym is a collaborative project bringing together complexity researchers in Ireland, the Netherlands and Belgium. It is investigating two key questions: (i) How do complex representational and communicative coding systems emerge, self-organise and evolve, from micro to macro levels, in the natural biosphere? (ii) How can this biological understanding be applied to the artificial evolution of complex coding systems in computational and/or robotic systems? The project will apply methods and techniques of complexity science to understand the emergence and evolution of biological "symbol systems" (also called "biosemiotic systems"), such as genetic coding (DNA-protein), RNA editing, cell signaling, etc. It will also investigate potential technological applications in distributed agent-based software and robotics. The project is organised in three major work packages: (i) WP1 will build on previous work in modeling prebiotic molecular evolution in spatially extended individual-based systems. It focuses on how "RNA coding" could evolve in such an environment. (ii) WP2 will investigate the origin and evolution of evolvable coding and translation in purely computational systems. (iii) WP3 will apply principles of language evolution in collective robotic systems to the emergence of complex languages in models of chemical communication among biological cells. The EvoSym project partners are: (i) Artificial Life Lab, Rince Institute, Dublin City University, Ireland. Principal Investigator: Prof. Barry

McMullin. (ii) Bioinformatics Group, Universiteit Utrecht, Netherlands. Principal Investigator: Prof. Paulien Hogeweg. (iii) Artificial Intelligence Laboratory, Vrije Universiteit Brussel, Belgium. Principal Investigator: Prof. Luc Steels.

http://evosym.rince.ie/

### Complexity in Spatial Dynamics (COSMIC)

A. Johansson*

*University College London, London, UK*

COSMIC (COmplexity in Spatial dynaMICs) is a project linking three research groups: Spatial Economics at the Free University of Amsterdam (VU), The Centre for Advanced Spatial Analysis (CASA) at University College London (UCL), and the National Centre for Geocomputation (NCG) at the National University of Ireland at Maynooth (NUIM). These centres all deal with quantitative urban science and geo-spatial analysis, and have expertise in complexity science applied to urban and regional systems. COSMIC is a network which will tie these groups together and establish some momentum for research into urban dynamic processes using new bottom up, digital data collected for entire populations using web 2.o technologies such as crowd-sourcing, GPS and more conventional data mining of large electronically available spatial data sets concerning social and economic transactions and interactions. We believe that such data will provide dramatically new insights into urban change which manifest themselves in often discontinuous forms which can be articulated using a variety of reaction-diffusion dynamics incorporating catastrophe, chaos, bifurcations, and phase transitions. In cities, such reactions range from the emergence of edge cities to patterns of residential segregation, embodying social exclusion in various forms. The project will first develop a typology of urban dynamic processes to guide the development of models using new digital data collected in real time from electronic transactions such as phone lines, electronic ticketing, and related geo-sensing. Our unifying focus will be on flow data associated with underlying networks with the models revolving around spatial interaction and movement from labour markets to pedestrian movement. VU will explore methods for estimating dynamic models of labour markets in Germany and urban navigation in Amsterdam, UCL will develop models of movement and location from phone and ticketing data in London, while NUIM will explore movement at in small scale environments represented at the building and streetscape scale in Dublin. The network will be supported by three major workshops, exchanges of researchers between sites, and strong external links to other groups, in anticipation that from this pilot project, a proposal for a much wider network will emerge. COSMIC like all the Complexity-Net initiatives is designed not only to indulge the interests of the researchers involved but also to widen these ideas to the European community of complexity scientists and beyond. External links to groups dealing with urban complexity around the world will be strengthened and besides the usual deliverables of such a project, papers, demonstrations, web dissemination, the pilot project will lead to a proposal for wider programme of work in this domain.

