# ECCS'06

# PROCEEDINGS OF THE

# EUROPEAN CONFERENCE ON COMPLEX SYSTEMS 2006

Towards a Science of Complex Systems

Jürgen Jost, Felix Reed-Tsochas, Peter Schuster (Editors)

# Contents

# Foreword

We would like to welcome you to the European Conference on Complex Systems 2006, which is being held at the Said Business School in Oxford. ECCS '06 is the second annual conference of the recently established European Complex Systems Society. It follows on from the first conference organized by the European Complex Systems Society, which was held in November 2005 at the Cité Internationale Universitaire de Paris. And as ECCS '06 is getting underway, plans have already been drawn up for ECCS '07, which will be held in Dresden in October 2007. Complex systems research in Europe is currently undergoing an exciting period of significant growth, with substantial research funds available both from the national research councils and the European Commission. Many of this year's participants will come from one of the growing number of centres of excellence in Europe with a focus on complexity science.

As in the previous year, the format of the conference is based on three equally important ingredients. First, our plenary speakers are drawn from a broad range of disciplines, and are widely recognised as leaders in their respective fields, as well as leaders in crossing disciplinary boundaries. The plenary talks give conference participants, including those who are not experts in a given field, an opportunity to hear an intelligent and panoramic overview of a particular research area. Our hope is that the plenary talks may even encourage some conference participants to embark on new and unexpected interdisciplinary research projects.

Second, in the afternoons the conference features multi-track sessions for the presentation of high quality, peer-reviewed research papers. We believe that these papers reflect some of the most exciting international research on complex systems currently underway. In such a highly interdisciplinary conference it is impossible to identify completely distinct and non-overlapping conference tracks, but on the basis of the submissions that we have received we have done our best to try to delineate the following four broadly defined themes:

- Biology and Cognition
- Concepts and Methods
- Networks
- Social and Economic Systems

Third, on the final two days of the conference we will be hosting 13 satellite workshops, which reflect topics that have been identified as interesting in a bottom-up manner by the research community.

Overall the orientation of the conference is highly interdisciplinary, and mixes together a broad range of disciplines and a variety of rigorous research methods, in a way that should stimulate new ideas, encourage meaningful dialogue, and help build the complex systems research community. The overarching theme of the conference is encapsulated in the phrase "towards a new science of complex systems". This reflects our view that empirical studies of complex systems have made very substantial progress in recent years as a result of advances in information and communication technology, and due to large increases in computational power. As a result of this technological progress an increasing mass of data in many application domains is now both accessible and manageable. At the same time, and no less importantly, we now have good evidence that complex systems in what would conventionally be considered radically different application domains appear to share many new and fundamental theoretical questions. This in turn encourages the development of novel and cross-disciplinary theoretical tools which can help us achieve a better understanding of complex systems. We should not forget that modelling and understanding the

dynamics of complex systems remains one of the major challenges for modern science.

This conference is only possible because many people in the complex systems research community have been very generous in freely contributing their time and efforts. For substantial financial support we would like to thank European Commission's IST Programme, which has contributed significant funds via the ONCE-CS Coordination Action (contract no. 015539), the European Commission's NEST Pathfinder Initiative, which has contributed funds via the GIACS Coordination Action (contract no. 012380), and the EPSRC in the UK.

On behalf of the ECCS '06 Programme Committee and the European Complex Systems Society Conference Steering Committee, we hope that you will find your stay in Oxford enjoyable and stimulating.

Felix Reed-Tsochas, Oxford
Peter Schuster, Vienna
Jürgen Jost, Leipzig

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# Programme

## September 25, 2006

**08:15-9:45** : *Registration and Coffee* Lobby

**9:45-10:15** : *Welcome* Nelson Mandela Lecture Theatre
Felix Reed-Tsochas on behalf of the Programme Committee

Ralph Dum on behalf of the European Commission IST Programme

**10:15-11:05** : *Invited Plenary Speaker 1* Nelson Mandela Lecture Theatre

Morphological Computation - Connecting Brain, Body, and Environment,
*Rolf Pfeifer* 44 **PDF**

**11:05-11:55** : *Invited Plenary Speaker 2* Nelson Mandela Lecture Theatre

Cellular Automata as a Complex System Paradigm: Short-Cut Theorems and Complexity,
*Eric Goles* 38 **PDF**

**11:55-12:45** : *Invited Plenary Speaker 3* Nelson Mandela Lecture Theatre

Virtualization - Curse or Cure?,
*Matthias Kaiserswerth* 40 **PDF**

**12:45-14:00** : *Lunch* Conference Marquee

**14:00-16:00** : *Biology and Cognition 1* Edmond Safra Lecture Theatre

Geometric Basis for Asymmetric Diffusion (Long Paper),
*Norman Packard, Rob Shaw* **50 PDF**
Optimal Formulation of Complex Chemical Systems with a Genetic Algorithm (Long Paper),
*Morgan Theis, Gianluca Gazzola, Michele Forlin, Martin Hanczyc, Mark Bedau* **50 PDF**
From evolving software towards models of dynamically self-assembling processing systems (Long Paper),
*Uwe Tangen* **51 PDF**

**14:00-16:00** : *Concepts and Methods 1* Lecture Theatre 4

Complex system approach to language games (Long Paper),
*Andrea Baronchelli, Emanuele Caglioti, Vittorio Loreto, Luc Steels* **48 PDF**
Coordinated Communication, a Dynamical Systems Perspective (Long Paper),
*Bart De Vylder* **49 PDF**
The Computational Complexity of Complex Systems: the Role of Topology and Functionality (Long Paper),
*Gregory Provan* **49 PDF**

**14:00-16:00** : *Networks 1* Rhodes Trust Lecture Theatre

Shape and efficiency in growing spatial distribution networks (Long Paper),
*Michael Gastner* **51 PDF**

Weighted networks: Examples and characteristics (Long Paper),
*Janos Kertesz, Jukka-Pekka Onnela, Jari Saramaki, Kimmo Kaski* **51 PDF**

Hypernetworks for reconstructing the dynamics of multilevel systems (Long Paper),
*Jeffrey Johnson* **52 PDF**

**14:00-16:00** : *Social and Economic Systems 1* Nelson Mandela Lecture Theatre

Credit Interlinkages and Bankruptcy Avalanches in a Network Economy (Long Paper),
*Domenico Delli Gatti, Mauro Gallegati, Alberto Russo, Bruce Greenwald, Joseph E. Stiglitz* **47 PDF**

Impact of Trust on the Performance of a Recommendation System in a Social Network (Long Paper),
*Stefano Battiston, Frank E. Walter, Frank Schweitzer* **47 PDF**

The role of tie strengths in societal networks (Long Paper),
*Jukka-Pekka Onnela, Jari Saramäki, Jarkki Hyvänen, Gabor Szabo, David Lazer, Kimmo Kaski, Janos Kertesz, Albert-László Bárabási* **48 PDF**

**16:00-16:30** : *Coffee break* Conference Marquee

**16:30-18:30** : *Biology and Cognition 2* Edmond Safra Lecture Theatre

Network Analysis of Biochemical Reactions in Complex Environments (Short Paper),
*Elias August, Mauricio Barahona* **59 PDF**

Catalysis by Self-Assembled Structures in Emergent Reaction Networks (Short Paper),
*Gianluca Gazzola, Andrew Buchanan, Norman Packard, Mark Bedau* **59 PDF**

Disease diversity and fluctuations in dynamic small world networks (Short Paper),
*Ana Nunes, Tudor Nedelea, Marcos Simoes, Margarida Telo da Gama* **59 PDF**

**16:30-18:30** : *Concepts and Methods 2* Lecture Theatre 4

Distributed control of collective motion of robots through mainly local interactions (Short Paper),
*Arturo Buscarino, Luigi Fortuna, Mattia Frasca, Alessandro Rizzo* **55 PDF**

Detecting the Long-Range Dependence in the Internet Traffic with Packet Trains (Short Paper),
*Peter Haga, Gabor Vattay* **56 PDF**

A Complex Systems Approach in ATM Modeling (Short Paper),
*Soufian Ben Amor, Marc Bui, Ivan Lavallee* **56 PDF**

**16:30-18:30** : *Networks 2* Rhodes Trust Lecture Theatre

Community Detection in Complex Networks using Genetic Algorithm (Short Paper),
*Mursel Tasgin, Haluk Bingol* **57 PDF**

The Laplacian Spectrum of Complex Networks (Short Paper),
*Almerima Jamakovic, Piet Van Mieghem* **57 PDF**

Highly Clustered Networks with Preferential Attachment to Close Nodes (Short Paper),
*Matteo Dell'Amico* **58 PDF**

Role of modular and hierarchical structure in making networks dynamically stable (Short Paper),
*Raj Kumar Pan, Sitabhra Sinha* **58 PDF**

**16:30-18:30** : *Social and Economic Systems 2* Nelson Mandela Lecture Theatre



**18:00-19:30** : *Poster Session 1* Conference Marquee

Managerial intervention and instability in healthcare organisations: the role of complexity in explaining the scope of effective management,
*David Brookfield, Denis Smith* **68 PDF**

Emergence of Cooperation in Innovation Networks,
*Michael Koenig, Stefano Battiston, Frank Schweitzer* **69 PDF**

Simulation of Higher Order Self-Assembly,
*Jens Peter Schroer, Kristian Lindgren* **70 PDF**

Clustering as a mechanism for repulsion between particles in DPD simulations,
*Johan Nyström, Anders Eriksson, Martin Nilsson Jacobi, Kolbjörn Tunström* **71 PDF**

Fairness state with plastic preferences,
*Elena Ramirez, Juan Guillermo Diaz Ochoa* **71 PDF**

The role of priority in the mobility of a system of two kinds of random particles,
*Michael Maragakis, Panos Argyrakis, Shlomo Havlin* **72 PDF**

BitBang: A Model and Framework for Complexity Research,
*Tiago Baptista, Telmo Menezes, Ernesto Costa* **73 PDF**

Power Games: The Impact of Sharing Power on Development Projects,
*Crighton Nichols* **74 PDF**

Reconstructing Models for Local Government from Survey Data,
*Jeffrey Johnson, Clive Downs* **75 PDF**

## September 26, 2006

**09:00-09:50** : *Invited Plenary Speaker 4* Nelson Mandela Lecture Theatre

'The Complexity of "Thought" - Two Fundamental Issues',
*David Mumford* **43 PDF**

**09:50-10:40** : *Invited Plenary Speaker 5* Nelson Mandela Lecture Theatre

Tale of Two Cultures: Phase Transitions in Physics and Computer Science,
*Cris Moore* **42 PDF**

**10:40-11:00** : *Coffee break* Conference Marquee

**11:00-11:50** : *Invited Plenary Speaker 6* Nelson Mandela Lecture Theatre

A probabilistic view of deterministic dynamical systems,
*Marcelo Viana* **46 PDF**

**11:50-12:40** : *Invited Plenary Speaker 7* Nelson Mandela Lecture Theatre

Self-Organising Systems : a Typology,
*Henri Atlan* **36 PDF**

**12:40-14:00** : *Lunch* Conference Marquee

**14:00-16:00** : *Biology and Cognition 3* Edmond Safra Lecture Theatre

HUGO: A Cognitive Architecture with an Incorporated World Model (Long Paper),
*Jiri Wiedermann* **75 PDF**

A simple model of cognitive processing in repeated games (Long Paper),
*Kristian Lindgren, Anders Eriksson* **76 PDF**

The effect of finite population size on the evolutionary dynamics in multi-person Prisoner's Dilemma (Long Paper),
*Anders Eriksson, Kristian Lindgren* **76 PDF**

**14:00-16:00** : *Concepts and Methods 3* Lecture Theatre 4

Inferring Global Synchrony from Local Symbolic Dynamics (Long Paper),
*Sarika Jalan, Fatihcan Atay, Juergen Jost* **80 PDF**

Quotient Manifold Projections and Hierarchical Dynamics (Long Paper),
*Martin Nilsson Jacobi* **80 PDF**

A unifying framework for complexity measures of finite systems (Long Paper),
*Nihat Ay, Eckehard Olbrich, Nils Bertschinger, Juergen Jost* **80 PDF**

**14:00-16:00** : *Networks 3* Rhodes Trust Lecture Theatre

Exact Solutions for Models of Cultural Transmission and Network Rewiring (Long Paper),
*Tim Evans, Douglas Plato* **77 PDF**

Decentralised control of material or traffic flows in networks (Long Paper),
*Stefan Laemmer, Hiroshi Kori, Karsten Peters, Dirk Helbing* **77 PDF**

Self-organizing principles for material flow control in complex networks (Long Paper),
*Karsten Peters, Dirk Helbing* **78 PDF**

**14:00-16:00** : *Social and Economic Systems 3* Nelson Mandela Lecture Theatre

Competitive advantage of geographical clusters: Complexity science and network theory approach (Long Paper),
*Nunzia Carbonara, Ilaria Giannoccaro, Vito Albino* **78 PDF**

Matching and Network Effects (Long Paper),
*Marcel Fafchamps, Marco van der Leij, Sanjeev Goyal* **79 PDF**

Emergent structures and dynamic processes in a distributed manufacturing network (Long Paper),
*Serguei Saavedra, Felix Reed-Tsochas, Brian Uzzi, Janet Efstathiou* **79 PDF**

**16:00-16:30** : *Coffee break* Conference Marquee

**16:30-18:10** : *Biology and Cognition 4* Edmond Safra Lecture Theatre

Hierarchies and modules in complex biological systems (Long Paper),
*Ovidiu Radulescu, Alexander Gorban, Sergei Vakulenko, Andrei Zinovyev* **85 PDF**

Spectral analysis of gene expression profiles using gene networks (Long Paper),
*Franck Rapaport, Andrei Zinovyev, Marie Dutreix, Emmanuel Barillot, Jean-Philippe Vert* **86 PDF**

**16:30-18:10** : *Concepts and Methods 4* Lecture Theatre 4

A General Framework for Agent-based Modelling of Complex Systems (Short Paper),
*Mike Holcombe, Simon Coakley, Rod Smallwood* **83 PDF**

Introducing Complex Automata for Modelling Multi-Scale Complex Systems (Short Paper),
*Alfons Hoekstra, Bastien Chopard, Pat Lawford, Rod Hose, Manfred Krafczyk, Joerg Bernsdorf* **83 PDF**
Abrupt Behaviour Changes in Cellular Automata under Asynchronous Dynamics (Short Paper),
*Damien Regnault* **84 PDF**

**16:30-18:10** : *Networks 4* Rhodes Trust Lecture Theatre

Detecting rich-club ordering in complex networks (Short Paper),
*Vittoria Colizza, Alessandro Flammini, M. Angeles Serrano, Alessandro Vespignani* **84 PDF**
The network structure and evolution of online communication (Short Paper),
*Pietro Panzarasa, Tore Opsahl* **85 PDF**
Preferential attachment in the growth of social networks: the case of Wikipedia (Short Paper),
*Andrea Capocci, Vito D.P. Servedio, Francesca Colaiori, Luciana S. Buriol, Debora Donato, Stefano Leonardi, Guido Caldarelli* **85 PDF**

**16:30-18:10** : *Social and Economic Systems 4* Nelson Mandela Lecture Theatre

Physical And Relational Networks In The Aegean Bronze Age (Long Paper),
*Tim Evans, Ray Rivers, Carl Knappett* **81 PDF**
The effect of travel restrictions on the spread of a highly contagious disease (Short Paper),
*Martin Camitz, Fredrik Liljeros* **81 PDF**
In Search of the Perfect Partnership (Short Paper),
*David Smith, Neil Johnson, Ben Burnett, Thomas Cox* **82 PDF**
How to cheat BitTorrent and Why Nobody Does (Short Paper),
*David Hales, Simon Patarin* **82 PDF**

**18:00-19:30** : *Poster Session 2* Conference Marquee

Sleep microstructure analysis using Recurrence Plots: evidence for a subcortical oscillator ?,
*Lorenzo Priano, Fabio Saccomandi, Alessandro Mauro, Caterina Guiot* **87 PDF**
On Degree-Based Decentralized Search in Complex Networks,
*Shi Xiao, Gaoxi Xiao* **88 PDF**
Probabilistic inductive classes of graphs,
*Natasa Kejzar, Vladimir Batagelj* **89 PDF**
Control of a Chaotic Autocatalytic Reaction System,
*Ankur Mukherjee, S.K. Scott, Dominic Searson, Mark Willis, Allen Wright* **90 PDF**
Distance and height statistics in growing networks,
*Renaud Lambiotte, Paul Krapivsky* **91 PDF**
Statistical analysis of Polish public transport networks,
*Julian Sienkiewicz, Janusz A. Holyst* **91 PDF**
Ising model on two connected Barabasi-Albert networks,
*Krzysztof Suchecki, Janusz Holyst* **91 PDF**
Network Discovery in Random Graphs,
*Thomas Erlebach, Alexander Hall, Matus Mihalak* **92 PDF**
Effect Of Forcing Term On A Three Dimensional Artificial Neural Network,
*Pritha Das, Atin Das* **92 PDF**
A Scale-Free Network Growth Model Based On Local Operators,
*Fatih Ogun, Haluk Bingol* **92 PDF**
A model for Social Networks,
*Riitta Toivonen, Jukka-Pekka Onnela, Jari Saramäki, Jarkki Hyvänen, Janos Kertesz, Kimmo Kaski* **93 PDF**

Evolving Artificial Cell Signaling Networks,
*James Decraene, George Mitchell, Ciaran Kelly, Barry McMullin* **94 PDF**

Do wandering albatrosses really perform Levy flights when foragin?,
*Andrew Edwards, Nick Watkins, Mervyn Freeman, Richard Phillips* **95 PDF**

Simulation and Measurement of a Two-stage Complex Network Model,
*Hongwei Luo, Kathy Horadam* **95 PDF**

On Protocell "Computation",
*Ciaran Kelly, Barry McMullin, Darragh O'Brien* **96 PDF**

Analysis of diameter distributions in tree-ring growth,
*Maurizia Gandini, Paola Nola, Guido Caldarelli* **96 PDF**

Structure and dynamics of mycelial networks,
*Dan Bebber, Mark Fricker, Peter Darrah, Juliet Hynes, Lynne Boddy* **97 PDF**

Analysis of IRC (Internet Relay Chat) Networks,
*Murat Sensoy, Haluk Bingol* **97 PDF**

Inferring Connectivity from Dynamics on Networks,
*Max Little, Patrick McSharry* **98 PDF**

Maximum entropy method for the reconstruction of networks,
*Yohann Grondin, Derek Raine* **98 PDF**

Network Disconnectedness: a Novel Robustness Metric for Infrastructure Networks,
*Alex K. S. Ng, Janet Efstathiou* **99 PDF**

Towards a unified model of protocell evolution,
*Anders Eriksson, Olof Garnerup, Martin Nilsson Jacobi, Steen Rasmussen* **99 PDF**

Study of language evolution and population dynamics of two interacting species on scale free and random networks,
*Alkiviadis Kalampokis, Kosmas Kosmidis, Panos Argyrakis* **100 PDF**

Structural stability, morphogenesis and epigenetic landscape,
*Sara Franceschelli* **101 PDF**

The effect of network mixing patterns on contact tracing efficacy,
*Istvan Kiss, Rowland Kao* **102 PDF**

Epidemiological Theory, Social Networks and the Basic Reproduction Ratio,
*Rowland Kao, Istvan Kiss* **103 PDF**

## September 27, 2006

**09:00-09:50** : *Invited Plenary Speaker 8* Nelson Mandela Lecture Theatre

Epidemic spreading and complex networks,
*Alessandro Vespignani* **45 PDF**

**09:50-10:40** : *Invited Plenary Speaker 9* Nelson Mandela Lecture Theatre

Bacterial Chemotaxis: Using Computer Models to Unravel Molecular Mechanisms,
*Dennis Bray* **37 PDF**

**10:40-11:00** : *Coffee break* Conference Marquee

**11:00-11:50** : *Invited Plenary Speaker 10* Nelson Mandela Lecture Theatre

Extreme events - a challenge to the understanding of complex dynamics,
*Holger Kantz* **39 PDF**

**11:50-12:40** : *Invited Plenary Speaker 11* Nelson Mandela Lecture Theatre

Complex Systems Modeling in the Anthropocene,
*Sander van der Leeuw* **41 PDF**

**12:40-14:00** : *Lunch* Conference Marquee

**14:00-16:00** : *Concepts and Methods 5* Lecture Theatre 4

Conceptual Representations: What do they have to say about the Density Classification Task by Cellular Automata? (Long Paper),
*Manuel Marques, Ruli Manurung, Helen Pain* **107 PDF**

Computational Complexity of Some Enumeration Problems About Uniformly Sparse Boolean Network Automata (Long Paper),
*Predrag Tosic* **108 PDF**

How to Cluster Evolving Graphs (Short Paper),
*Marco Gaertler, Robert Görke, Dorothea Wagner, Silke Wagner* **108 PDF**

Generating Significant Graph Clusterings (Short Paper),
*Daniel Delling, Marco Gaertler, Dorothea Wagner* **109 PDF**

**14:00-16:00** : *Networks 5* Rhodes Trust Lecture Theatre

Defense Strategies against Network Worms: Formulation, Evaluation, and Comparison (Long Paper),
*Zoran Nikoloski* **103 PDF**

Computing Clustering Coefficients in Data Streams (Short Paper),
*Luciana Salete Buriol, Gereon Frahling, Stefano Leonardi, Alberto Marchetti-Spaccamela, Christian Sohler* **104 PDF**

Statistics of cycles in large networks (Short Paper),
*Konstantin Klemm, Peter F. Stadler* **104 PDF**

Self-Organized Criticality and Co-evolution of Network Structure and Dynamics (Short Paper),
*Piotr Fronczak, Agata Fronczak, Janusz Holyst* **104 PDF**

Cooperation: popularity or cliquishness ? (Short Paper),
*David Chavalarias* **105 PDF**

**14:00-16:00** : *Social and Economic Systems 5* Nelson Mandela Lecture Theatre

Modelling the future of cities (Long Paper),
*Denise Pumain, Anne Bretagnolle, Benoit Glisse* **106 PDF**

Binding Social and Semantic Networks (Long Paper),
*Camille Roth* **107 PDF**

Semiotic Dynamics in Online Social Communities (Long Paper),
*Ciro Cattuto, Vittorio Loreto, Luciano Pietronero* **107 PDF**

**16:00-16:30** : *Coffee break* Conference Marquee

**16:30-18:10** : *Concepts and Methods 6* Lecture Theatre 4

Small cluster statistics and Levy size distributions (Short Paper),
*Oleg Bakunin* **111 PDF**
Stability of Attractor Cycles in Random Boolean Networks (Short Paper),
*Steffen Schober* **112 PDF**
Random Numbers in Distributed Systems (Short Paper),
*Heiko Bauke, Stephan Mertens* **112 PDF**

**16:30-18:10** : *Social and Economic Systems 6* Nelson Mandela Lecture Theatre

Multi-assets artificial stock market with heterogeneous interacting agents (Long Paper),
*Silvano Cincotti, Linda Ponta, Stefano Pastore* **109 PDF**
The Geography of Scientific Productivity: Scaling in U.S. Computer Science (Short Paper),
*Rui Carvalho, Michael Batty* **109 PDF**
Modelling an Innovative Industry with Agent-based Simulation (Short Paper),
*Klaus Wersching* **110 PDF**
Open Source Teams, Firm Size and Wealth Distribution: An agent based model approach (Short Paper),
*Vijay Dakshinamoorthy* **110 PDF**

**19:30-00:00** : *Conference Banquet* Christ Church, Oxford

# Workshops

# Complex Adaptive Systems and Interacting Agents

Satellite workshop to the European Conference on Complex Systems
Saïd Business School, University of Oxford 28-29 September 2006

### Keynote speakers

Jean-Philippe Bouchaud (CEA Saclay), Ton Coolen (King's College London), Matteo Marsili (ICTP Trieste)

### Scientific organisers

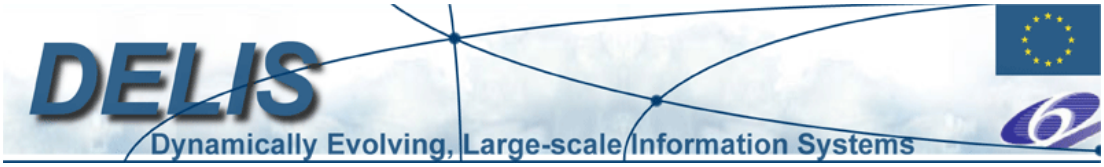
Andrea De Martino (CNR-INFM, Roma, Italy), Tobias Galla (The Abdus Salam ICTP, Trieste, Italy), Enzo Marinari (Università di Roma "La Sapienza", Italy), David Sherrington (University of Oxford, UK)

### Workshop description

The emergence of complex aggregate behaviour from basic rules of engagement between microscopic interacting entities is a common feature of model systems studied in both physics and economics. The workshop aims at presenting an interdisciplinary overview of our understanding of the link between the microscopic interactions and the resulting global behaviour in systems of heterogeneous interacting agents, of the methods used to study it and of the consequences in different fields, in particular from the viewpoint of statistical physics, biology, engineering sciences, social sciences and economics.

### Topics

- **General:** systems of heterogeneous interacting agents, link between microscopic behaviour and global properties, emerging collective phenomena and self-organisation
- **Thematic:** models of financial markets, novel empirical stylized facts of socio-economic systems, optimization problems of microeconomics, static and evolutionary game theory, systemic fragility and risk management, economic growth and cycles, social dynamics, opinion formation and decision making, supply and production networks, eco-systems and competitive ecologies, urban systems and traffic modeling, peer-to-peer systems and communication networks
- **Methods:** exact analytical techniques, computer simulations, empirical methods




# ECCS Workshop: Optimisation in Complex Networks

September 28-29, 2006 / Said Business School, University of Oxford
Organisers: Paul Spirakis (CTI Patras), Berthold Vöcking (RWTH Aachen)

Information systems like the Internet, the World Wide Web, telephone networks, mobile ad-hoc networks, or peer-to-peer networks have reached a level that puts them beyond our ability to deploy, manage, and keep them functioning correctly through traditional techniques. Reasons for this are their sheer size with millions of users and interconnected devices and their dynamics; they evolve dynamically over time, i.e., components change or are removed or inserted permanently. Most of the existing and foreseen complex networks are furthermore built, operated and used by a multitude of diverse economic interests. For such systems, we often have to abandon the goal of global optimality and instead make use of approximation algorithms that can guarantee only to find a solution that is close to optimal or heuristics that guarantee optimality only from a local perspective, e.g., in form of a Nash equilibrium. The goal of this workshop is to present and discuss different optimisation methods and techniques that are able to cope with the possibly conflicting objectives of the participating entities.

The focus of the workshop lies on the following topics:

- scheduling and resource allocation problems
- decision making with multiple objectives
- distributed algorithms for wireless/sensor networks
- game theoretic approaches and selfish optimisation
- approximation and randomised algorithms
- mathematical analysis of heuristics

The program with 15 talks is centred around the following invited presentations:

Artur Czumaj, University of Warwick
Sublinear-Time Algorithms
Thursday, 10:15 am - 11:00 am

Martin Skutella, Dortmund University
Solving Evacuation Problems Efficiently: Earliest Arrival Flows with Multiple Sources
Thursday, 3:15 pm - 4:00 pm

Carsten Witt, Dortmund University
Runtime Analysis of a Simple Ant Colony Optimization Algorithm
Friday, 10:15 am - 11:00 am

The workhop is scheduled on Thursday, Sept. 28, from 9:00 am to 6:00 pm and Friday, Sept. 29, from 9:00 am to 12:30 pm in the *James Martin Institute Seminar Room*. Further details of the program can be found at *http://www-i1.informatik.rwth-aachen.de/ECCS2006.html*.

**ECCS '06 Satelite Workshop**
**Social and Historical Dynamics**
**28-29 September 2006**
**Seminar Room A, Saïd Business School, Oxford**

**http://eclectic.ss.uci.edu/~drwhite/Conf/ECCS06.htm**

***Organisers:***
Douglas White
University of California, Irvine
drwhite@orion.oac.uci.edu
and
Peter Turchin
University of Connecticut
peter.turchin@uconn.edu

**Workshop Themes:**
Emergence, Robustness, Resilience, and Coevolution in Historical, Social, and Network Dynamics

**Workshop Summary:**
The SATELLITE WORKSHOP Social and Historical Dynamics at the European Conference on Complex Systems 2006 (ECCS '06), meeting 9:00 to 6:00, 28 and 29th of September, 2006, at the Said Business School, University of Oxford, will be co-hosted with the James Martin Institute for Science and Civilization. Talks by anthropologists, archaeologists, biologists, computer scientists, ecologists, historians, physicists, and sociologists covering discussions on Emergence, Robustness, Resilience, and Coevolution in Historical, Social, and Network Dynamics (Modelling and Simulation; Networks and Complexity; Networks, Emergence and Historical Dynamics; and Kinship Networks, Complexity, Social Evolution, and Cross-Cultural Comparison) will be given by Tony Wilkinson, Carl Knappett/Tim Evans/Ray Rivers, Art Griffin/Charles Stanish, Stephen Lansing, Emily Erikson/Peter Bearman, Quentin van Dooselaere, Camille Roth, Peter Turchin, Douglas White, Adam Kuper, Michael Houseman, Klaus Hamberger, Cyril Grange.

**ECCS '06 Satelite Workshop**
**EVOLUTION, EMERGENCE, GENERATION (EEG)**
**28-29 September 2006**
**Seminar Room 14, Saïd Business School, Oxford**

# Workshop Goals and Contents

EEG workshop, ECCS 06's satellite, is aimed at launching an inderdisciplinary confrontation among evolutionary, emergentist and generative paradigms and the related methodologies, in order to develop a theoretical debate about the nature of explanation in complex systems. We strongly believe that this theoretical debate could contribute to the understanding of strenghts and limitations of the different approaches under analysis, whose importance is widely acknowledged but rarely focused in Complex Systems community.

The workshop has received a huge number of contribution from various research fields.
Top level reviewers limited their acceptance according to originality, soundness and relevance criteria.
We reserved for the papers that were not unanimously accepted the short paper-slots.
Moreover we divided the sections according to the scientific area to which their content refers.
In particular we chose EEG in Socio-Technical Systems, Biological and Cultural Development, Enterprises and Organizations.

Invited speakers such as prof.Nigel Gilbert and Edmund Chattoe will introduce the sections.
A final discussion will sum up the main contributions of the workshop and our joint work for the years to come. Pre-proceedings will be provided and a Social Event, with John Casti's dinner speech (Santa Fe' Institute) will take place.

# Workshop Preliminary Program

| | |
|---|---|
| Location | Seminar Room 14 |
| 9.00-9.20 | Welcome |
| 9.20-10.20 | E. Chattoe (Invited speaker) |
| Session 1 | EEG in Enterprises and organizations |
| 10.20-11.00 | R.Pareschi: From Enterprises as Networks to Networks of Enterprises: a modelling approach to enterprise evolution based on logic (Long talk) |

11.00-11.30 Coffee break

11.30-12.10 G. Chapman: 'Co-opertition', or, cooperation, competition and the emergence of hierarchy in networks (Long talk)

12.10-12.50 M Gallegati, M. Catalano, E. Gaffeo: Market interaction and emergent macro regularities (Long talk)

13.00-14.00 Lunch

Session 2 EEG in Eco- and Socio- technical systems

14.00-14.40 P. Ormerod and R. Colbaugh: How cascades of failure and extinction evolve in a complex system (Long talk)

14. 40-15.05 S. Occelli: Levering complexity for local system governance in a digital era: notes for a research agenda (Short talk)

15.05-15.45 G. Holtz: An evolutionary model of radical socio-technical change (Long talk)

15. 45-16.15 Tea break

16.15-16.55 D. L. McGinnis and D.A.Bennett: Balance in a Complex Systems- Coupled Natural-Human Systems around Yellowstone National Park (Long talk)

16.55-17.20 D. A. Bennett, D. L. McGinnis, and W.Tang: The Emergence of Complex Landscape Dynamics (Short talk)

19.30 Social dinner and dinner-talk of Prof. John Casti (Seminar Room 9)

Friday 29th September 2006

Location Seminar Room 14

9.00–10.00 N. Gilbert (Invited speaker)

Session 3 EEG in Biological and Cultural Development

10.00-10.40 D.Read: Biological Evolution to Cultural Evolution (Long talk)

10.40-11.05 M.Paolucci: A Simulative Approach to Group Selection (Short talk)

11. 05-11.25 Coffee Break

11.25-11.45 A. Borden: The survivability of memes

11.45-12.45 Final discussion

12.45-13.00 Closing discussion

**ECCS '06 Satelite Workshop**
**SOCIAL AND ECOLOGICAL NETWORKS**
**28-29 September 2006**
**Nelson Mandela Lecture Theatre, Saïd Business School, Oxford**
**http://complex.ffn.ub.es/~oxford/**

**Scientific Organisers:** **Guido Calderelli (INFM-CNR Rome)**
**Albert Díaz-Guilera (Universitat de Barcelona, Spain)**
**Alessandro Flammini (Indiana University, USA)**
**Santo Fortunato (Indiana University, USA)**

**Workshop Summary**

The network organization is almost universal in biological systems and can be found on all structural levels, from physiological, immune and neural networks to social organization of insects, birds, mammals and men up to the all encompassing ecological networks at the highest hierarchical level. Despite many theoretical and experimental efforts, the current knowledge of networks remains rather limited. One possible explanation, besides the complexity of the subject, lies in the fact that researchers have tended to emphasize those aspects of networks that distinguish them - instead of considering them from a single perspective and thus identifying their common features. Only recently it has become clear that there are many common properties, shared by various types of networks.

A network can be viewed as a set of largely identical sub-units that interact, i.e. communicate, with each other. Once the collection of these sub-units has been identified, three important properties that govern the behaviour of a network can be distinguished: (a) the connectivity of the network that determines which subunits interact with which other subunits, (b) the strength and nature of these interactions, and (c) the correlations in the above quantities present in the network.

Until recently, complex networks have been modelled using the classical random network theory introduced by Erdős and Rényi. The Erdős & Rényi model assumes that each pair of nodes (that is, constituents) in the network is connected randomly with probability *p*, leading to a statistically homogeneous network in which, despite the fundamental randomness of the model, most nodes have the same number of links <k> (the degree). In particular, the connectivity follows a Poisson distribution that peaks strongly at <k> implying that the probability of finding a highly connected node decays exponentially ($P(k) < e^{-k}$ for $k >> <k>$). On the other hand, empirical studies on the structure of the World-Wide Web, Internet and social networks have reported serious deviations from this random structure, showing that these systems are described by scale-free networks, for which P(k) follows a power-law, $P(k) < k^{-\gamma}$. Unlike exponential networks, scale-free networks are extremely heterogeneous, their topology being dominated by a few highly connected nodes (hubs) which link the rest of the less connected nodes to the system. Most of the activity in the field is devoted in measuring these unexpected properties and in finding a suitable explanation for such features.

The framework and methodologies of network theory are extensively applied both in Sociology and in Ecology. Beyond the obvious differences, both disciplines deal with complex systems of interacting agents that compete for resources, cooperate, respond and change the environment in which are embedded, and possibly evolve. The workshop intends to promote interactions between scientists investigating social and ecological systems with networks techniques, as both communities share common methods and may potentially benefit a lot from each other. The specific topics covered in the Workshop go from collective dynamics to community structure detection, from species evolution to food webs.

**ECCS '06 Satelite Workshop**
**Multi-Agents for modelling Complex Systems (MA4CS)**
**Friday, 29 September 2006**
**Reception Room, Saïd Business School, Oxford**
**http://liris.cnrs.fr/salima.hassas/MA4CS**

***Scientific organisers:***
Dr. Salima Hassas
Salima Hassas, University of Lyon 1, France
http://liris.cnrs.fr/salima.hassas
hassas@liris.cnrs.fr
and
Dr. Giovanna Di-Marzo Serugendo
University of *Birkbeck, London, United Kingdom*
http://cui.unige.ch/~dimarzo
dimarzo@dcs.bbk.ac.uk

***Topics to be covered***
The main topics of interest include but are not restricted to:

- Multi-agents based simulation of complex systems,
- Self-organizing mechanisms in MAS
- Dynamics and emergent organizations in MAS
- Models for social and spatial organizations coupling in MAS
- MAS based modelling of bio-inspired systems and systems inspired by nature
- Tools and methodologies for multi-agents modelling of complex systems,
- Formal models and theories of multi-agents modelling of complex systems,
- Applications of MAS based modelling in complex systems
- Control and governance of Multi-agents based Complex systems
- …

***Workshop abstract***
This proposal is aimed to be a second edition of the MACS'05 WS, held as a satellite WS of the last ECCS'05 conference (see the WS website at http://www710.univ-lyon1.fr/~hassas//MA4CS/MA4CS05.html ). The first edition of the MA4CS WS was very successful. It has attracted more than 30 participants from different disciplines, interested in multi-agents modelling of Complex Systems. The program contained 6 presentations (selected by an international PC, from 15 submissions) and 4 invited talks given by out-sanding researchers in the field.

The 2nd edition of MA4CS, will be focused on the important actual issue of control and governance complex systems based on multi-agents modelling.

**ECCS '06 Satelite Workshop**

# Networks: Computation, Communication and Applications PhD Student Workshop NCCA'06

**28 September 2006**

**Edmond Safra Lecture Theatre, Saïd Business School, Oxford**

**http://users.ox.ac.uk/~scat2974/ncca/home.htm**


Organisers:

Alex K. S. Ng[1], Terrence S. T. Mak[2], Ping-Chung NG[1], Janet Efstathiou[1]

[1]University of Oxford, [2]Imperial College London

{alex.ng, ping.ng, janet.efstathiou}@eng.ox.ac.uk, t.mak@imperial.ac.uk



## ABSTRACT

Network applications, such as systems modelling, simulations and computing, have adopted diverse interpretations and have long been exploited among different domains of engineering science. In the past few years, the emergence of the study of complex networks has created a new perspective on many fields of science. Discoveries of common patterns and characteristics of network topology from different domains have attracted growing interest in the subject. Two exciting examples are the discoveries of small-world and scale-free properties in many natural and artificial network systems. Novel measures, theories, insights, network characteristics and classifications have been continuously proposed and discussed vigorously in the field of Network Science. However, applications of Network Science theories are sparse in the area of engineered networks. NCCA (Networks: Computation, Communication and Applications) aims to provide the best opportunity to share and exchange technologies and applications of network science to engineering problems for postgraduate students worldwide.

**ECCS '06 Satellite Workshop**

# Industrial Workshop on Manufacturing and Supply Networks *

**Edmond Safra Lecture Theatre**

**Saïd Business School**
**Friday, 29 September 2006**
**2.00 – 6.00 pm**

**Organiser:** Janet Efstathiou
Department of Engineering Science, Oxford University
janet.efstathiou@eng.ox.ac.uk

Techniques from the emerging theory of complex agent-based networks are giving us new insights on the structure and dynamics of manufacturing and supply networks. This workshop will present and discuss new findings and applications from real world networks. We particularly welcome industrial participation in this workshop, with ample time for discussion and comparison of findings with industrial experience.

The **objectives** of the workshop are:
- Present recent findings on supply network structure
- Compare findings across industrial sectors
- Compare academic findings with industrial experience
- Discuss and develop research questions
- Identify potential data sources.

**Papers have been invited** on topics in the area of manufacturing and supply networks. Papers will be developed for a special issue of an academic journal.

**Discussion** will be initiated on, amongst others, the following issues:
- Measures of and evidence for the dynamic nature of supply networks
- The behaviour of firms in the network
- How firms manipulate their position in the network
- The kinds of links that exist in the supply network
- The constraints on network links
- What else firms are looking for from their links in the network
- The current and future impact of the internet
- Comparing in-house and networked manufacturing networks

**Confirmed Speakers**

Janusz Holyst, Faculty of Physics, Warsaw University of Technology
*'Statistical properties of firm and branch networks in Poland'*

Serguei Saavedra Sanchez, Department of Engineering Science, University of Oxford
*'Emergent structures and dynamic processes in a supply network'*

Dirk Pieter van Donk, Faculty of Management and Organization, University of Groningen
*Title to be announced*

* This workshop is part of the MMCOMNET project (contract no. 012999), which is funded by the European Commission under the NEST Pathfinder Initiative on *Tackling Complexity in Science*. For further information on MMCOMNET see http://sbs-xnet.sbs.ox.ac.uk/complexity/complexity_mmcomnet.asp.