### Localizing signatures of catastrophic failure (LOCAT)

S. Lennartz*, M. Zaiser, I. Main, I. Butler, S Zapperi, F. Kun

*University of Edinburgh, Edinburgh, UK*

Large-scale catastrophic failure events such as earthquakes have a very complex nature. Different forces are interacting with different materials on both microscopic and macroscopic scales. The local properties and their distributions are not well known, and the interactions between the large number of components are still not fully understood, making prediction of individual large earthquakes difficult, if not impossible. In this project we concentrate on finding localizing signatures of catastrophic failure. Therefore, we study not only real earthquakes, but also (i) laboratory experiments, where we put pressure on rocks and measure acoustic emissions, and (ii) modeled data like the avalanches on a random fuse network. These systems show the same features as real earthquakes, e.g. the Gutenberg-Richter (scale-invariant) distribution of the size of the avalanches, and a similar complexity. But here we have the advantage, that, in contrast to real earthquakes, we know several system parameters like the system size, or the applied stress, and in the numerical models even the detailed local parameters of the system elements. We are interested in how possible localizing processes and their signatures depend on or affect the bulk parameters on a range of scales in space and time. This multi-scale, multi-physics approach may give an insight in why such localizing signatures, common under controlled laboratory conditions, are rarely observed prior to real earthquakes. At a minimum we conclude that the scale-invariant nature of the geometry of fracture systems cannot be taken as evidence for linear

scaling of physical processes from the laboratory to the natural case.

### Applying Computational Epigenetic Micromodel to predict Colon Cancer

K. Raghavan*, H.J. Ruskin,

*Dublin City University, Dublin, Ireland*

Phenotype or the visible traits of an organism are influenced by 3 main factors, namely surrounding environment, genotype (or genetic content), and, chemical changes to the DNA molecules and proteins associated to these, without altering the actual contents - a phenomenon, known as Epigenetics. Characterization of the epigenetic profile of humans, followed by sequencing the human genome contents, has identified the key role of histone modifications (HM) and stable DNA methylation (DM) in determining gene expression levels. DM refers to the modification of cytosine base molecules and is the most stable, heritable and well-conserved epigenetic change. Aberrations in DM, specifically hypo/hyper methylation was the first such change to be linked to cancer. Histone proteins, apart from protecting and managing DNA molecules, form, with these, the basic unit of nucleosomes in the human genome. A combination of dynamic modifications within specific amino acids in each histone, together with DNA methylation, leads to activation or suppression of genes. While new findings on the impact of DM and HM are reported, precise information on the nature of complex interactions between DM and the network of histone modifications during normal and disease conditions (such as cancer), is lacking. Such motivations have initiated attempts to build computational models, to represent the molecular events and investigate their intrinsic interdependency. This helps to understand how information is passed from basic, sub-cellular layer to produce effects at tissue and organ level. Here, we discuss about the developments, to a prototype model with novel framework for integration of epigenetic information from different sources. The comprehensive layout of this model permits stochastic investigation of dynamic histone modifications and inherent DNA methylation associated with patterns in DNA sequences, (derived from signal processing methods). The model is tested with a large dataset containing a network of genes known to be associated with colon cancer through epigenetic events, (obtained from specialized epigenetic databases). This application aims to address issues of scale and relevance at phenotype level from the genome containing aberrant molecular changes during cancer initiation. Up scaling techniques (parallelization) used to test large datasets are also explained.

### Predictability of Extreme Weather Events (PREDEX)

A.E. Sterk*, P. Rabassa Sans

*University of Exeter, Exeter, UK*

Classical extreme value theory is concerned with the distribution of the maximum over a collection of random variables. This theory can be applied to a process generated by a (chaotic) deterministic system composed with an observable quantifying the event intensity. This is the basic idea behind the extreme value theory for chaotic deterministic dynamical systems, which is a rapidly expanding area of research. PREDEX is an interdisciplinary project which delivers new mathematical techniques to quantify the predictability of extreme events in complex systems. In this talk we present two recent accomplishments of PREDEX: 1) The observables which are typically studied in the literature are expressed as functions of the distance with respect a point within the attractor. However, physical observables, such as windspeed or vorticity in atmospheric models, are not of this form. We consider extreme value limit laws for observables which are not necessarily functions of the distance from a density point of the dynamical system. In this case, the limit law is no longer determined by the functional form of the observable alone, but it also depends on the local dimension of the invariant measure and the geometry of the underlying attractor. 2) Extreme value theory does not address the finite-time predictability of extreme events in deterministic systems. We develop concepts based on error growth rates to study the finite-time predictability of extreme wind speeds in atmospheric models. Such extreme events are less predictable than generic events.

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