One Day Satellite Workshop, 28th September 2006

*Complexity and Dynamics: Volatility and Stability in City and Regional Systems*

Organisers:

M. Batty (UCL: m.batty@ucl.ac.uk) &
P. M. Allen (Cranfield: p.m.allen@cranfield.ac.uk)

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The focus of the workshop will not merely be on urban dynamics but on volatility and stability in city and regional systems, focussing on key concepts in complexity such as chaos, bifurcation, emergence, path dependence and so on. There is now a substantial body of research dealing with such questions from many different perspectives which are loosely assembling under the sciences of complexity. The workshop will attempt to present a state of the art summary of the field, dealing with such topics as agent based, cellular automata and micro-simulation models; models of residential location transportation and traffic flow; multi-level modelling, urban economic models and theories, as well as cognitive approaches to self-organisation and urban dynamics. City and regional systems are often examined using various theories of morphology and this workshop will emphasize such ideas in terms of scaling, fractals, neighbourhood dynamics, and action-at-distance.

*The program will included keynote presentations from*

Denise Pumain (University of Paris I, France): *Multilevel Urban and Regional Modelling with Multi-Agent Systems, and*

Guy Engelen (VITO: Flemish Institute for Technological Research, Belgium): *Geodynamica: Dynamic Simulation Using Cellular Automata*

*Other contributors so far include*

Itzhak Benenson and Juval Portugali (Tel-Aviv University), Dirk Helbing (ITE, Dresden University of Technology), Paul Ormerod (Volterra Consulting, London), Bridget Rosewell (GLA Economics), Efrat Blumenfeld-Lieberthal (Technion, Haifa), Jeff Johnson (Open University), Joana Barros (Birkbeck College, University of London), Ferdinando Semboloni: (University of Florence) amongst others.

The workshop will also feature a panel discussion on the use and development of complexity science for public policy making in the urban and regional domain.

The web site for the workshop is at http://www.casa.ucl.ac.uk/ECCS06/. Abstracts of the papers are also available from the web site where the detailed programme is printed.

**ECCS'06 Satellite Workshop**

# Embracing Complexity in Art and Design

**Thursday 28 September 2006, 9:00-12:30**

**The Boardroom, Saïd Business School**

**Organisers: Jeffrey Johnson, Theodore Zamenopoulos, Katerina Alexiou,**
**The Open University**

## About the workshop

The workshop will be the second in the series, following the one held at ECCS'05 in Paris. Last year's workshop was organized as part of the activities of a UK government AHRB/EPSRC funded research cluster called Embracing Complexity in Design (www.complexityanddesign.net). The cluster was set up with the purpose of creating a research community that explores the cross-fertilization between complex systems science, design research and practice, as well as art. We found that members of the design community are increasingly coming to understand the importance of complexity theory, while members of the complexity community are increasingly coming to understand that the challenges facing design researchers offer rich opportunities to both apply and advance complexity science.

The workshop will cover the spectrum of design, for example, engineering design, computer science, fine art, architecture, construction management, and organisational science. The focus will be on exploring the many relationships with complexity, *e.g.*

- many designed products and systems are inherently complex, e.g. aeroplanes, buildings, cities, microchips, information systems, manufacturers, organisations
- designers need to understand the often complex dynamic processes and supply chains used to fabricate and manufacture products and systems: design, products and processes co-evolve
- the social and economic context of design is complex, embracing market economics, legal regulation, social trends, mass culture, fashion, and much more
- the process of designing can involve complex social dynamics, with many people processing and exchanging complex heterogeneous information over complex human and communication networks, in the context of many changing constraints.

**Workshop organization and timetable:**

The workshop will last for about 3.5 hours. Speakers will be invited to give presentations so as to cover the main areas. Alongside the presentations we may set up a small exhibition of artists' works illustrating their talks.

**Contact**: If you wish to take part please contact: a.alexiou@ucl.ac.uk, t.zamenopoulos@ucl.ac.uk or j.h.johnson@open.ac.uk

**ECCS'06 Satellite Workshop**

# Education and Training in Complex Systems

**Friday 29 September, 2-6pm, Seminar Room 14**

***About the workshop***

The workshop is intended to be the annual European forum for those interested in Complex Systems education around the world. It is intended give everyone an opportunity to tell the community what they are doing, and for everyone to receive an authoritative overview of issues important to educators in complex systems science. Its annual proceedings will be published on the ONCE-CS (and then ECSS) website, augmented by other reports and information.

The workshop will consist mostly of invited presentations, but slots will be available for short ad-hoc presentations by those attending the workshop. The workshop will have a session to discuss issues that come up. It will close with a plenary review by the organisers.

***Topics to be covered***

(1) A core curriculum for complex systems education.
(2) The need for education in complex systems in Europe 2006-2013
(3) The European PhD in Complex Systems
(4) European Masters programs in Complex Systems
(5) Existing initiatives: ONCE-CS, GIACS, EPSRC, Santa Fe
(6) Policy and initiatives of the ECSS
(7) Accreditation
(8) Views of the future

***Length of the workshop***

This first workshop will be half a day. It is intended to raise awareness and put information and the issues in the public arena. It is intended to be the major input to the Education Committee of the ECSS, which will carry forward any issues on behalf of the CS community.

***Scientific organiser(s)*** Jeffrey Johnson, Katerina Alexiou and Theodore Zamenopoulos, Department of Design and Innovation, The Open University

***Contact:*** j.h.johnson@open.ac.uk

**ECCS '06 Satelite Workshop**

# Pedagogical Issues in Multi-Agent Modelling

**29 September 2006**

**James Martin Institute Seminar Room, Saïd Business School, Oxford**

**Organiser:** **Ken Kahn (Oxford University Computing Service)**
**E-mail:** kenneth.kahn@oucs.ox.ac.uk

## Workshop Topics

The topics to be covered include (but are not limited to):

- Student friendly modelling toolkits
- Pedagogic approaches to introducing computer modelling
- Software to aid non-programmers in building models
- What, if any, is the role of game playing and game making?

## Abstract

Students can learn to design, build, run, analyse and revise computational models using a wide variety of programming languages and libraries. They can be asked to build models from scratch, revise toy models, or compose and parameterise pre-built components. They can be asked to look for similarities and differences between their models and those of their fellow students. What roles should real world data play? How can students be supported in performing sensitivity analysis? What are the more effective learning strategies and for what purposes?

Accepted submissions will be presented at the workshop and paper handouts will be made available to all participants. We are also plan to hold a panel discussion.

Presentation Format for the

# 'Forum of Complexity Scientific Research Projects ' (CRP Forum)

during ECCS'06 at Oxford.

Please try to organise the presentation of your compexity project in the following way into 3 sections (if possible):

**Section 1: Theoretical Methods and Tools**

How much of the different tools and methods do your typical complexity science projects involve? Typical (non-exclusive) types of tools and methods are

(a) Graph theory or network theory
(b) Statistical mechanics type methods
(c) General statistical methods
(d) Agent-based approaches (with further specification)
(e) Dynamical Systems (methods for analysis, i.e. bifurcation theory etc.)
(f) Game theoretic aspects
(g) Computational implementations of above
(h) Computer Science tools
(i) etc.

Please also indicate the relationship between the methods (if several are used) to solve the scientific questions you are asking. Try to list the scientific questions on which your project is based at the beginning of your presentation.

**Section 2: Application Orientation**: Complexity approaches are often broad and can be applied to different disciplines. How much relevance will your research results have for the following areas (add areas that are missing for your project)?

(a) Biology
(b) Chemistry
(c) Ecology
(d) Economics
(e) Finance
(f) Physics
(g) Sociology
(h) Infrastructure (traffic, data networks etc.)
(i) etc.

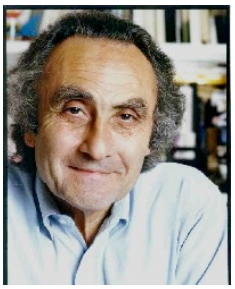
**Section 3: Data Orientation and Experimental Set-Up**: Complexity approaches are often relying on a multitude of data sources and experimental settings. What are the major sources contributing to your project(s):

(a) Direct experiments and collaborations with experimentalists
(b) Data bases (either self-constructed or usage of existing ones)
(c) Thought experiments
(d) (Electronic) data mining, including software agents etc.
(e) Robots, or other engineered systems
(f) etc.

# Invited Speakers

## Self-Organising Systems : a Typology

Henri Atlan, EHESS, Paris, France



**Abstract**

Numerous models of self-organisation are found in the literature, in almost every discipline, making use of different formalisms, such as information theory, systems dynamics, automata theory, neural networks, and others. However, the features of self-organisation are not always the same.

Based on some examples, a classification will be proposed. First, structural self-organisation (emergence of patterns) must be distinguished from functional self-organisation (emergence of functions). A second distinction will be made between functional organisations in a "weak" sense, in a "strong" sense, and in an "intentional" sense. This latter distinction will be based on different possible origins for the meaning which defines the emerging function.

**Speaker Profile**

Henri Atlan is Professor Emeritus of Biophysics at the University of Paris VI and the Hebrew University of Jerusalem, and director of research in Philosophy of Biology at the EHESS in Paris. He has set up and is currently director of the Human Biology Research Center at the Hadassah University Hospital in Jerusalem, where experimental and theoretical research are being conducted in the fields of medical imaging, cell biophysics, and immunology with clinical applications to autoimmune diseases and Aids. He is the author of numerous works in cell biology and immunology, information theory, artificial intelligence, and philosophy of biology. He has developed a theory of self-organisation based on a Complexity from Noise principle and several models of self-organisation applied to biology. He is currently chief-editor of the journal ComPlexUs.

**Bacterial Chemotaxis:**
**Using Computer Models to Unravel Molecular Mechanisms**

Dennis Bray,
University of Cambridge, UK

**Abstract**

The set of biochemical reactions by which an E. coli bacterium detects and responds to distant sources of attractant or repellent molecules is probably the simplest and best understood example of a cell signalling pathway. The pathway has been saturated genetically and all of its protein components have been isolated, measured biochemically, and their atomic structures determined. We are using detailed computer simulations, tied to experimental data, to ask how the pathway works as an integrated unit. Increasingly we find that the physical location of molecular components within the molecular jungle of the cell interior is crucial for an understanding of their function. Signal amplification, for example, appears to depend on the propagation of activity across clusters of receptors and associated molecules.

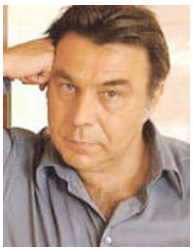
Simulation of the swimming behaviour of individual bacteria allows us to define the parameters necessary for movement and accumulation of bacteria in defined gradients of attractants. Effective accumulation requires both high sensitivity and rapid adaptation, with rates of methylation some ten times higher than indicated by in vitro assays. Responses to conflicting gradients of different attractants suggest a "canalization" mechanism that favours the first attractant encountered.

**Speaker Profile**

Dennis Bray is Emeritus Professor (active) at the newly-constituted Department of Physiology, Development and Neuroscience, University of Cambridge. He is coauthor of multiple editions of Molecular Biology of the Cell and Essential Cell Biology and author of Cell Movements, now in its second edition. Bray has had a long research career with over 100 primary publications in the fields of nerve growth and cell motility and, more recently, bacterial chemotaxis. His current work on the molecular basis of the E. coli signalling pathway is computationally based and involves collaborations with physicists and physical chemists. In recent years he has been widely sought as a lecturer and instructor at meetings and courses on the interface between cell biology and physics at locations such as MBL Woods Hole, Caltech, Aspen Center for Physics, MPI Dresden, and AMOLF Amsterdam. Dennis Bray is an enthusiastic advocate of the computational approach to living cells and his work provides insight into the evolution of signalling pathways, the formation of intracellular protein complexes, the propagation of allosteric interactions in protein assemblies, the generation of intracellular gradients, and the combinatorial complexity of proteins in signal pathways.

## Cellular Automata as a Complex System Paradigm: Short-cut Theorems and Complexity

Eric Goles,
Valparaiso Institute For Complex Systems (ISCV),
Center for Mathematical Modelling,
University of Chile and Universidad Adolfo Ibáñez,
Santiago, Chile.



**Abstract**

Cellular Automata are one of the simplest models which exhibit interesting emergent properties. This lecture will discuss the prediction problem: given a particular Cellular Automaton (CA) is it possible to determine a short-cut theorem which allows us to know its dynamics in a simple algorithmic way (more efficient than running the CA on a computer). Evidently it will not always be possible. Therefore I will also show some classes of CA and related models where we cannot predict their dynamical behavior. For this aspect we will make use of concepts from computer science like Turing machines, universality, circuit simulation, communication complexity and others. Some of the classes to be presented are: neural nets, sand-piles in one and more dimensions and Langton's ant.

**Speaker Profile**

Eric Goles is currently professor and researcher in Theoretical Computer Science at Adolfo Ibañez University, Santiago, Chile. He is also Scientific Director of the Institute for Complex Systems at Valparaiso-Chile, and an associated researcher at the Center for Mathematical Modeling in Santiago. He has obtained two doctorates in Engineering and Mathematics at the University of Grenoble-France. He has also previously held positions in the French CNRS (1981-88), the University of Chile, and from 2000 to 2005 headed the Chilean Council of Science and Technology. He has obtained several awards, among them the Chilean prize of Science (1993), membership of the Chilean and Croatian Academy of Science, and the Jules Verne Prize (UNESCO-CNRS, Paris, 2004) for a program of scientific outreach for open television. He is the author of more than120 research articles, 10 books, and has given invited talks at numerous Conferences, Institutes and Universities. His current research activities focus on complexity of the dynamics of genetic networks, comparison between different updating modes in discrete dynamical systems and numerical simulations related with Cellular Automata and Communication Complexity.

## Extreme Events –
## A Challenge to the Understanding of Complex Dynamics

Holger Kantz,
Max-Planck-Institut für Physik komplexer Systeme, Germany

**Abstract**
Systems with complex dynamics have the potential to generate extreme events: huge deviations of the system's state from its time averaged behaviour. Due to their large impact on human life, the understanding and prediction of extreme events is of utmost relevance. Clearly, events such as earthquakes, floods, storms, economic crises, freak waves, are intensely studied within their respective scientific discipline. From a mathematical point of view, extreme value statistics offers a universal tool for their characterisation and for the extrapolation to previously unobserved event magnitudes. However, on the background of complex systems, a dynamical approach might add new insights: An extreme event in a dynamically evolving system is not just a statistical instance, but it has its dynamical origin and hence precursors. In this talk we emphasise this point of view and discuss concepts and scenarios for a dynamical generation of extreme events and introduce time series tools for their prediction. Remaining uncertainty is captured by the probabilistic nature of such predictions, such that the verification of prediction schemes is an additional issue. The methods will be illustrated by predictions of turbulent gusts in surface wind.

**Speaker Profile**
Holger Kantz is Head of the Nonlinear Dynamics and Time Series Analysis Research Group at the Max Planck Institute for the Physics of Complex Systems in Dresden, and an Adjunct Professor in Theoretical Physics at the University of Wuppertal. He obtained his Diplom in Physics at the University of Wuppertal in 1986, and completed a PhD in Physics under the supervision of Peter Grassberger in 1989. After a period as a Postdoctoral Fellow in Florence, he retuned to Wuppertal in 1991 as a scientific and teaching assistant, and completed his Habilitation in Theoretical Physics in 1996.

His research interests include deterministic chaos, nonlinear stochastic processes, statistical physics, time series analysis, and the atmospheric boundary layer. He has published around 90 articles in international journals on these topics, as well as 3 volumes of proceedings, and is the co-author (with Thomas Schreiber) of a textbook on Nonlinear Time Series Analysis which is published by Cambridge University Press.

Virtualization – Curse or Cure?

Matthias Kaiserswerth,
IBM Research, Switzerland

**Abstract**

This talk broadly aims to address two related topics. First, to provide an overview of research in the area of complex systems that is being carried out worldwide at IBM Research Labs. Second, to identify the issues and challenges related to complex systems that are of particular interest to industry. Here the particular focus of the talk will be on the trend towards virtualization in the IT industry, and the potential for making the management of IT simpler.

**Speaker Profile**

Matthias Kaiserswerth is Vice-President for Global Systems Management and Compliance Area Strategy at IBM. Since January 2006 he leads the IBM Research Strategy in Systems Management and Compliance, coordinating the research work across IBM's eight global research laboratories. From 2002 until the end of 2005 he was the Managing Director of an IBM Integrated Account. He lead a team of sales and services people serving the global power and automation company ABB headquartered in Switzerland. During this time he grew revenues by more than 80%, mostly due to a 10 year $1.7B infrastructure outsourcing contract closed in 2003.

In 2000 Matthias Kaiserswerth became the director of IBM's Zurich Research Laboratory. He was responsible there for some 200 researchers in the field of physical sciences, communications technology, and computer science. Additional responsibilities were for the IBM Zurich Industry Solutions Lab where IBM hosts customers to meet with its researchers to discuss future technology and emerging business trends.

From 1997 through 1999, Dr. Kaiserswerth was on assignment at the IBM TJ Watson Research Center where he lead the networking software and security research. In addition, he was responsible for setting IBM Research's global security research strategy and starting IBM efforts in the emerging field of privacy technology research.

From 1988 through 1997 he worked as a Research Staff Member in the IBM Zurich Research Laboratory on various research projects ranging from high-performance communication systems to message brokering in a medical environment. Most recently, he worked on smart cards and Java security, which lead to the OpenCard industry standard for using smart cards in a Java environment and Visa's Java Cardtm Price Breakthrough program based on the IBM Zurich Research JCOP platform.

Dr. Kaiserswerth received his MSc and PhD in Computer Science from McGill University in Montreal, Canada and from Friedrich-Alexander University in Erlangen-Nuremberg, Germany respectively. He is an honorary professor at Friedrich-Alexander University where he teaches applied computer science.

## Complex Systems Modeling in the Anthropocene

Sander van der Leeuw, Arizona State University

**Abstract**

Human societies are increasingly in control of the Earth System. Slowly but surely, over the millennia, the responsibility for maintaining our planet as a place where it is good to be human has shifted from nature to people. That introduces many new degrees of freedom and many potential instabilities in the system, few of which we understand. We are slowly becoming aware of profound, human-induced changes in our natural environment, and a major research effort is on the way to understand these better and design policies and measures to deal with them. But what about the ***social*** challenges of sustainability? The demographic explosion of the last half century, the communications revolution, and the resultant 'globalization' have exacerbated existing contrasts between rich and poor, North and South, healthy and ill, and have introduced many new, as yet unknown, tipping points and potential dangers to sustainability. And there is no reason why these should not materialize even before the natural dangers do.

The success of the natural and life sciences in identifying and highlighting the potential dangers has been based on detailed observation, quantification, rigorous analysis, advanced modelling and visualization. At the core of their success is the awareness that the dynamics concerned are complex, open systems dynamics. What do we need to do in order to equal that success in dealing with the social challenges to sustainability?

**Speaker Profile**

Sander van der Leeuw is Professor and Director of the School of Human Evolution and Global Change at ASU. His work focuses on the dynamics of societies and their environment. His research interests are in the study of long-term dynamics of socio-environmental systems, reconstruction of ancient technologies, (ancient and modern) regional man-land relationships, GIS and modelling. Since 1981, he has worked on applying Complex Systems Theory in various ways in all these domains.

From 1992, he coordinated a series of major research projects financed by the European Union in the area of socio-natural interactions and environmental problems. Among these projects are ARCHAEOMEDES I (1992-1994) and II (1996-1999), concerned with understanding and modelling the natural and anthropogenic causes of desertification, land degradation and land abandonment and their spatial manifestations, using the Complex Systems approach. The "Environmental Communication" project (1996-8) studied the difficulties of communication between scientists and decision-makers, while the MODULUS project (1997-1999) modelled land-use decision making from a complex systems perspective. The ISCOM project (The Information Society as a Complex System, 2003-2006) investigated the relationship between innovation and urban dynamics. In July 2001, he was appointed Secretary-General of the French National Council for the Coordination of the Humanities and Social Sciences, and in 2003 as Deputy Director for Social Sciences at the CNRS (2002-2003) and at the National Institute for the Sciences of the Universe, in charge of a program similar to the Long Term Ecological Research program in the US. After teaching appointments at Leyden, Amsterdam, Cambridge (UK) and Paris (Panthéon-Sorbonne) he is presently Director of the School of Human Evolution & Social Change at Arizona State University. He is an External Professor at the Santa Fe Institute (USA), a Correspondent of the Royal Dutch Academy of Arts and Sciences, and holds a Chair at the Institut Universitaire de France.

**A Tale of Two Cultures:**
**Phase Transitions in Physics and Computer Science**

Cris Moore,
University of New Mexico and Santa Fe Institute, USA

**Abstract**

Certain problems in computer science, such as Satisfiability and Graph Coloring, are classified as NP-complete. These are the hardest search problems, in the sense that if we can find an efficient algorithm to solve them, we could solve thousands of other hard problems as well (and the nature of mathematical truth would be completely different from what we now believe). In the early 1990s, workers in the field of Artificial Intelligence noticed that if we create random instances of these problems, they make a sharp transition, akin to a phase transition in physics such as the freezing of water, in which they abruptly become unsolvable. Over the past 15 years, a marvellous collaboration between mathematicians, computer scientists, and statistical physicists has sprung up to understand these transitions, using a mixture of numerical experiment, physical intuition, and rigorous proof. I will describe some recent results in the area, and discuss how ideas from each field have gained respect and acceptance in the other.

**Speaker Profile**

Cristopher Moore received his Ph.D. in Physics from Cornell University at the age of 23. He was a postdoc at the Santa Fe Institute and is now an Associate Professor in the Computer Science Department at the University of New Mexico, with a joint appointment in the Department of Physics and Astronomy. He has written over 80 papers at the boundary between physics and computer science, including on quantum computing, phase transitions in NP-complete problems, and models of social networks. He is currently writing a book with Stephan Mertens entitled "The Nature of Computation", which will be published next year by Oxford University Press.

## The Complexity of "Thought" - Two Fundamental Issues

David Mumford,
Brown University, USA

**Abstract**

Since Aristotle, people have modelled thought as a logical process. But, increasingly, the computer science community is convinced that it is better modelled by statistics, specifically Bayesian inference. This raises some difficult questions: how can learn, store and use rapidly the required complex stochastic models? Can the complexities of syntax be treated statistically?

I will talk about recent ideas on both these issues and then briefly discuss work on linking brains and computers.

**Speaker Profile**

David Mumford is currently University Professor in the Division of Applied Mathematics at Brown University. He was awarded the Fields medal in 1974 for work in algebraic geometry, was a MacArthur Foundation Fellow from 1987 to 1992, and President of the International Mathematical Union from 1995 to 1998. Before coming to Brown University, he served as the Chairman of the Mathematics Department at Harvard. Here he provides a personal perspective on how his research interests developed:

I was born in Three Bridges, Sussex, England in 1937 but moved to the US in 1940. I went to Harvard as a Freshman in 1953 where I was very interested by Wiener's vision of Cybernetics and the fusion of neurobiology and computers. But both of these fields were very primitive then and I followed my PhD adviser Oscar Zariski into the beautiful abstract field of algebraic geometry. I stayed on at Harvard, working in algebraic geometry, and eventually becoming Higgins Professor of Mathematics. About 1983, I read David Marr's work on vision and turned back to my earlier interests. Since then I have tried to understand how mathematics can clarify the complex processes of thinking and especially of perception. Variational techniques and PDE's turned out to capture some of the problems in vision. But around 1989 I learned of the ideas of Grenander, how Bayesian statistical inference can be used to reason in noisy uncertain environments. I moved to Brown University in 1995 to work with his group. To flesh out this approach, which I now believe is central to modelling thought of every kind, I have worked on many problems in vision and cortical modelling. Although every field in AI is notorious for overstating its progress, I hope to live to see it achieve some computational milestones.

**Morphological Computation –**
**Connecting Brain, Body, and Environment**

Rolf Pfeifer,
Artificial Intelligence Laboratory,
University of Zurich, Switzerland

**Abstract**

Traditionally, in robotics, artificial intelligence, and neuroscience, there has been a focus on the study of the control or the neural system itself. Recently there has been an increasing interest into the notion of embodiment and consequently intelligent agents as complex dynamical systems in all disciplines dealing with intelligent behavior, including psychology, cognitive science and philosophy. In this talk, we explore the far-reaching and often surprising implications of this concept. While embodiment has often been used in its trivial meaning, i.e. „intelligence requires a body“, there are deeper and more important consequences, concerned with connecting brain, body, and environment, or more generally with the relation between physical and information (neural, control) processes. Often, morphology and materials can take over some of the functions normally attributed to control, a phenomenon called “morphological computation”. It can be shown that through the embodied interaction with the environment, in particular through sensory-motor coordination, information structure is induced in the sensory data, thus facilitating perception and learning. An attempt at quantifying the amount of structure thus generated will be introduced using measures from information theory. In this view, “information structure” and “dynamics” are complementary perspectives rather than mutually exclusive aspects of a dynamical system. A number of case studies are presented to illustrate the concepts introduced. Extensions of the notion of morphological computation to self-assembling, and self-reconfigurable systems (and other areas) will be briefly discussed. The talk will end with some speculations about potential lessons for robotics.

**Speaker Profile**

Rolf Pfeifer received his masters degree in physics and mathematics and his Ph.D. in computer science from the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland. He spent three years as a post-doctoral fellow at Carnegie-Mellon University and at Yale University. Since 1987 he has been a professor of computer science at the Department of Informatics, University of Zurich, and director of the Artificial Intelligence Laboratory. Having worked as a visiting professor and research fellow at the Free University of Brussels, the MIT Artificial Intelligence Laboratory, the Neurosciences Institute (NSI) in San Diego, and the Sony Computer Science Laboratory in Paris, he was elected "21st Century COE Professor, Information Science and Technology" at the University of Tokyo for 2003/2004, from where he held the first global, fully interactive, videoconferencing-based lecture series "The AI Lectures from Tokyo" (including Tokyo, Beijing, Jeddah, Warsaw, Munich, and Zurich). His research interests are in the areas of embodiment, biorobotics, artificial evolution and morphogenesis, self-reconfiguration and self-repair, and educational technology. He is the author of the book "Understanding Intelligence", MIT Press, 1999 (with C. Scheier). His new popular science book entitled "How the body shapes the way we think: a new view of intelligence," MIT Press, 2006 (with Josh Bongard) is scheduled to appear this fall.

## Epidemic Spreading and Complex Networks

Alessandro Vespignani,
Indiana University Bloomington, USA

**Abstract**

Networks which trace the activities and interactions of individuals, social patterns, transportation fluxes and population movements on a local and global scale have been analyzed and found to exhibit complex features encoded in large scale heterogeneity, self-organization and other properties typical of complex systems.

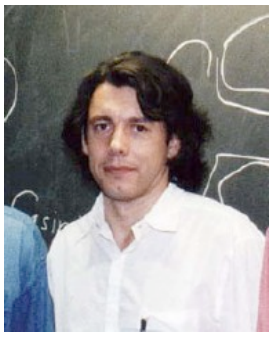
We discuss the impact of these complex features on the behavior of epidemic spreading processes. We first discuss the general framework obtained for basic compartmental models (SIR, SIS) and then report on the effect of the heterogeneity of real world transportation networks in meta-population models for the forecast of the large scale spreading of diseases.

**Speaker Profile**

Alessandro Vespignani is currently a professor of Informatics, Cognitive Science and Physics at Indiana University where he is the coordinator of the Complex Systems Group and affiliated faculty of the Biocomplexity Institute. He has obtained his Ph.D. at the University of Rome "La Sapienza." After holding research positions at Yale University and Leiden University, he has been a member of the condensed matter research group at the International Center for Theoretical Physics (UNESCO) in Trieste. Before joining Indiana University Vespignani has been a faculty of the Laboratoire de Physique Theorique at the University of Paris-Sud working for the French National Council for Scientific Research (CNRS) of which he is still member at large. Vespignani is also the coordinator of the Complex Network Lagrange Laboratory (CNLL) at the Institute for Scientific Interchange in Torino, Italy. Recently Vespignani's research activity focuses on the interdisciplinary application of statistical and numerical simulation methods in the analysis of epidemic and spreading phenomena and the study of biological, social and technological networks. Vespignani is author, together with Pastor-Satorras, of the book Evolution and Structure of the Internet, published by Cambridge University Press. He was among the five scientists nominated for the Wired Magazine Rave Award in science for 2004.

## A Probabilistic View of Deterministic Dynamical Systems

Marcelo Viana,
IMPA, Brazil



**Abstract**
Over the last two or three decades, the theory of dynamical systems has been developing a novel and much more stochastic approach to the understanding of long term evolution of deterministic systems. Certain objects with a prominently probabilistic flavor are emerging as crucial for such understanding, and a number of major results substantiate a whole new view of complex dynamical evolution. I will survey some of these developments, and hint at perspectives for the near future.

**Speaker Profile**
Marcelo Viana is a Professor of Mathematics and the current Deputy Director of the Instituto de Matematica Pura e Aplicada (IMPA) in Rio de Janeiro.

His research interests focus on Dynamical Systems and Ergodic Theory, where he has written some fifty research papers and two books. He was a plenary speaker at the International Congress of Mathematicians Berlin 1998 and the International Congress of Mathematical Physics Paris 1994, and an invited speaker at the International Congress of Mathematicians Zurich 1994. To date he has supervised the thesis of seventeen doctoral students.

He is a member of the Brazilian Academy of Sciences and TWAS-Academy of Sciences of the Developing World, and has received several other academic distinctions and Prizes, including the Ramanujan Prize 2005, the Latin American Mathematical Union Award 2000, and the TWAS Award in Mathematics 1998.

# List of Abstracts

## Credit Interlinkages and Bankruptcy Avalanches in a Network Economy

Domenico Delli Gatti, Mauro Gallegati, Alberto Russo, Bruce Greenwald, Joseph E. Stiglitz

*Social and Economic Systems 1*

We model a network economy with three sectors: downstream firms, upstream firms, and banks. Agents are linked by productive and credit relationships so that the behavior of one agent influences the behavior of the others through network connections. Credit interlinkages among agents are a source of bankruptcy diffusion: in fact, failure of fulfilling debt commitments would lead to bankruptcy chains. All in all, the bankruptcy in one sector can diffuse to other sectors through linkages creating a vicious cycle and bankruptcy avalanches in the network economy. Our analysis show how the choices of credit supply by both banks and firms are interrelated. While the initial impact of monetary policy is on bank behaviour, we show the interactive play between the choices made by banks, the choices made by firms in their role as providers of credit, and the choices made by firms in their role as producers.

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## Impact of Trust on the Performance of a Recommendation System in a Social Network

Stefano Battiston, Frank E. Walter, Frank Schweitzer

*Social and Economic Systems 1*

Social agents naturally use their social and professional networks to filter information by trustworthiness. In this paper, we present a model on an automated distributed recommendation system on a social network and we investigate how the dynamics of trust among agents affect the perfomance of the system. Agents search their social network for recommendations on items to be consumed and the propagation of the query through agents at several degrees of separation enhances the efficiency of their search. Moreover, agents have heterogeneous preferences so that trust between neighbours can be used to filter information coming from remote agents. We identify the range of the density of the network and the degree of heterogeneity of agent preferences in which trust improves the performance of the recommendation system.

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## The role of tie strengths in societal networks

Jukka-Pekka Onnela, Jari Saramäki, Jarkki Hyvönen, Gabor Szabo, David Lazer, Kimmo Kaski, Janos Kertesz, Albert-Laszlo Barabasi

*Social and Economic Systems 1*

Electronic communications offer new avenues to study and understand the structure of social networks, providing detailed records of a number of interpersonal activities, from phone conversations to emails and instant messages. Here we examine a network constructed from phone log data of millions of mobile phone users, offering simultaneous access to the communication network's large scale structure and the strength of the ties between individuals. We observe a strong local coupling between interaction strengths and the network's local structure, with the counterintuitive consequence that social networks are robust to the removal of the strong ties, but fall apart following a phase transition if the weak ties are absent. We show that this coupling significantly slows diffusion in social networks by trapping the information in communities, antithetical to efficient information transfer.

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## Complex system approach to language games

Andrea Baronchelli, Emanuele Caglioti, Vittorio Loreto, Luc Steels

*Concepts and Methods 1*

The mechanisms leading language conventions to be socially accepted and adopted by a group are object of an intense debate. The issue can be of course addressed by different points of view, and recently also complex system science has started to contribute, mainly by means of computer simulations and analytical approaches. In this paper we study a very simple multi agent model of convention spreading and investigate some of the crucial aspects of its dynamics, resorting, whenever possible, to quantitative analytic methods. In particular, the model is able to account for the emergence of global consensus out of local (pairwise) interactions. In this regard, a key question concerns the role of the size of the population. We investigate in detail how the cognitive efforts of the agents in terms of memory and the convergence time scale with the number of agents. We also point out the existence of an hidden timescale ruling a fundamental aspect of the dynamics, and we discuss the nature of the convergence process.

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## Coordinated Communication, a Dynamical Systems Perspective

Bart De Vylder

*Concepts and Methods 1*

Over the past years, several computational models have been introduced to study the coordination of communication between distributed agents. Although these models have given valuable insights into the mechanisms required for letting agents develop a successful communication system, few theoretical results have been obtained which substantiate these findings. In this paper we introduce a theoretical framework which allows us to analyze and compare different existing models in a uniform way. Therefore we only look at the observable behavior of an agent and not at the internal mechanisms that cause that behavior. In particular, we define an agent's response function and argue that a stability analysis of its fixed points reveals crucial information about the convergence properties of the dynamical system of interacting agents.

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## The Computational Complexity of Complex Systems: the Role of Topology and Functionality

Gregory Provan

*Concepts and Methods 1*

Recent research in complex systems has focused on the use of several classes of graph to model the topology a wide variety of naturally-occurring systems, ranging from biological systems, the WWW, to human-designed mechanical systems. However, little research has analysed the impact of the types of inference tasks that can be performed efficiently on such a structure. Some empirical studies indicate that there may be wide variability in inference complexity: for example, routing has log-time complexity, yet graph colouring appears to have exponential-time complexity. To complement the average-case results shown for small-world graphs, we describe some worst-case complexity results for well-known NP-complete problems that are restricted to mimic particular properties of small-world graphs. We identify two broad functional problem classes that have different computational complexity on small-world networks, which we call path-based and consistency-based problems; we show that path-based problems can be solved more efficiently than can consistency-based problems for every graph topology analysed.

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## Geometric Basis for Asymmetric Diffusion

Norman Packard, Rob Shaw

*Biology and Cognition 1*

Diffusion rates through a membrane can be asymmetric, if the diffusing particles are spatially extended and the pores in the membrane have asymmetric structure. This phenomenon is demonstrated here via a deterministic simulation of a two-species hard-disk gas, and via simulations of two species in Brownian motion, diffusing through a membrane that is permeable to one species and not the other. In its extreme form, this effect will rapidly seal off flow in one direction through a membrane, while allowing free flow in the other direction. The system thus relaxes to disequilibrium, with very different densities of the permeable species on each side of the membrane. A single species of appropriately shaped particles will exhibit the same effect when diffusing through appropriately shaped pores. We hypothesize that purely geometric effects discussed here may play a role in common biological contexts such as the ion channels.

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## Optimal Formulation of Complex Chemical Systems with a Genetic Algorithm

Morgan Theis, Gianluca Gazzola, Michele Forlin, Martin Hanczyc, Mark Bedau

*Biology and Cognition 1*

We demonstrate a method for optimizing desired functionality in real complex chemical systems, using a genetic algorithm. The chemical systems studied here are mixtures of amphiphiles, which spontaneously exhibit a complex variety of self-assembled molecular aggregations, and the property optimized is turbidity. We also experimentally resolve the fitness landscape in some hyper-planes through the space of possible amphiphile formulations, in order to assess the practicality of our optimization method. Our method shows clear and significant progress after testing only 1 % of the possible amphiphile formulations.

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## From evolving software towards models of dynamically self-assembling processing systems

Uwe Tangen

*Biology and Cognition 1*

Several types of micro-controllers are put into a primordial soup abstracted as a ring. The special feature of this setup is that self-replication is not possible. Microcontrollers only have access to foreign program-code not to their own. It turns out that the seeding programs vanish long before being able to proliferate when each program is automatically granted access to the neighboring code. An active attachment-procedure with a lock-and-key scheme (i.e. specific binding) is required to allow an evolutionary start. As expected, the error-threshold [1] applies here as well. As a second step, these fully fledged assembler programs are then partitioned into dynamical assembling pieces of simple linear program pieces essentially without any further control-structures but exhibiting the same functionality. Two different micro-controllers are studied under evolutionary conditions and longterm evolutionary behavior is investigated. A pathway towards the direct simulation of self-assembling nanoscale chemistry is opened.

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## Shape and efficiency in growing spatial distribution networks

Michael Gastner

*Networks 1*

We study spatial distribution networks, such as gas pipelines or train tracks, which grow from an initial source or sink of the commodity transported by the network. The efficiency depends on two properties. First, the paths to the root are ideally not much longer than the "crow flies" distance. Second, the length of all connections in the network should be low. Even though these two criteria cannot be optimized simultaneously, real networks are nevertheless nearly optimal in both respects. We propose two models to explain how this situation can arise and analyze the fractal properties of the resulting networks.

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## Weighted networks: Examples and characteristics

Janos Kertesz, Jukka-Pekka Onnela, Jari Saramäki, Kimmo Kaski

*Networks 1*

Introducing weights on the links of a network is a natural way to characterize the interactions. We define the subgraph intensity and coherence to describe such networks. Based on these concepts we present an appropriate generalization of the clustering coefficient and of motif statistics. Using several examples from sociology, biology and finance we demonstrate that the proper handling of the weights is crutial in understanding the relationship between structure and function of complex networks.

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## Hypernetworks for reconstructing the dynamics of multilevel systems

Jeffrey Johnson

*Networks 1*

Hypernetworks, a natural generalisation of networks, support an extensive mathematical theory of multidimensional multilevel systems. Hypernetworks are defined in the context of networks and hypergraphs and their related Galois Lattice. N-ary relations map structures up multilevel representations, and the resulting structure forms the domains and codomains for mappings representing intra-level dynamics. The definitions will be illustrated by examples from the design of artificial human and socio-technical systems.

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## The Public Research University as a Complex Adaptive System

Susanne Lohmann
*Social and Economic Systems 2*

A research university, like the brain of a human, is a biological complex system. Unlike the human brain, however, the university is a human complex system. Two attributes define it as such. The university exists in human minds, and it runs on human brains.

The architecture of the university brain, if you want to call it that, does not exist in nature. Instead, the university leads a virtual existence distributed across a multitude of human minds. People have incomplete and diverse understandings of the university, with some overlap and a lot of disagreement. And yet people's partially incompatible understandings collectively "are" the university. If people believe that this is the university, then this is the university.

University reform is thus a project of shifting a distributed collective belief system. It is at once ridiculously easy and impossibly hard. University reform is easy because the university is a social construction: it serves at our pleasure, and we can re-imagine it at will. Anything goes in university design. Then again, university reform is hard precisely because people's beliefs are scattered about all over the place, and so university reformers cannot appeal to a common understanding.

Even though the university is a figment of our collective imagination, the university's inhabitants are human, and they exist in nature. The neurons of the university brain, if you so will, are human brains. By shackling together human brains, the university enables people collectively to solve problems that would stump loners or groups working in an institution-free environment.

Precisely because the university runs on human brains, our evolved psychology constrains the set of institutional solutions to problems of collective action in the university. Not everything goes in university design. For the university to work its magic, its architecture must be adapted to – even harness to its own ends – the cognitive and emotional makeup of the human brain.

Consider an institution that encourages people, as members of scientific networks, to join teams and race other teams for the prize of coming in first; as members of academic departments, to obsess over whom to admit into the club and to feel superior to those left out in the cold; as members of university bureaucracies, to fight vicious turf battles; as members of state and federal governments, to support the institution in the expectation that its activities will improve economic competitiveness; as market participants, to cast their lot with a given institution because of its status in the institutional pecking order: this institution will do just fine. It is called a university, and it solves collective action problems the natural way, by framing them as problems the stone-age brain would have encountered in a hunter-gatherer environment short of complex institutions.

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## Social and Economic Complexity: the co-evolution of Reality, Knowledge and Values

Peter Allen, Liz Varga
*Social and Economic Systems 2*

Abstract: In this paper we consider the complexity of social and economic systems. In particular, we look at the importance of the ideas of co-evolution in which the aims and goals, and knowledge of agents (axiology and epistemology) essentially constitutes their identities, and the diversity and heterogeneity of these are the driving force of co-evolutionary change of reality (ontology). The emergence of these fundamental mechanisms is discussed from ecology, and then economic and organizational models are used to show how this successfully describes reality.
Keywords: Epistemology, axiology, ontology, complexity, economics, ecology, social systems, co-evolution, uncertainty, knowledge

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## A First Order Language to Coevolve Agents in Complex Social Simulations

Telmo Menezes, Ernesto Costa
*Social and Economic Systems 2*

Principles from the sciences of complexity may be applied to the problem of generating interesting and surprising high-level behaviours in 3D world simulations. We present a first order language designed to represent agents' internal reasoning rules that is suitable for a coevolutionary environment. An algorithm is described to use a set of rules expressed in this language to produce decisions. Genetic operators are defined. The first experimental results are presented, showing that agents implementing our model are able to develop interesting behaviours under open-ended evolution. In this initial results, the agents show the ability to bootstrap their own evolutionary process, by developing reproductive technology.

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## One in Four Is Enough - Strategies for Selecting Ego Mailboxes for a Group Network View

Antonio Zilli, Francesca Grippa, Peter Gloor, Robert Laubacher

*Social and Economic Systems 2*

Recently, researchers have started analyzing e-mail archives of individuals and groups as an approximation of social ties. However it can be hard to obtain complete e-mail archives covering all exchanges between a group of individuals. Frequently, only e-mailboxes of a subset of the analyzed actors are available for analysis. In this project we report on some experiments to find the best ego networks (i.e. mailboxes) to give a "reasonably" complete picture of the full social group network. We also report on the stability of social network metrics with respect to incomplete networks. We have collected the complete individual mailboxes over a period of 20 weeks of 53 researchers working in the same lab. Applying snowball sampling and subsequently adding more members of the group, we have compared a globally optimal selection strategy, adding the next-best member with respect to the chosen metric, a locally best strategy, adding the next best member within the already known network, and a random selection strategy. As sampling metrics, we used individual and group betweenness centrality, group density, number of nodes and edges, and others. Results show that good approximations of group network structures are already obtained with 25% to 30% of the mailboxes of the community.

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## Emergence of Cooperation in a Network Environment Introducing Social Distance

Hiroshi Kuraoka, Nobutada Fujii, Kanji Ueda

*Social and Economic Systems 2*

In this paper, emergence of cooperation in a network environment is explored. Interactions are modeled using a spatial prisoner's dilemma in which social distance is introduced, reflecting the existence of homophily, the tendency of agents to interact with likes in terms of agent attributes, and the network of interaction links, which evolves adapting to the outcome of the game. We observed that different ranges of homophily produce a variety of network topologies. Results showed that the ranges of homophily are closely associated with the robustness of cooperation that emerges among network environments.

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## Distributed control of collective motion of robots through mainly local interactions

Arturo Buscarino, Luigi Fortuna, Mattia Frasca, Alessandro Rizzo

*Concepts and Methods 2*

Models of collective motion represent an interesting class of complex systems made up of moving particles interacting mainly on the basis of local rules. In this work, the effects of the introduction of long-range connections between the individuals of the system are investigated. Two different models have been taken into account, leading to the conclusion that long-range connections increase both group coordination and the tendency to follow the preferred direction of informed individuals.

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## Detecting the Long-Range Dependence in the Internet Traffic with Packet Trains

Peter Haga, Gabor Vattay

*Concepts and Methods 2*

In this paper we demonstrate a new method to measure one of the key state parameters of paths in the Internet, the background traffic arrival process. The traffic arrival process has been investigated in several studies, since the recognition of its self-similar nature ten years ago. The statistical properties of the traffic arrival process are very important since they are fundamental in modeling the dynamical properties. To determine that kind of statistical properties usually passively collected traces are used. However, these traces are not available in general. Here we demonstrate how the end-to-end packet train technique can be used to determine the main properties of the traffic arrival process. We show that the packet train dispersion is sensitive to the congestion on the network path. We introduce the packet train stretch as an order parameter to describe the phase transition between the congested and uncongested phases of the bottleneck links of the path. We find that the distribution of the background traffic arrival process can be determined from the average packet train dispersion at the critical point of the system.

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## A Complex Systems Approach in ATM Modeling

Soufian Ben Amor, Marc Bui, Ivan Lavallee

*Concepts and Methods 2*

The dynamical behavior of the densely interconnected Air Traffic Management (ATM) system is difficult to analyze unless the appropriate theoretical tools are used. In this communication, we present a theoretical model based on a holistic approach, taking into account the structural and dynamical complexity of the ATM system. This work investigates in particular the effect of non-local interactions (distant and heterogeneous control sectors) on the fluidity of the aircraft traffic. We show the relationship between the density of congested sectors, and the non-locality parameter representing distant sectors and time effects.

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## Community Detection in Complex Networks using Genetic Algorithm

Mursel Tasgin, Haluk Bingol

*Networks 2*

Community structure identification has been an important research topic in complex networks and there has been many algorithms proposed so far to detect community structures in complex networks, however most of the algorithms are not suitable for very large networks because of their time-complexity. Another drawback of these algorithms is that they need apriori knowledge about the community structure like number of communities or some threshold values in order to truly identify the community structure. Genetic algorithm for detecting communities in complex networks is presented here. It is scalable to very large networks and does not need any priori knowledge about number of communities or any threshold value. The algorithm tries to find the best splitting of the network into communities that yields the highest network modularity using genetic algorithm methods. It has O(e) time-complexity where e is the number of edges in the network. Its accuracy is tested with the known Zachary Karate Club and College Football datasets. Enron e-mail dataset is used for scalability test.

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## The Laplacian Spectrum of Complex Networks

Almerima Jamakovic, Piet Van Mieghem

*Networks 2*

The set of all eigenvalues of a characteristic matrix of a graph, also referred to as the spectrum, is a well-known topology retrieval method. In this paper, we study the spectrum of the Laplacian matrix of an observable part of the Internet graph at the IP-level, extracted from traceroute measurements performed via RIPE NCC and PlanetLab. In order to investigate the factors influencing the Laplacian spectrum of the observed graphs, we study the following complex network models: the random graph of Erdös-Renyi, the small-world of Watts and Strogatz and the scale-free graph, derived from a Havel-Hakimi power-law degree sequence. Along with these complex network models, we also study the corresponding Minimum Spanning Tree (MST). Extensive simulations show that the Laplacian spectra of complex network models differ substantially from the spectra of the observed graphs. However, the Laplacian spectra of the MST in the Erdös-Renyi random graph with uniformly distributed link weights does bear resemblance to it. Furthermore, we discuss an extensive set of topological characteristics extracted from the Laplacian spectra of the observed real-world graphs as well as from complex network models.

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## Highly Clustered Networks with Preferential Attachment to Close Nodes

Matteo Dell'Amico

*Networks 2*

We analyse the properties of networks formed using a variant of the preferential attachment algorithm introduced by Barabesi and Albert, where a new node i connects to the old node j with a probability that is proportional to its degree $k_j$. In our model, nodes are assigned a random position on a ring, and connection probability is proportional to $(k_j)^\alpha/(d_{ij})^\sigma$, where $d_{ij}$ is the distance between i and j, and $\alpha$ and $\sigma$ are positive parameters. When $\gamma = \sigma/\alpha$ is fixed and $\alpha$ grows to infinity, an even simpler model selecting the m nodes having the highest value of $k$æ$/(d_{ij})^\gamma$ is produced. The resulting family of networks shows various properties, most interestingly scale-free, small-world, and hierarchical structure, that are commonly found in real-world networks.

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## Role of modular and hierarchical structure in making networks dynamically stable

Raj Kumar Pan, Sitabhra Sinha

*Networks 2*

According to the May-Wigner theorem, increasing the complexity of random networks results in their dynamical instability. However, the prevalence of complex networks in nature, where they necessarily have to be robust to survive, appears to contradict this theoretical result. A possible solution to this apparent paradox maybe through the introduction of certain structural features of real-life networks, in particular, modularity and hierarchical levels. In this paper, we first show that the existence of these structures in an otherwise random network will make it more unstable. Next, we introduce the realistic constraint that every link has an associated cost, and, find that modular networks are indeed more stable than homogeneous networks. Increasing modularity in such networks results in the appearance of large number of hubs and heterogeneous degree distribution, a general property shared by many networks including scale-free networks. Our results provide a dynamical setting for explaining the ubiquity of such networks in reality.

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## Network Analysis of Biochemical Reactions in Complex Environments

Elias August, Mauricio Barahona

*Biology and Cognition 2*

We present extensions to Chemical Reaction Network Theory which are relevant to biochemical modelling. We show that a weakly reversible chemical reaction network has a bounded absorbing set if mass is conserved in all reaction steps that do not involve explicit inflows or outflows - an assumption that is fulfilled by many biochemical networks. This result provides a qualitative criterion to establish that a biochemical network will not diverge by checking structural properties of the graph of the reaction network. It can also be used to characterise certain bifurcations from stationary to oscillatory behaviour. We provide a deficiency-zero-like theorem for reactions under dimensionally-restricted conditions as experienced in the cellular environment. Under these conditions, the law of mass action does not strictly apply and reactions can be described by power-law kinetics. We illustrate our results with applications to some simple biological examples.

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## Catalysis by Self-Assembled Structures in Emergent Reaction Networks

Gianluca Gazzola, Andrew Buchanan, Norman Packard, Mark Bedau

*Biology and Cognition 2*

We introduce a new variant of dissipative particle dynamics (DPD) models that includes the possibility of dynamically forming and breaking strong bonds. The emergent reaction kinetics may then interact with self-assembly processes. We observe that self-assembled amphiphilic aggregations such as micelles have a catalytic effect on chemical reaction networks, changing both equilibrium concentrations and reaction rates. These simulation results are in accordance with experimental results on the so-called "concentration effect."

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## Disease diversity and fluctuations in dynamic small world networks

Ana Nunes, Tudor Nedelea, Marcos Simoes, Margarida Telo da Gama

*Biology and Cognition 2*

In the long term behaviour of endemic diseases, spatial correlations have a major effect in the enhancement of resonant stochastic fluctuations, providing realistic patterns of recurrent epidemics. The persistence threshold of a given disease on a small world network that models the host population contact structure plays an important role in explaining disease diversity, together with the basic disease parameters on which it depends. Here we show that, at fixed basic reproductive ratio, the amplitude of the fluctuations and therefore the persistence threshold depend crucially on the infectious period.

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### Creating a framework for modelling complexity on socio-economic networks

Andrew Evans, Alison Heppenstall, Mark Birkin

*Poster Session 1*

This paper presents ongoing work focusing on the development of a framework within which complex geographical systems can be both understood and modelled. This work is forms part of a larger project entitled "Spatially Embedded Complex Systems Engineering" (SECSE), funded by the EPSRC. Further details of the work of other project partners can be found at www.secse.net.

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### Greedy Cheating Liars and the Fools Who Believe Them

Stefano Arteconi, David Hales

*Poster Session 1*

Recently, evolutionary algorithms based on "tags" have been adapted for application in peer-to-peer (P2P) systems. Using this approach nodes compare their utilities with random others and copy behaviours and links based on which node has the higher utility. Although such algorithms have been shown to posses many of the attractive emergent properties of the previous tag models, such as self-organised cooperation and coordination, they rely on the honest reporting of node utilities, behaviours and links. But what if a node does not follow the specified protocol and attempt to subvert it for its own selfish ends? We examine the robustness of this approach to two kinds of cheating behaviour in the nodes: a) when nodes lie and cheat to maximize their own utility and b) when nodes act nihilistically to try to destroy cooperation in the network. We find that in a) a certain percentage of such "greedy cheating liars" actually can improve system performance and in b) the network can still function even containing high levels of such nodes.

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### Ferromagnetic fluid as a model of social impact

Piotr Fronczak, Agata Fronczak, Janusz Holyst

*Poster Session 1*

The paper proposes a new model of spin dynamics which can be treated as a model of sociological coupling between individuals. Our approach takes into account two different human features: gregariousness and individuality. We will show how they affect a psychological distance between individuals and how the distance changes the opinion formation in a social group. Apart from its sociological aplications the model displays the variety of other interesting phenomena like self-organizing ferromagnetic state or a second order phase transition and can be studied from different points of view, e.g. as a model of ferromagnetic fluid, complex evolving network or multiplicative random process.

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## Complexity Research at University of Centrall Florida

Thomas Clarke, David Kaup, Brian Goldiez, Keith Garfield, Linda Malone, Rex Oleson, Randall Shumaker, Annie Wu, Adam Campbell

*Poster Session 1*

The poster presents an overiew of three research projects in the field of complex systems being conducted at various departments of the University of Central Florida. These projects are: Human Crowd Behavior Simulation, Simulating Teams of Autononomus Vehicles and Human Machine Interaction.

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## Mutual Information as a tool for Identifying Phase Transitions in Complex Systems

Robert Wicks, Sandra Chapman, Richard Dendy

*Poster Session 1*

There is growing interest in the use of mutual information to characterise the behaviour of complex systems in both physical and life sciences. Mutual information has previously been shown to be able to identify phase transitions in stationary complex systems; here it is shown to be an analytical tool able to identify the phase transition of a dynamical system.

Simple models for flocking in biological systems are of considerable interest from a complex systems perspective. The Vicsek model can be used as a testing ground for new techniques because it has potential applications to real world systems spanning complex systems science, including plasma physics, fluid dynamics, vibrating granular media and flocking studies. We investigate the dynamics of the Vicsek model of interacting self propelled particles using mutual information. The mutual information of the system is found to peak at the phase transition in a similar manner to the susceptibility of the system.

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## Emergent Socially Rational Utilitarianism in a Peer-to-Peer System

Andrea Marcozzi, David Hales

*Poster Session 1*

For many applications peer-to-peer (P2P) systems require their member nodes (or agents) to behave in a socially beneficial (non-egotistical) way. Kalenka and Jennings (1999) termed this requirement as the "Principle of Social Rationality": if an agent has a choice of actions it should chose the action that maximizes the social utility (sum of all agent utilities in the system). This principle can be contrasted with classical individual rationality that states agents should select actions that maximize their individual utility. In this poster we take an existing P2P model (the SkillWorld) and modify the utilities to explore a large space of possible values. In each case we checked if the protocol maximized the collective utility or not. We found in each case that if the collective cost of an action was less than or equal to the collective benefit the protocol self-organized the network to a state where nodes selected this action. We present a synthesis of results from computer simulations covering over ten billion interactions.

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## Offdiagonal Complexity: A computationally quick complexity measure for graphs and networks

Jens Christian Claussen

*Poster Session 1*

A vast variety of biological, social, and economical networks shows topologies drastically differing from random graphs; yet the quantitative characterization remains unsatisfactory from a conceptual point of view. Motivated from the discussion of small scale-free networks, a biased link distribution entropy is defined, which takes an extremum for a power law distribution. This approach is extended to the node-node link cross-distribution, whose nondiagonal elements characterize the graph structure beyond link distribution, cluster coefficient and average path length. From here a simple (and computationally cheap) complexity measure can be defined. This Offdiagonal Complexity (OdC) is proposed as a novel measure to characterize the complexity of an undirected graph, or network. While both for regular lattices and fully connected networks OdC is zero, it takes a moderately low value for a random graph and shows high values for apparently complex structures as scale-free networks and hierarchical trees. The Offdiagonal Complexity apporach is applied to a Barabasi-Albert scale-free network and randomly rewired surrogates thereof.

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## A Network Game with Attackers and a Defender:A Survey

Marios Mavronicolas, Vicky Papadopoulou, Anna Philippou, Paul Spirakis

*Poster Session 1*

We survey a research line recently initiated by Mavronicolas *et al.*, concerning a *strategic game* on a graph $G(V, E)$ with two confronting classes of randomized players: $\nu$ *attackers* who choose vertices and wish to minimize the probability of being caught by the *defender*, who chooses edges and gains the expected number of attackers it catches. So, the defender captures system rationality. In a *Nash equilibrium*, no single player has an incentive to unilaterally deviate from its randomized strategy. The *Price of Defense* is the worst-case ratio, over all Nash equilibria, of the *optimal* gain of the defender (which is $\nu$) over the gain of the defender at a Nash equilibrium. We present a comprehensive collection of trade-offs between the Price of Defense and the computational efficiency of Nash equilibria.

- We present an algebraic characterization of (*mixed*) Nash equilibria.
- No (non-trivial) instance of the graph-theoretic game has a *pure* Nash equilibrium. This is an immediate consequence of some *covering* properties proved for the *supports* of the players in all (*mixed*) Nash equilibria.
- We present a reduction of the game to a *Zero-Sum Two-Players Game* that proves that a general Nash equilibrium can be computed via Linear Programming in polynomial time. However, the reduction does not provide any apparent guarantees on the Price of Defense.
- To obtain guarantees on Price of Defense, we present an analysis of several structured Nash equilibria:
  - In a *Matching Nash equilibrium*, the support of the defender is an *Edge Cover* of the graph. Matching Nash equilibria are shown to still be computable in polynomial time, and that they incur a Price of Defense of $\alpha(G)$, the *Independence Number* of $G$.
  - In a *Perfect Matching Nash equilibrium*, the support of the defender is a *Perfect Matching* of the graph. Perfect Matching Nash equilibria are shown to be computable in computed in polynomial time, and that they incur a Price of Defense of $\frac{|V|}{2}$.
- We consider a generalization of the basic model with an increased power for the defender: it is able to scan a simple *path* of the network instead of a single edge. Deciding existence of a pure Nash equilibrium is shown to be an $NP$-complete problem for this model.

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## Coevolutionary dynamics: From finite to infinite populations

Arne Traulsen, Jens Christian Claussen, Christoph Hauert

*Poster Session 1*

Traditionally, frequency dependent evolutionary dynamics is described by deterministic replicator dynamics assuming implicitly infinite population sizes. Only recently, stochastic processes have been introduced to study evolutionary dynamics in finite populations. In previous work, we have noted that even simple coevolutionary dynamics of 2x2 games in finite populations can lead to unexpected stationary distributions of strategies significantly deviating from the Gaussian [1]. However, the relationship between deterministic and stochastic approaches remained unclear. In [2], we address this problem by explicitely considering the limit of infinite populations. In particular, we identify different microscopic stochastic processes that lead to the standard or the adjusted replicator dynamics. Moreover, differences on the individual level can lead to qualitatively different dynamics in asymmetric conflicts and, depending on the population size, can even invert the direction of the evolutionary process.

[1] Jens Christian Claussen and Arne Traulsen, Nongaussian fluctuations arising from finite populations: Exact results for the evolutionary Moran process, Physical Review E 71, 025101(R) (2005) (cond-mat/0409656).
[2] Arne Traulsen, Jens Christian Claussen and Christoph Hauert, Coevolutionary dynamics: From finite to infinite populations, Physical Review Letters 95, 238701 (2006) (cond-mat/0409655).

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## Markovian Dynamics for Hard Problem Instances. A critical survey and innovative applications

Charilaos Efthymiou, Paul Spirakis

*Poster Session 1*

In this work, we examine a powerful Monte Carlo technique for solving hard problems, namely that of fast mixing of Markov Chains. We first survey temporal mixing and various ways to estimate convergence times. We then proceed to relate this to Spatial Mixing. Then we indicate how such techniques can be applied to solve hard instances of problems such as graph coloring efficiently via statistical inference which exploits Spatial Mixing and an important parameter of graphs, namely the Treewidth.

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## Power-law spectra in time series generated by Rule 150 and other cellular automata

Jan Nagler, Jens Christian Claussen

*Poster Session 1*

We investigate the occurence of $1/f^\alpha$ in time series generated by elementary cellular automata. Cellular automata patterns are widespreadly observed in chemistry, biology, physics, and computer sciences, and are one possible paradigm how complex spatiotemporal behaviour can emerge from strikingly simple dynamics. Elementary cellular automata are the most basic class of those systems, defined on a one-dimensional lattice of binary states, or spins. The time evolution of each spin can depend on its own state and on the state of the two neighbors, defining 8 possible input combinations, hence 256 possible input-output relations defining the dynamics. We investigate a time series, or signal, defined by the total number of active states, corresponding to a total activity in a catalytic or pigment generating system, started with a single seed or a localized group of active states. While for the rule 90 (the Sierpinski automaton) the time series can be expressed in a simple analytic formula that resembles the self-similarity, for other automata the time series becomes less simple being quite prohibitive for an analytic calculation of the power spectrum. This is especially the case for the rule 150 automaton [1]. The total activity of the single-seeded cellular rule 150 automaton does not follow a one-step iteration like other elementary cellular automata, but can be solved as a two-step vectorial, or string, iteration, which can be viewed as a generalization of Fibonacci iteration [1] generating the time series from a sequence of vectors of increasing length. This allows to compute the total activity time series more efficiently than by simulating the whole spatio-temporal process, or even by using the closed expression. We systematically compute the power spectra of the one-dimensional elementary cellular automata introduced by Wolfram, with partially unexpected results: One of the so-called trivial automaton rules displays $1/f^\alpha$ spectra, and on the other hand various automata classified as chaotic or complex display no $1/f^\alpha$ spectra [2] While the spectra for the other automata are obtained numerically, we can generalize the time series of the Rule 90 automaton, approximating the exact time series of the Rule 150 automaton. This defines a class of fractal signals that are tailored to produce $1/f^\alpha$ spectra, and have a tuneable decay exponent.

[1] Jens Christian Claussen, Time-evolution of the Rule 150 cellular automaton activity from a Fibonacci iteration, arXiv.org/abs/math/0410429

[2] Jan Nagler and Jens Christian Claussen (2005), $1/f^\alpha$ spectra in elementary cellular automata and fractal signals, Phys. Rev. E 71, 067103

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## SIMPEST: an agent-based model to simulate plague epidemics in Madagascar

Dominique Badariotti, Arnaud Banos, Vincent Laperrière, Jean-Pierre Müller

*Poster Session 1*

Since European settlers brought plague to Madagascar, research on this particular epidemiologic case has been focusing upon this disease's transmission process- between the main host, rats, and the secondary one, humans, via a vector, fleas. Epidemiologists' research based on experimental method has achieved a fair knowledge of the transmission process. Nowadays, research aims to a better control of plague, studying its behavior by the way it appears, reappears, remains and spreads in its environment. This new purpose is to be fulfilled via a new kind of computer-based modeling derived from artificial intelligence techniques and complexity paradigm, this is to say, multi-agent modeling. This paper introduces SIMPEST, a prototype developed under the platform NetLogo, and exposes and discusses some preliminary results.

Link to the PDF file

## Efficiency in Technological Networks as Complex Organisations: An Approach from Game Theory

Nieves Arranz, Juan Carlos Fernandez de Arroyabe

*Poster Session 1*

The purpose of this paper has been to provide theoretical and empirical evidence on technological networks efficiency. We have considered the reality of technological networks as complex organization forms. Taking the departure point from normative principles of game theory, we have obtained important implications for the management of technological networks in relation with structural characteristics (type and number of partners and with the links and resources). We have carry out an empirical analysis of technological projects included in the V framework programme of the European Union. Our findings show firstly, the contingent nature of efficiency because each project has its own characteristic that is precise previously to determine; secondly, that the efficiency has a plural character. Thus network efficiency derives both from the kind of partner and the contributed resources, however next to the network efficiency coexists the individual efficiency of partner. In sum, the different approaches to efficiency make difficult the management of technological networks and that therefore they are considered complex organizations which develop between conflict and cooperation.

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## Perfect Sampling using the Stochastic Simulation Algorithm

Martin Hemberg, Mauricio Barahona

*Poster Session 1*

The specific characteristics of cellular biochemistry have made stochastic descriptions of chemical reactions increasingly necessary. However, the corresponding Master Equations (MEs) are hard to solve analytically and approximate solutions and numerical algorithms have been developed to deal with these systems. The most popular method today for analyzing stochastic reactions is Gillespie's Stochastic Simulation Algorithm (SSA). In many applications, one is interested in sampling from the stationary distribution in order to compare with experiments or an analytical model. A technical problem that manifests is: how long do we need to run the SSA before it has reached the stationary distribution? In this paper we address the issue of how to determine when the stationary distribution has been reached by combining the SSA with the Dominated Coupling From The Past (DCFTP) algorithm. This allows us to guarantee that the SSA will run until the stationary distribution has been reached. Using the irreversible first order reaction where the full time-dependent solution of the ME is available we establish rigorous bounds on the performance of the DCFTP and SSA. We investigate the error rates obtained using the new scheme and compare its performance to that of SSA. The method is illustrated using simple yet biologically relevant systems.

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## An overview, discussion, and demonstration of the Reconstruction Principle of Inductive Reasoning

Berkan Eskikaya

*Poster Session 1*

The term "Reconstruction Principle of Inductive Reasoning" refers to a technique in Systems Science that offers to improve upon observed data and attain a better estimate of the underlying source. It achieves this by eliminating unjustified and removing insignificant information from the data, as well as recovering some states that are missing from the data but are compatible with the underlying source. This presentation aims to give an overview of the principle, discuss its characteristics, and demonstrate its applicability to complex systems.

The Reconstruction Principle exists both in algorithmic and law-like form within the broader framework of Reconstructability Analysis, which is a domain of methodology that studies the various issues pertaining to the relation between parts and wholes in systems. The principle was identified and formulated by George Klir in the early 80s in the course of evaluating the operational behaviour of Reconstructability Analysis, and its validity has been confirmed by results based on many experiments performed on data from simulated as well as real-world systems.

Conceptually, Reconstructability Analysis is a form of "Enlightened Reductionism" with a focus on the multiple objectives of 1) reducing a whole to a sum of simpler parts, but 2) only as long as this reconstructed whole is exactly or very nearly the same as the original one. Operationally, Reconstructability Analysis offers a collection of methods to address the inherently conflicting aims of 1) reducing the descriptive complexity of a system by breaking it down into subsystems while 2) keeping the ensuing loss of information within justifiable limits.

Embedded in this conceptual and operational framework, the Reconstruction Principle of Inductive Reasoning states that, under certain conditions and especially when the available data is scarce, one can generally achieve a better estimate of the unknown original system by replacing the data-bound system with an unbiased reconstruction from a suitable set of its subsystems. This set of subsystems, which constitutes a structural model of the original system, is inferred from the data by the methods of Reconstructability Analysis described above.

In the special case of a probability distribution describing the behaviour of the system under investigation, the Reconstruction Principle can also be seen as a technique for adjusting probabilistic estimates. As such, it overlaps with similar methods in contingency table analysis, image processing, and statistical smoothing. The goal of this presentation is to review and discuss the characteristics of the Reconstruction Principle, and demonstrate its applicability to complex systems, here exemplified by Kauffman's NK model.

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## Mixing Simulation Styles - A Declarative Add-On for the General Purpose of Modelling Frameworks

Bogdan Werth

*Poster Session 1*

In this article I will argue that agent modelling tools like RePast, enriched with declarative abilities in particular, can contribute significantly to the quality, creativity and efficiency of social science simulation research efforts. Two approaches of declarative modelling, self developed declarative package and JESS add-on for RePast, are briefly introduced and compared. A small example of a model to project "social cost of carbon" developed with both approaches is introduced, in order to show directly the possibilities arising from the use of this technique. The model attempts to explain the pathway leading to vulnerability to droughts in West Africa and serves as an example of mixing declarative and procedural modelling styles.

Keywords: agent based modelling (ABM), modelling framework, expert system, JESS, RePast, declarative modelling, migration model.

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## Managerial intervention and instability in healthcare organisations: the role of complexity in explaining the scope of effective management

David Brookfield, Denis Smith

*Poster Session 1*

This paper seeks to examine the limitations of managerial intervention within the operation of organisations, especially as they relate to a range of complex environments. These, in turn, restrict the extent of management by measurement - a key component of management and accounting processes. The paper seeks to explain the context within which complex relations emerge that shape the extent of managerial influence; how this gives rise to the potential for destabilising intervention and the conditions in which this becomes a possibility. The theoretical framework proposed within this paper for understanding the scope of effective management is contextualized within the UK healthcare environment and is illustrated by reference to the example of the introduction of Payment by Results. Our conclusions are indicative of an environment that has significant areas of activity that are manageable and measurable only at fairly low levels of resolution.

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## Emergence of Cooperation in Innovation Networks

Michael Koenig, Stefano Battiston, Frank Schweitzer

*Poster Session 1*

We consider an innovation network in which nodes represent agents and edges represent catalytic interactions of knowledge exchange between these agents. The utility of each agent is determined by a stochastic differential equation including auto-catalytic as well as hetero-catalytic processes of knowledge sharing. A rewiring of any link between two agents is accepted iff this increases the utilities of both agents this link was incident to. The repeated updating of the innovation network leads to a saturation in an optimized network configuration. A hierarchy in network variables characterizes the equilibrium network. This property is reflected in the distribution of the agent's utilities, the distribution of links, clustering coefficients and the number and length of cycles in the network.

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## Simulation of Higher Order Self-Assembly

Jens Peter Schroer, Kristian Lindgren

*Poster Session 1*

Self-assembly of particles with certain surface properties is a topic which becomes more and more interesting in many research areas. The main problems of self-assembly of different particles are of two kinds: First, one has to find a method that determines a set of particles with certain properties so that an assembly into a desired structure is achieved. Second, once these particles are found, they have to be created as real chemical or biological components. The model proposed in this paper only considers the first problem: finding a set of particles that self-assembles into higher order structures. It uses a simple hard-sphere description of particles with circular patches on the particle surface, called binding sites. These binding sites allow the particles to attach to each other. Further the model is split into two parts of which the first one simulates the aggregate growth while the second part simulates the internal dynamics of the aggregate. The model is capable of creating a broad range of different structures, ranging in size from a few particles up to several hundreds. The first obtained results seem promising and allow us already to draw a few conclusions of this model. First, the model is capable of creating structures with a wide variety of shapes and sizes. The simulation of the internal dynamics of the cluster allows for creation and destruction of bonds. We consider this to be an important feature of the self-assembling process and therefore important to include. The model also allows for the formation of cycles in the aggregate's structure, something that has not been observed in an older version of the model that did not include the internal dynamics simulation, and that is not typically observed in traditional DLA. Further results show that the concentrations of the different particle types can influence the growth and structure of the aggregate quite significantly. Thus, not only the design of the particle (the particle surface with its binding sites) but also the concentrations of each particle type can be used as a mean of growth control. Current research conducted on this model is in the area of how evolution can be incorporated into the model. The approach considered in the current research is to use a genetic algorithm to evolve particle and binding site types that assemble into an aggregate with a desired form or function (also called target structure). The main point of concern is the choice of the fitness function, since several statistical features of the resulting particle type set are important for the self-assembly process. First, it is desirable that the set of particles assembles into the desired structure in most of the experiments, even if the process is disturbed by noise of various type. Further the aggregate should be resistant to environmental noise even after the assembly. This can be achieved by designing the component or particle set in such a way that the resulting target structure has a big energy gap between all other global possible structures to withstand environmental noise. The aim of our research is to design and investigate a number of fitness criteria for self-assembly in the presented model. We expect that at least some of the suggested properties will characterize the self-assembly process if the fitness function leads to a robust process. Further, different ways of defining a target structure are currently discussed and examined for their suitability.

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## Clustering as a mechanism for repulsion between particles in DPD simulations

Johan Nyström, Anders Eriksson, Martin Nilsson Jacobi, Kolbjörn Tunström

*Poster Session 1*

A model is presented to connect the dissipative particle dynamics (DPD) simulation technique with an underlying microscopic description. Dissipative particles in the DPD scheme are normally thought of as consisting of clusters of molecules, and to evolve under the influence of pairwise forces, consisting of conservative, dissipative and randomly fluctuating parts. The clusters are typically assumed to be spheres of constant mass and size, but a connection to the motion of the underlying molecules is generally not given. In the model presented here, the dissipative particles are obtained by applying a clustering algorithm to a set of particles performing Brownian motion. The clusters thus obtained are taken as the dissipative particles, and their locations are recalculated repeatedly as the underlying particles move. In this way, the dissipative particles are space filling and have varying sizes and masses. This is a similar approach as the one adopted by Flekkøy et al. ("Foundations of Dissipative Particle Dynamics"). It is shown that repulsion between clusters, i.e. between the dissipative particles, is obtained as a consequence of the fact that the underlying particles can move freely between clusters. In addition to the repulsion, a random part in the DP trajectories also exists, which comes from the internal motion of particles within each cluster and reflects the randomness in the motion of these underlying particles. An analytic model for the cluster centers movement is also presented and compared to the results obtained from the simulations. The one-dimensional case is studied in detail and the long-term motion of the cluster centers is shown to be diffusive when periodic boundary conditions are used. As opposed to normal DPD, the short term motion in this model can be described by Brownian motion in combination with discrete jumps arising when particles cross cluster borders.

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## Fairness state with plastic preferences

Elena Ramirez, Juan Guillermo Diaz Ochoa

*Poster Session 1*

The definition of preferences is a concept that concerns decision making in social systems (for instance in vote systems) and economics. We are interested in the phenomena of efficient choice related to economic fairness. In Arrow's impossibility theorem this situation is stressed as an impossibility of aggregate individual preferences among agents without running into unfairness. This situation was also analyzed in a previous model in a network of agents with a random allocation. Both researches are based on static preferences.

In a real social system the individuals are confronted to exchanges of information that can modify the way they think. In particular, the preferences of each person are influenced by this information exchange and can generate dissatisfaction into the agents after their choice. This consideration is not enough realistic and is not able to make an accurate analysis of the fairness state when the preferences are changing. Then we must to plug these two systems: the first one consider the formation of preferences and a second stage, when an allocation of goods is done.

Hence the preferences are changing, we want to investigate different learning schemes in dynamic game theory and consider their relative importance when constructing strategic decision models for economic applications. These learning processes can be easily observed by considering an evolutionary network to analyze the improvement into the social system.

Link to the PDF file

## The role of priority in the mobility of a system of two kinds of random particles

Michael Maragakis, Panos Argyrakis, Shlomo Havlin

*Poster Session 1*

Priority is an important concept that is present in many real-life systems, such as driving, information propagation, network routers etc. When we have two kinds of entities on the same site, we may want to assign a higher priority to move to the first entity over the second. In our model, we use computer simulations of a system with random particles of two kinds, A and B, with different movement priorities ($0<p<1$). The system is studied in a 2D lattice with periodic boundary conditions, Erdös-Renyi and Scale-Free networks. Particles A have a higher priority to move than particles B when both coexist in the same site ($pA>pB$). Several particles may coexist in the same space, whether lattice site or network node, without further interactions. We study the mean square displacement of both particles (MSD) and find a relationship between the slope of the MSD vs the MC steps (time), the priorities (pA and pB) and the densities (dA and dB). We investigate the range of density and priority values which limit the mobility of B, due to the high values of pA and dA. We also study the special case of a biased source-target system, where the particles begin at specific source points, in one side of the lattice, and move towards the other side.

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## BitBang: A Model and Framework for Complexity Research

Tiago Baptista, Telmo Menezes, Ernesto Costa

*Poster Session 1*

The science of complexity has been gaining momentum. It spans multiple areas of research and, most of them, use computer generated models to try to reproduce and thus study the phenomena. We describe a framework—BitBang—that aims to provide a base system in which to implement these models. This framework is agent-based, with roots in Alife systems. The framework provides a generic model upon which one can implement the desired system. It started as an effort to apply complexity science to modern computer games, and thus it provides an integration with modern 3D and physical engines. This can offer an added realism to the visualisation, but also adds details to the model being studied. As an example of the possible uses of this framework, we present a research scenario that tries to study the emergence of complexity underlying circadian clocks.

As stated above, this project started focused on giving game design and development new tools based on the science of complexity. This focus came from realizing that the great majority of computer games use traditional artificial intelligence strategies when modelling agent behaviour. Under this paradigm, when a new functionality is needed the system is extended and new modules that implement that functionality are added to the hierarchy. This approach achieved considerable success in hard logic tasks like military strategy and spatial reasoning but so far failed to achieve truly creative, innovative behaviour.

We argue that the reason for this lack of progress in developing artificial creative and innovative behaviour is that the paradigm used is inadequate for the task, and that under a new paradigm these goals are indeed achievable. This new paradigm would be the science of complexity.

To clarify our distinction between complicated and complex, we define a complicated system as one that results from the aggregation of specialised linear sub-systems and a complex system as one that emerges from the local interactions of simple agents self-organizing in a given environment. Trivially we may state than in a complex system the whole is greater than the sum of its parts.

The method we propose does not promote divisionism, gaining features by an increase in complexity. We favour emergent functionality. In a complex system if modules do form, this happens by processes of self-organization and not by decision of human designer.

Under these assumptions we propose a conceptual model for simulating complex systems, and BitBang, a software framework that implements this conceptual model.

The model we propose has roots in Alife systems, it defines an agent based approach describing the artificial world, as opposed to describing the artificial brain. Our world is composed of entities. These can either be inanimate objects which we designate as things, or entities that have reasoning capabilities and power to perceive and affect the world—the agents. Both have traits that characterise them, such as colour, size, or weight—the features. The agents communicate with, and change the environment using perceptions and actions, makings decisions using the brain. All these are fairly abstract concepts, and in this model they keep that abstract property, as we can take advantage of it. Having that in mind we now further describe each of these components.

With BitBang, we believe we can provide an important tool to the community of complex systems research. Moreover, we think that the kind of modelling of complex systems that the framework provides, namely the use of 3D and physics, can provide new and interesting results, as well as a new way to look at and think about our models.

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## Power Games: The Impact of Sharing Power on Development Projects

Crighton Nichols

*Poster Session 1*

There has been a growing focus on the importance of Decentralisation, Participation and Empowerment (DPE) in various aspects of development strategies. The reasons for this seem intuitive enough, but a coherent theoretical framework that explains why these factors are so important to development strategies is lacking. This article explores the idea that one way of looking at DPE is to view them as attempts to share or distribute power. In some cases these attempts are nothing more than statements of intent made by governments in charge to order to obtain more financial aid for the sole purpose of strengthening and consolidating their own positions of power. However, those attempts that actually do successfully manage to distribute power to the masses, or at least significantly empower the local community, have sometimes produced remarkable results. These "successful" projects, and the theoretical framework that explains why sharing or distributing power can have such a strong influence on the outcome of a project, form the basis of this article.

In a recent article, Barnett & Duvall provide a useful taxonomy of power based on the kinds of social relations power works through (interaction or constitutional) and the specificity of the social relations (direct or diffuse). This article focuses on the interaction / constitution dimension, and explores the relationship between these two forms of power and the implications of this on the distribution of power. Complexity theory, an extension of systems theory that originated in the natural sciences and recently has started to be applied to the social sciences, is then utilized to show theoretically how distributing power within an organisation can lead to more successful outcomes. Despite the complications associated with measuring power, when defined in this way it can still be a useful tool in assessing the impact of the changes on poverty, as it reflects the multi-dimensional nature of poverty itself.

In one case study examined in this article, the lessons learnt on the importance of self-organisation / management and cultural identity in the Colombian Amazon are being replicated in a number of both "developed" and "developing" nations throughout the world through the help of various NGOs. The empowerment of the indigenous community was greatly boosted by the transfer of land ownership. This facilitated the development of their own health and education programs, which were based on their culture and values such as expressing their relationship to the earth (e.g. "belonging to it" as opposed to "owning it"). This helped build and reinforce a sense of identity, which in turn acted as a catalyst to form a stronger sense of community that ultimately lead to further self-organisation and collective action to facilitate positive humanitarian, social, economic, and political change.

A second case study explores the distribution of power between the police and youth in a "disadvantaged" community in the UK. Led by the local sergeant, the police deliberately gave some of the power vested in them by the authorities back to the community, especially the youth. By working with the local community instead of against them – as the community often perceived the more traditional role of the police – the police created an atmosphere of trust and cooperation, which offered considerable benefits to the youth of the community.

The final case study investigates the role of a government initiated Training and Enterprise Council (TEC) to facilitate the development of local industry. In this case, the managing director of the organisation, with the help of an organisational psychologist, created a working environment that was less "command-and-control" and more "coexist-and-contextualise". The result was a considerably more flexible, dynamic and innovative TEC, which in turn helped it become more effective.

In conclusion, by providing a theoretical framework that explains how the distribution of power influences the outcome of development projects, and exploring different cases that examine the feasibility of this framework, the research aims to provide a greater understanding of the changing of the rules of the (power) game, and the subsequent impact of these rules on the success of development projects and the lives of the poor.

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## Reconstructing Models for Local Government from Survey Data

Jeffrey Johnson, Clive Downs

*Poster Session 1*

Local Government is a complex multilevel system of systems. There are many local social interacting subsystems such as local authority departments, voluntary organisations, and national Government departments. Information and record keeping are key to the activities of Local Government, and reflects the complexity of the system. Local authorities need to conduct surveys and analyse the data they produce. It is from such surveys that models of the system are reconstructed, and if the data do not capture the complexity of the system those trying to implement policy will not be dealing with reality. In this context we report on Reading Council's implementation of a recent national survey, and perform a preliminary analysis of the data from the perspective of complex systems science. the ways in which this science might help Local Government tackle its many difficult problems are discussed.

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## HUGO: A Cognitive Architecture with an Incorporated World Model

Jiri Wiedermann

*Biology and Cognition 3*

We present a design of cognitive system architecture with an internal world model. The internal world model is realized with the help of artificial mirror neurons. We consider generalized artificial mirror neurons acting both as a mechanism for assembling and learning multimodal sensorimotor information and as associative memory for invoking multimodal information given only some of its components. We show that within an artificial cognitive system a network of generalized mirror neurons can simultaneously serve as an internal world model recognized by the agent and as that of the agent's position within this world. We also specify a self-organizing control mechanism, which is based on the basic operations over concepts that were essentially identified by the British 18th century philosopher David Hume. This control mechanism makes use of the internal world model constructed in agent's interaction with real world and straightforwardly supports imitation learning. Building heavily on the properties of the generalized mirror net and on automatic abstract concept creation, we offer an algorithmic explanation of computational language acquisition, thinking and consciousness in our model. Rather than describing an implementation of the respective mechanisms, the aim of the paper is to present a plausible hypothesis concerning the architecture and functionality of artificial systems exhibiting higher cognitive functions.

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## A simple model of cognitive processing in repeated games

Kristian Lindgren, Anders Eriksson

*Biology and Cognition 3*

In repeated interactions between individuals, we do not expect that exactly the same situation will occur from one time to another. Contrary to what is common in models of repeated games in the literature, most real situations may differ a lot and they are seldom completely symmetric. The purpose of this paper is to discuss a simple model of cognitive processing in the context of a repeated interaction with varying payoffs. The interaction between players is modelled by a repeated game with random observable payoffs. Cooperation is not simply associated with a certain action but needs to be understood as a phenomenon of the behaviour in the repeated game. The players are thus faced with a more complex situation, compared to the Prisoner's Dilemma that has been widely used for investigating the conditions for cooperation in evolving populations. Still, there are robust cooperating strategies that usually evolve in a population of players. In the cooperative mode, these strategies select an action that allows for maximizing the sum of the payoff of the two players in each round, regardless of the own payoff. Two such players maximise the expected total long-term payoff. If the opponent deviates from this scheme, the strategy invokes a punishment action, which aims at lowering the opponent's score for the rest of the (possibly infinitely) repeated game. The introduction of mistakes to the game actually pushes evolution towards more cooperative strategies even though the game becomes more difficult.

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## The effect of finite population size on the evolutionary dynamics in multi-person Prisoner's Dilemma

Anders Eriksson, Kristian Lindgren

*Biology and Cognition 3*

We study the influence of stochastic effects due to finite population size in the evolutionary dynamics of populations interacting in the multi-person Prisoner's Dilemma game. This paper is an extension of the investigation presented in a recent paper [Eriksson and Lindgren (2005), J. Theor. Biol. 232(3), 399]. One of the main results of the previous study is that there are modes of dynamic behaviour, such as limit cycles and fixed points, that are maintained due to a non-zero mutation level, resulting in a significantly higher level of cooperation than was reported in earlier studies. In the present study, we investigate two mechanisms in the evolutionary dynamics for finite populations: (i) a stochastic model of the mutation process, and (ii) a stochastic model of the selection process. The most evident effect comes from the second extension, where we find that a previously stable limit cycle is replaced by a trajectory that to a large extent is close to a fixed point that is stable in the deterministic model. The effect is strong even when population size is as large as 10,000. The effect of the first mechanism is less pronounced, and an argument for this difference is given.

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## Exact Solutions for Models of Cultural Transmission and Network Rewiring

Tim Evans, Douglas Plato

*Networks 3*

We look at the evolution through rewiring of the degree distribution of a network so the number edges is constant. This is exactly equivalent to the evolution of probability distributions in models of cultural transmission with drift and innovation, or models of homogeneity in genes in the presence of mutation. We show that the mean field equations in the literature are incomplete and provide the full equations. We then give an exact solution for both for their long time solution and for their approach to equilibrium. Numerical results show these are excellent approximations and confirm the characteristic simple inverse power law distributions with a large scale cutoff under certain conditions. The alternative is that we reach a completely homogeneous solution. We consider how such processes may arise in practice, using a recent Minority Game study as an example.

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## Decentralised control of material or traffic flows in networks

Stefan Laemmer, Hiroshi Kori, Karsten Peters, Dirk Helbing

*Networks 3*

We present a self-organising, decentralised control method for material flows in networks. The concept applies to networks where time sharing mechanisms between conflicting flows in nodes are required and where a coordination of these local switches on a system-wide level can improve the performance. We show that, under certain assumptions, the control of nodes can be mapped to a network of phase-oscillators.

By synchronising these oscillators, the desired global coordination is achieved. We illustrate the method in the example of traffic signal control for road networks. The proposed concept is flexible, adaptive, robust and decentralised. It can be transferred to other queuing networks such as production systems. Our control approach makes use of simple synchronisation principles found in various biological systems in order to obtain collective behaviour from local interactions.

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## Self-organizing principles for material flow control in complex networks

Karsten Peters, Dirk Helbing

*Networks 3*

We have studied decentralized, adaptive methods for the control of material flows in a wide class of material flow systems reaching from traffic to production networks. Due to conflicts of usage, optimal flows in networks are typically not stationary. Depending on the actual operation mode of the material flow network, different self-organization principles may be optimal. Here we present examples for two basic control principles: On the one hand side, system wide coordination by means of synchronization can be reached by a coupling of neighboring control elements, while a centralized control is not necessarily required. But also establishing suitable local interaction mechanisms, local coordination may eventually spread all over the system. Both principles benefit from the interesting features of self-organizing systems: Based on non-linear interactions, a locally emerging pattern may have global effects. This can be viewed as phase transition in the system.

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## Competitive advantage of geographical clusters: Complexity science and network theory approach

Nunzia Carbonara, Ilaria Giannoccaro, Vito Albino

*Social and Economic Systems 3*

This paper deals with the competitive advantage of geographical clusters (GCs), that is a relevant topic in the literature. To address this topic, GC is considered as a complex adaptive system (CAS) and the competitive advantage of GCs is associated to their adaptive capacity. Three theoretical propositions concerning the GC adaptive capacity are formulated by using complexity theory. First, we identify three main properties of CASs that affect the adaptive capacity, namely the interconnectivity, the heterogeneity, and the level of control, and define how the value of these properties influence the adaptive capacity. Then, we associate these properties with specific GC characteristics so obtaining the key conditions of GCs that give them the adaptive capacity so assuring their competitive advantage. To test these theoretical propositions, a case study on two real GCs is carried out. The considered GCs are modeled as networks where firms are nodes and inter-firms relationships are links. Heterogeneity, interconnectivity, and level of control are considered as network properties and thus measured by using the methods of the network theory.

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## Matching and Network Effects

Marcel Fafchamps, Marco van der Leij, Sanjeev Goyal

*Social and Economic Systems 3*

This paper examines the existence and magnitude of network effects in the matching of workteams. We study the formation of coauthor relations among economists over a thirty year period. Our principal finding is that a collaboration emerges faster among two authors if they are closer in the social network of economists. This proximity effect on collaboration is strong and robust. We also provide some evidence that matching depends on experience, junior authors being more likely to collaborate with senior authors.

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## Emergent structures and dynamic processes in a distributed manufacturing network

Serguei Saavedra, Felix Reed-Tsochas, Brian Uzzi, Janet Efstathiou

*Social and Economic Systems 3*

Network research has focused on growth, yet a complete theory of networks requires an understanding of contraction and loss. The contracting behaviour of a network may be understood as a natural or engineered mechanism driving either the extinction or the optimisation of the system. This potentially broad class of permanently shrinking networks includes diverse types of social systems that ultimately fail or lose capacity, economic systems such as collapsing markets, physical systems that become obsolete such transportation and communication networks, or perhaps evolving biological systems, thereby raising new questions about the deletion mechanisms that explain stability and collapse. As a first attempt to model network contraction, we use unique data on the famous New York City garment industry supplier network, which experienced the dramatic loss of over 3000 firms from 1985 - 2003. We are especially interested in the overall structural characteristics and dynamic properties of the supply network, because this network has not been centrally designed or stipulated. Instead, it reflects the evolution of a population of firms engaged in a highly distributed manufacturing process, and the consequences which emerge from local behavioural mechanisms that can be attributed to firms and the links between them. Confronting the assumption that growth promotes stationarity, here we show that the network's macroscopic structure exhibits surprising stationarity for most of the contraction process before ultimately undergoing a natural transition. Finally, we propose a basic contraction mechanism to understand the evolution of this shrinking network.

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## Inferring Global Synchrony from Local Symbolic Dynamics

Sarika Jalan, Fatihcan Atay, Juergen Jost

*Concepts and Methods 3*

We present a method based on symbolic dynamics for the detection of synchronization in networks of coupled oscillators. The symbolic dynamics are defined using special partitions of the phase space which prevent the occurrence of certain symbol sequences related to the characteristics of the dynamics. These partitions are chosen to best distinguish chaotic (but deterministic) dynamics from random ones in the uncoupled case. In the coupled case, they allow for a rapid detection of qualitative types of emerging collective dynamics. As a direct application, we can detect synchronization of coupled chaotic dynamics on networks from a single randomly selected node by comparing the transition probabilities with those of the uncoupled function. The method utilizes a relatively short time series of measurements and hence is computationally very fast. Furthermore, it is robust against parameter uncertainties, is independent of the network size, and does not require knowledge of the connection structure. We present our method for the one-dimensional logistic map, the two-dimensional Hénon map, and the three-dimensional Lorenz oscillator as local dynamical function, and for various different coupling structures.

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## Quotient Manifold Projections and Hierarchical Dynamics

Martin Nilsson Jacobi

*Concepts and Methods 3*

In this paper we explore the mathematical structure of hierarchical organization in smooth dynamical systems. We start by making precise what we mean by a level in a hierarchy, and how the higher levels need to respect the dynamics on the lower levels. We derive a mathematical construction for identifying distinct levels in a hierarchical dynamics. The construction is expressed through a quotient manifold of the phase space and a Lie group that fulfills certain requirement with respect to the flow. We show that projections up to higher levels can be related to symmetries of the dynamical system. We also discuss how the quotient manifold projections relate to invariant manifolds, invariants of the motion, and Noether's theorem.

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## A unifying framework for complexity measures of finite systems

Nihat Ay, Eckehard Olbrich, Nils Bertschinger, Juergen Jost

*Concepts and Methods 3*

We develop a unifying approach for complexity measures, based on the principle that complexity requires interactions at different scales of description. Complex systems are more than the sum of their parts of any size, and not just more than the sum of their elements. We therefore analyze the decomposition of a system in terms of an interaction hierarchy. In mathematical terms, we present a theory of complexity measures for finite random fields using the geometric framework of hierarchies of exponential families. Within our framework, previously proposed complexity measures find their natural place and gain a new interpretation.

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## Physical And Relational Networks In The Aegean Bronze Age

Tim Evans, Ray Rivers, Carl Knappett

*Social and Economic Systems 4*

In this paper we present a new interdisciplinary perspective on regional interaction patterns in archaeological contexts. It combines insights from graph theory, social network analysis and statistical physics to treat the interactions between sites in geographical space in terms of a network which minimises an associated Hamiltonian. To explore the various issues involved a case study from a heterogeneous physical environment is chosen, the archipelago environment of the southern Aegean, in particular the rich dataset of the Aegean Bronze Age. Our findings are of broader relevance for the study of interaction networks, as the use of statistical physics in this fashion represents a novel application in social science contexts.

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## The effect of travel restrictions on the spread of a highly contagious disease

Martin Camitz, Fredrik Liljeros

*Social and Economic Systems 4*

Travel restrictions may reduce the spread of a contagious disease that threatens public health. In this study we investigate what effect different levels of travel restrictions may have on the speed and geographical spread of an outbreak of a disease similar to SARS. We use a stochastic simulation model incorporating survey data of travel patterns between municipalities in Sweden collected over three years. We find that a ban on journeys longer than 50 km drastically reduces the speed and the geographical spread of outbreaks, even when compliance is less than 100%. The result is found to be robust for different rates of inter-municipality transmission intensities. Travel restrictions may therefore be an effective way to mitigate the effect of a future outbreak.

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## In Search of the Perfect Partnership

David Smith, Neil Johnson, Ben Burnett, Thomas Cox
*Social and Economic Systems 4*

We tend to spend an enormous amount of time and effort in our lives forming and maintaining relationships of all sorts. In addition to our personal lives, the formation of commercial and political relationships is fundamental to our Society. For example, as consumers we are all individually in customer-client relationships with particular gas, electricity and phone companies; our employers are typically involved in business partnerships with other companies; and our countries are involved in ever-changing political, strategic and commercial alliances (e.g. the EU and NATO). And, as they say, even 'birds and bees do it'. Indeed, Nature is awash with various types of mating and grouping rituals. But as people, companies, institutions and even countries become more 'sophisticated' – or just downright picky – in their requirements for a potential partner, does this mean that the world is going to be driven to a state where reliable long-term working partnerships do not form?

There are several obvious reasons why finding the right partner is so complicated: First, that partner must actually exist – somewhere. Second, you have to establish contact with this perfect partner. The fact that the right partner might be just out of reach of your existing network of contacts, is a particularly unfortunate but typical event. Third, even if you find your perfect match, you may not be the perfect match for them. A wants B who wants C who wants D who wants A. Fourth, and most importantly, you are not the only one looking. Since you and everyone else is simultaneously looking for that special relationship, we are each part of a collection of decision-making objects competing for a limited resource, which in this case is the perfect partner.

Our research examines this complexity in how partnerships form and break up, and how their duration and stability is affected by the attributes of the constituent objects.

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## How to cheat BitTorrent and Why Nobody Does

David Hales, Simon Patarin
*Social and Economic Systems 4*

The BitTorrent peer-to-peer file-sharing system attempts to build robustness to free-riding by implementing tit-for-tat-like strategy within its protocol. It is often believed that this strategy alone is responsible for the the high-levels of cooperation found within the BitTorrent system. However, we highlight some of the weaknesses of the approach and indicate where it would be easyto cheat and free-ride. Given that cheating of this kind currently appears rare, this motivates the question: why is the system not dominated by free-riders? We advance a hypothesis which argues that BitTorrent may resist free-riders in a way that has not been previously fully comprehended. Ironically, this process relies on what is commonly believed to be a weakness of BitTorrent - the lack of meta-data search. One consequence of this is to partition the BitTorrent network into numerous isolated swarms - often with several independent swarms for an identical file - which is one of the necessary conditions for a kind of evolutionary group selective process, a process that has been recently identified in similar simulated systems. A further implication of the hypothesis is that, given the choice, users may choose unconditional altruism rather than the more restrictive reciprocal tit-for-tat approach as a result of the same group selective process.

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## A General Framework for Agent-based Modelling of Complex Systems

Mike Holcombe, Simon Coakley, Rod Smallwood

*Concepts and Methods 4*

Agent-based approaches to modelling complex systems and phenomena are becoming popular and are proving successful in a number of areas. However, the underlying basis of these techniques is sometime rather 'ad-hoc' and the models are often only applied to specific systems. This paper describes a general approach that is based on the use of fully general computational models, using a formal model of an agent and a rigorous approach to building systems of communicating agents within virtual environments, a technology which is, nonetheless, accessible to researchers in experimental biology and medicine. A collection of tools has been built which allow for efficient simulation of such systems and their visualisation. Included in this work is the implementation of the simulations on parallel clusters of computers to enable large numbers of agents to be simulated. Application areas where the method has been successfully applied include biology, medicine and economics. In the former the detailed models have led researchers to fundamentally new discoveries.

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## Introducing Complex Automata for Modelling Multi-Scale Complex Systems

Alfons Hoekstra, Bastien Chopard, Pat Lawford, Rod Hose, Manfred Krafczyk, Joerg Bernsdorf

*Concepts and Methods 4*

We introduce Complex Automata, a generic methodology to model multi-scale complex systems. A Complex Automaton is a scalable hierarchical aggregation of Cellular Automata and agent-based models, each modelling components of the Complex System. The components represent a sub-system operating on its typical spatial and temporal scales. The concept of a scale map is introduced to identify components and to define appropriate couplings. For two case studies a high level description in terms of a Complex Automaton will be presented.

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## Abrupt Behaviour Changes in Cellular Automata under Asynchronous Dynamics

Damien Regnault

*Concepts and Methods 4*

We propose an analysis of the relaxation time of the elementary finite cellular automaton 214 (Wolfram coding) under alpha-asynchronous dynamics (i.e. each cell independently updates with probability 0< alpha < 1 at each time step).

While cellular automata have been intensively studied under synchronous dynamics (all cells update at each time step), much less work is available about asynchronous dynamics. In particular, the robustness to asynchronism is a feature which is far from being cleared up.

In a classifying attempt, Fates et al have listed all the double-quiescent elementary cellular automata under fully asynchronous dynamics (one single cell is updated at each time step) according to their relaxation time. This mathematical analysis confirmed the behaviours observed by simulation, truly different from the synchronous dynamics. In a sequel paper, they extended their analysis to this class of automata under alpha-asynchronous dynamics. Moreover they exhibit new phenomena which are impossible under fully asynchronous dynamics, the global behaviour of most of the automata is the same under both alpha-asynchronism and full asynchronism. However unlike the previous paper, they did not complete the whole classification of relaxation times and left some conjectures concerning four automata, among which automaton 214 which seems to have a specific behavior under alpha-synchronous dynamics. Our work partially answers one of those conjectures, and both illustrates the richness of the behaviours involved by asynchronism on cellular automata and the challenge of their mathematical prediction. Far from being a marginal case study, our analysis provides a very relevant example of the way the dynamics is affected by asynchronism and of the mathematical tools which can be used to predict the asymptotic behaviour of such complex models.

Link to the PDF file

## Detecting rich-club ordering in complex networks

Vittoria Colizza, Alessandro Flammini, M. Angeles Serrano, Alessandro Vespignani

*Networks 4*

Uncovering the hidden regularities and organizational principles of networks arising in physical systems ranging from the molecular level to the scale of large communication infrastructures is the key issue for the understanding of their fabric and dynamical properties. The "rich-club" phenomenon refers to the tendency of nodes with high centrality, the dominant elements of the system, to form tightly interconnected communities and it is one of the crucial properties accounting for the formation of dominant communities in both computer and social sciences. Here we provide the analytical expression and the correct null models which allow for a quantitative discussion of the rich-club phenomenon. The presented analysis enables the measurement of the rich-club ordering and its relation with the function and dynamics of networks in examples drawn from the biological, social and technological domains.

Link to the PDF file

## The network structure and evolution of online communication

Pietro Panzarasa, Tore Opsahl

*Networks 4*

We investigate the network structure and evolution of an online community of students at the University of California, Irvine. A connection is established between two students if an online message has been sent between them. We study a variety of statistical properties, including the mean and distribution of the number of connections, typical distances from one student to another, the existence and size of a giant component, and the degree of clustering in the network. We then analyse how these properties evolve as the network expands by the addition of new students and new connections.

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## Preferential attachment in the growth of social networks: the case of Wikipedia

Andrea Capocci, Vito d.p. Servedio, Francesca Colaiori, Luciana S. Buriol, Debora Donato, Stefano Leonardi, Guido Caldarelli

*Networks 4*

We present an analysis of the statistical properties and growth of the free on-line encyclopedia Wikipedia. By describing topics by vertices and hyperlinks between them as edges, we can represent this encyclopedia as a directed graph. The topological properties of this graph are in close analogy with that of the World Wide Web, despite the very different growth mechanism. In particular we measure a scale–invariant distribution of the in– and out–degree and we are able to reproduce these features by means of a simple statistical model. As a major consequence, Wikipedia growth can be described by local rules such as the preferential attachment mechanism, though users can act globally on the network.

Link to the PDF file

## Hierarchies and modules in complex biological systems

Ovidiu Radulescu, Alexander Gorban, Sergei Vakulenko, Andrei Zinovyev

*Biology and Cognition 4*

We review several mathematical methods allowing to identify modules and hierarchies with several levels of complexity in biological systems. These methods are based either on the properties of the input-output characteristic of the modules or on global properties of the dynamics such as the distribution of timescales or the stratification of attractors with variable dimension. We also discuss the consequences of the hierarchical structure on the robustness of biological processes. Stratified attractors lead to Waddington's type canalization effects. Successive application of the many to one mapping relating parameters of different levels in an hierarchy of models (analogue to the renormalization operation from statistical mechanics) leads to concentration and robustness of those properties that are common to many levels of complexity. Exemples such as the response of the transcription factor NF$\kappa$B to signalling, and the segmentation patterns in the development of Drosophila are used as illustrations of the theoretical ideas.

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**Spectral analysis of gene expression profiles using gene networks**

Franck Rapaport, Andrei Zinovyev, Marie Dutreix, Emmanuel Barillot, Jean-Philippe Vert

*Biology and Cognition 4*

Microarrays have become extremely useful for analysing genetic phenomena, but establishing a relation between microarray analysis results (typically a list of genes) and their biological significance is often difficult. Currently, the standard approach is to map a posteriori the results onto gene networks to elucidate the functions perturbed at the level of pathways. However, integrating a priori knowledge of the gene networks could help in the statistical analysis of gene expression data and in their biological interpretation. Here we propose a method to integrate a priori the knowledge of a gene network in the analysis of gene expression data. The approach is based on the spectral decomposition of gene expression profiles with respect to the eigenfunctions of the graph, resulting in an attenuation of the high-frequency components of the expression profiles with respect to the topology of the graph. We show how to derive unsupervised and supervised classification algorithms of expression profiles, resulting in classifiers with biological relevance. We applied the method to the analysis of a set of expression profiles from irradiated and non-irradiated yeast strains. It performed at least as well as the usual classification but provides much more biologically relevant results and allows a direct biological interpretation.

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## Sleep microstructure analysis using Recurrence Plots: evidence for a subcortical oscillator ?

Lorenzo Priano, Fabio Saccomandi, Alessandro Mauro, Caterina Guiot

*Poster Session 2*

Recurrence Plots (RPs) is a graphical tool for assessing time series of dynamical systems by means of colour maps, first described in 1987(1). This method visually displays the temporal windows in which the phase space trajectory visits roughly the same area in the phase space, so disclosing hidden periodicities or oscillations in the time evolution of dynamical systems. Since 'hot' and 'cold' colours are associated to 'near' and 'far' vectors respectively, random and deterministic signals are visually discernable by uniform or structured RPs regions. Several applications of RP to physiological signals, including electroencephalogram (EEG) signals during NREM and REM sleep stages (sleep macrostructure), have been proposed and have been related to other non-linear analysis parameters such as correlation dimension, fractal dimension and entropy (2,3). Up to now, however, a RPs analysis of sleep microstructure has not been performed yet. This include peculiar transient EEG phenomena usually lasting from 0.5 seconds to a few seconds (mainly K complexes (4) and bursts of delta waves, excluding arousals) ad exhibiting a pseudoperiodic pattern during sleep deepening. Our preliminary study analyzes the sleep microstructure in 5 young healthy subjects. Results show that RP method could discriminate: a) attractor-driven oscillation patterns of the transient EEG phenomena during transitions towards deep sleep, visually represented by slow wave sleep (SWS) and expression of EEG synchronization; b) the loss of this attractor-driven oscillations (chaotic oscillations) several seconds before the occurrence of REM phases. Data are consistent with the hypothesis that a subcortical oscillator is activated throughout the deepening of NREM sleep but is suddenly damped before the occurrence of REM phases.

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## On Degree-Based Decentralized Search in Complex Networks

Shi Xiao, Gaoxi Xiao

*Poster Session 2*

Decentralized search aims to find the target node in a large network by using only local information. The applications include peer-to-peer file sharing and web search, etc. In this paper, we simulate the fundamental degree-based decentralized search method [1] where a searching request is forwarded to the largest-degree neighborhood node until the target is identified. The main objective of our study is to evaluate how the performance of the searching method is affected by the amount of local information being available to each node. We find that – The performance of the decentralized search method is sensitive to the amount of local information available. As shown in Fig. 1(a), when each node can tell whether the target is within 3-hop neighborhood of itself, the searching method is highly effective. The performance of the method, however, is seriously downgraded when each node has only 1-hop or 2-hop neighborhood information.

– The problem cannot be easily fixed by having partial 3-hop information. Specifically, we test the case where each node has complete two-hop neighborhood information and meanwhile, can consult with a limited number of largest-degree adjacent nodes on whether the target is within their 2-hop neighborhood. Our observations in Fig. 1(b) show that the performance is not quite satisfactory

Finally, we test whether a route found by the degree-based decentralized method can be easily shortened. We propose a simple refinement algorithm as follows. Starting from the source node (i.e., the node on which the searching request was initialized), we find along the route the first node adjacent to the target node. Denote this node as node m. Then again starting from the source node, we find along the route the first node adjacent to m. Repeat the procedure under the source node itself is the first adjacent node. In our simulations, this simple greedy algorithm steadily reduces the average hop-length of each route to be close to that of the shortest-path routes between all the source-target node pairs. The observations in this study would be helpful for the future developments of more efficient decentralized searching methods.

Fig. 1. Evaluations of the fundamental degree-based decentralized search method [1] with different amounts of local information where (a) each node has 1-, 2- and 3-hop neighborhood information respectively; and (b) each node has partial 3-hop neighborhood information. The simulations are conducted in a 6470-node Internet model [2]. In this paper, we assume that there is only one target node in the network. REFERENCES [1] L. A. Adamic, R. M. Lucose, A. R. Puniyani, and B. A. Huberman, Search in power-law networks, Physical Review E, 64, 2001. [2] http://moat.nlanr.net/Routing/rawdata This work was partly supported by Microsoft Research Asia (MSR-A).

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## Probabilistic inductive classes of graphs

Natasa Kejzar, Vladimir Batagelj

*Poster Session 2*

The idea of mathematical induction is well known for some centuries. It can be used to prove for a statement to hold or to define a certain class of objects. To define an *inductive class* of objects [2] we have to give (1) a class of *initial* objects, and (2) a list of *generating rules* that transform object(s) already in the class into an object also in the class. The inductive class consists exactly of the objects that can be obtained from the initial objects in finite number of steps using the generating rules. Eberhard [3] was the first one to define classes of graphs using an inductive definition. In graph theory the inductive definitions for several classes of graphs were proposed.

In our work we think of a graph as a "skeleton" of the network. With inductive definitions of graphs one can describe the evolution of a graph in some prescribed manners. The transitions (transformations by rules) can be viewed as implicit time steps. We extend the standard notion of inductive classes of graphs (ICGs) with probability. We consider two main possibilities: (1) adding probability to a rule selection, and (2) using probability to determine the part of a graph where the rule is applied.

We will describe the restrictions and the assumptions that have to be met before applying probability to a certain ICG. Further on we will look at some specific graph/network properties when applying certain probabilistic ICG, such as the change of the number of vertices and edges through time, the expected vertex degrees, etc. We will show some general results for ICGs that meet the assumptions and we will try to apply these results to some existent network models (i.e. preferential attachment model [1], feedback network model [4]).

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## Control of a Chaotic Autocatalytic Reaction System

Ankur Mukherjee, S.K. Scott, Dominic Searson, Mark Willis, Allen Wright

*Poster Session 2*

CONTROL OF A CHAOTIC AUTOCATALYTIC REACTION SYSTEM

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Control of product selectivity (the ratio of the quantity of desired product to the total quantity of products) is an important consideration for chemical processing in multi-product environments, specially when desired selectivity depends intrinsically on immediate market requirements. The aim of this work is to investigate whether product selectivity may be improved by using feedback control of the product concentration for a chaotic autocatalytic reaction in a continuous stirred tank reactor (CSTR). In this system, two products are produced by a reaction scheme that exhibits non-linear feedback characteristics and properties of multi-stability, oscillations and chaos. Bifurcation studies on this system have been reported by (Abasaeed, 2000) and (Davies and Scott, 2001) where it was shown that chaotic behaviour is obtained over a range of reactor residence time values.

(Davies and Scott, 2001) used simple proportional feedback (SPF) algorithm proposed by (Petrov et al., 1992) to control the product concentration in the chaotic region of the CSTR through manipulation of the residence time of the reactor. To implement this algorithm, an observable system output is measured experimentally within the chaotic region and standard system identification techniques applied to quantify its behaviour and determine the control law.

The principal objective of this research is to compare product selectivity results obtained using SPF algorithm with a proportional integral (PI) control algorithm, implemented using the Ott, Greborgi Yorke (OGY) scheme (Ott et al., 1990). A PI control law has many potential advantages over the SPF algorithm; it is well known that integral action eliminates steady state errors and errors caused by noisy system output measurements and external disturbances.

Firstly, the performances of the two algorithms are compared when the output measurements are corrupted by process noise. Normally distributed Gaussian noise of zero mean and a variance of 1% of the amplitude of oscillations of the clean (non-noisy) period 1 limit cycle was added to the sampled concentration measurements. It is shown that periodic oscillations are only achieved with the PI controller. When using the SPF controller, the noise on the concentration measurements pushes the trajectory away from the stable manifold of the fixed point resulting in chaotic system behaviour. Secondly, the disturbance rejection properties of the two controllers are investigated. Additive reactant inlet feed flow rate disturbances are applied to the system and it is demonstrated that the PI controller exhibits superior disturbance rejection properties as to that of the SPF algorithm.

Finally, it is shown that for this system, product selectivity is identical in chaotic (open loop) or in periodic (closed loop) operation. However, effective closed loop control using the PI algorithm enables selective collection of the product stream e.g. by using a two-way valve switching at fixed time intervals. This allows optimisation of the control strategy through specification of the periodic nature (period-1, period-2 etc) of the oscillations, which maximises a product selectivity/quantity trade-off.

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## Distance and height statistics in growing networks

Renaud Lambiotte, Paul Krapivsky

*Poster Session 2*

The importance of the localization of a node in a network for its dynamics is stressed. First, citation networks are empirically studied, and it is show that the likehood for two nodes to interact strongly depends on the distance between these nodes in the network. Then, we introduce a model for growing networks with copying mechanisms, and analytically derive different structural properties, i.e. number of links, number of triangles, distance statistics... In parallel, the minimal heights statistics of different models of random trees are investigated, where entering nodes have more than one outgoing link. We show that the cumulative distribution of heights approaches a traveling wave form, whose velocity can be determined by maximum velocity selection. The approach is generalized to models with preferential attachment, and leads to theoretical predictions for the mean height grow. One of the proposed models exhibits the formation of condensates.

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## Statistical analysis of Polish public transport networks

Julian Sienkiewicz, Janusz A. Holyst

*Poster Session 2*

We have analyzed Polish public transport networks of sizes ranging form N = 152 to N = 2881. To have a better insight into the character of those systems we use two different types of network topologies (spaces). Depending on the assumed definition of network topology the degree distribution can either follow a power law or can be described using an exponential function. Distributions of path lengths in all considered networks are given by asymmetric, unimodal functions. We also examine the dependence of inter-node distances on the product of their degrees. Clustering, assortativity coefficient and betweenness centrality are studied. All considered networks exhibit small world behavior and are hierarchically organized. We have observed a transition between disassortative small networks N $<$ 500 and assortative large networks N $>$ 500.

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## Ising model on two connected Barabasi-Albert networks

Krzysztof Suchecki, Janusz Holyst

*Poster Session 2*

We investigate analytically the behavior of Ising model on two connected Barabasi-Albert networks. Depending on relative ordering of both networks there are two possible phases corresponding to parallel or antiparallel alingment of spins in both networks. A difference between critical temperatures of both phases disappears in the limit of vanishing inter-network coupling for identical networks. The analytic predictions are confirmed by numerical simulations.

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## Network Discovery in Random Graphs

Thomas Erlebach, Alexander Hall, Matus Mihalak

*Poster Session 2*

We study the number of queries at randomly selected nodes that are needed for approximate network discovery. For the approximate discovery of Erdös-Renyi random graphs $G_{n,p}$ in the layered graph query model, we show that a constant number of queries is sufficient if $p$ is a constant, but $\Omega(n^\alpha)$ queries are needed if $p = n^{\epsilon-1}$ for arbitrarily small $\epsilon > 0$, where $\alpha > 0$ is a constant depending only on $\epsilon$.

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## Effect Of Forcing Term On A Three Dimensional Artificial Neural Network

Pritha Das, Atin Das

*Poster Session 2*

In our earlier work (IJBC, 2002b) the dynamics of an artificial neural network (ANN) consisting of three artificial neurons connected in all possible way was studied. The system, given by three differential equations, passes from stable to periodic and then to chaotic regimes and returns to stationary regime with change in parameter values of synaptic weights and decay rates. In this work, we propose to include a forcing (oscillatory) term in the network to incorporate the fact that brain is often subject to external perturbation. We will compare the ANN with and without the forcing term by drawing phase portraits, bifurcation diagram and by results of mathematical and numerical analysis. The results are quite interesting as it is found that the stationary states (periodic) of the network are driven to chaotic regimes by the forcing term and vice-versa. Apart from importance of parameters discussed in this paper, we conclude that introduction of forcing term contributes in controlling dynamics of the system; particularly chaos. This may have far-reaching effect in restoring disordered neural system and related diseases.

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## A Scale-Free Network Growth Model Based On Local Operators

Fatih Ogun, Haluk Bingol

*Poster Session 2*

In this paper, a new model for scale-free networks is proposed. Instead of common models, which use the entire network topology during the growth process, the growth in the new model is based on the local topology only. The model uses operators to attach new nodes to the network based only on the local topological information. The model has the capability to produce different K values. The dynamic range of K values is obtained by changing the selection probabilities of the local operators.

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## A model for Social Networks

Riitta Toivonen, Jukka-Pekka Onnela, Jari Saramäki, Jarkki Hyvänen, Janos Kertesz, Kimmo Kaski

*Poster Session 2*

Social networks are organized into communities with dense internal connections. In addition, these networks have been observed to be assortative, i.e. highly connected vertices tend to connect to other highly connected vertices, and have high clustering coefficients, small average path lengths, and degree distributions where hubs have relatively low degree. We have designed a model for social networks [1] which reproduces these characteristics. In this growing, undirected network, the community structure arises from random attachment to initial contacts and implicit preferential attachment to their neighbors. Development of edge weights can also be incorporated with the neighborhood connections, generating weighted community networks where edges within communities tend to have higher weight than the edges connecting communities. The resulting networks can be used as substrates for studies of sociodynamic phenomena. We also discuss the effect of community structure on dynamic processes taking place on the networks.

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## Evolving Artificial Cell Signaling Networks

James Decraene, George Mitchell, Ciaran Kelly, Barry McMullin

*Poster Session 2*

Cell Signaling networks (CSNs) are bio-chemical systems of interacting molecules in cells. Typically, these systems take as inputs chemical signals generated within the cell or communicated from outside. These trigger a cascade of chemical reactions that result in changes of the state of the cell and (or) generate some chemical output, such as prokaryotic chemotaxis or coordination of cellular division.

Realising (and evolving) Artificial Cell Signaling Networks (ACSNs) may provide new ways to design computer systems for a variety of application areas. We are investigating the use of ACSNs to implement computation, signal processing and (or) control functionality. We review some of the the research issues which this raises: – As a "computational" device, a CSN is most naturally compared to a traditional analog computer. There may be applications where a molecular level analog computer, in the form of a CSN, may have distinct advantages. CSNs may offer capabilities of high speed and small size that cannot be realised with solid state electronic technology. More critically, where it is required to interface computation with chemical interaction, a CSN may bypass difficult stages of signal transduction that would otherwise be required. This could have direct application in so-called "smart drugs" and other bio-medical interventions. – Evolutionary Algorithms are non-deterministic search and ptimisation algorithms inspired by the principles of neo-Darwinism. Such techniques are relevant to the study of ACSNs because: the complex, and unpredictable, interactions between different components of CSNs, make it very difficult to design them "by hand" to meet specific performance objectives. However, natural evolution shows that in suitable circumstances, effective CSNs functionality can be achieved through evolutionary processes. – "Crosstalk" phenomena happen when signals from different pathways become mixed together. This arises very naturally in CSNs due to the fact that the molecules from all pathways may share the same physical reaction space. In traditional communications and signal processing engineering, crosstalk is regarded as a defect that therefore has the potential to cause system malfunction. This can also clearly be the case of crosstalk in CSNs. However, in the specific case of CSN's, crosstalk also has additional potential functionality, which may actually be constructive. – It is also argued that key properties in biochemical networks are to be robust, this is so as to ensure their correct functioning. Such properties are highly desirable in dynamic engineered systems when subjected to internal and external uncertainty and perturbation.

Acknowledgements: This work was supported by the European Community as part of the FP6 ESIGNET Project (12789).

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## Do wandering albatrosses really perform Levy flights when foragin?

Andrew Edwards, Nick Watkins, Mervyn Freeman, Richard Phillips

*Poster Session 2*

We examine the hypothesis that wandering albatrosses (Diomedea exulans) undergo Levy flights when roaming the skies in search of oceanic food sources. Levy flights are random walks whose step lengths are taken from a probability distribution that has infinite variance. The Levy flight consequently has no typical scale, and this has been interpreted as being an efficient way of searching for food on the ocean surface. We first re-analyse the original data that were used to infer Levy flights. These data come from wet/dry loggers that record the time periods for which the birds were airborne or on the ocean surface. We cast doubt as to whether these data are sufficient to conclude Levy flight behaviour. This prompts us to analyse recent data from birds fitted concurrently with much higher resolution wet/dry loggers and with GPS loggers or satellite transmitters. We use the state-space modelling approach of Jonsen et al. (2003, Ecology, 84:3055) to account for observation error in the data and to estimate the true locations of the birds at regular time intervals. The new data allow us to compare conclusions based solely on wet/dry loggers with those from true spatially defined data.

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## Simulation and Measurement of a Two-stage Complex Network Model

Hongwei Luo, Kathy Horadam

*Poster Session 2*

Real-world complex networks such the Internet, social networks and biological networks have increasingly attracted the interest of researchers from many areas. Accurate modelling of the statistical regularities of these large-scale networks is critical to understand their global evolving structures and local dynamical patterns. Two main families of models have been widely studied: those based on the Erdös and Renyi random graph model and those on the Barabasi-Albert scale-free model. In this paper we develop a new model: the Hybrid model, which incorporates two stages of growth and simulates the transition between a randomly connected network and a scale-free network. We measure the Hybrid model by extensive numerical simulations, focusing on its degree distribution, characteristic path length and clustering coefficient.

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## On Protocell "Computation"

Ciaran Kelly, Barry McMullin, Darragh O'Brien

*Poster Session 2*

The EU FP6 Integrated Project PACE ("Programmable Artificial Cell Evolution") is investigating the creation, de novo, of chemical "protocells". These will be minimal "wetware" chemical systems integrating molecular information carriers, primitive energy conversion (metabolism) and containment (membrane). Ultimately they should be capable of autonomous reproduction, and be "programmable" to realise specific desired function. A key objective of PACE is to explore the application of such protocell technology to build novel nanoscale computational devices. In principle, such computation might be realised either at the level of an individual protocell or at the level of self-assembling, multi-cellular, aggregates. In the case of the individual protocell level, a form of "molecular computation" may be possible in the manner of "cell signalling networks" in modern cells. This might be particularly appropriate where a protocell is deployed to interface directly with molecular systems, such as in "smart drug" applications. "Programming" of molecular computation functionality might be realised by evolutionary techniques, i.e., applying selection to polulations of (reproducing) protocells. Reflexive string rewriting systems may provide an appropriate formal model of molecular computation. The behaviour of minimal reflexive string rewriting systems, incorporated in reproducing containers (protocells), is being explored in simulation. This is a basis for possible design of minimal protocell "computers".

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## Analysis of diameter distributions in tree-ring growth

Maurizia Gandini, Paola Nola, Guido Caldarelli

*Poster Session 2*

In this paper we present a study of the statistical properties of the size distribution of tree diameters. We analyse deviations from the basic hypothesis of multiplicative growth. The results seem to suggest a more complicated structure for the environment fluctuations. We present a model of growth inspired to self-similar phenomena in order to fit the data.

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## Structure and dynamics of mycelial networks

Dan Bebber, Mark Fricker, Peter Darrah, Juliet Hynes, Lynne Boddy

*Poster Session 2*

The fungal mycelium is a transport network that grows and competes in a complex and changing environment. The architecture of the network continuously adapts to local nutritional or environmental cues, damage or predation, through growth, branching, fusion and regression. We investigated whether mycelial network architecture is optimized for resource capture, exploration, translocation, or defence.

We used image analysis techniques to digitize the mycelia of cord-forming saprotrophic fungi grown over soil microcosms from wood block inocula, and to assign transport capacities and physical resiliences to the cords. Responses of the network to resource acquisition were tested via the addition of further wood blocks. Growth of the network was characterized by spatially dense production of links and nodes, followed by selective removal of some links and reinforcement of others. Network evolution can therefore be likened to a Darwinian process of over-production followed by selection. The effect of this was to increase network transport efficiency, in terms of shortest paths measures versus the material cost of the network. The networks responded to the acquisition of resources by reinforcing connections to new wood blocks, relative to nodes at similar Euclidean distances from the original inoculum. Network resilience to attack was modelled via the effect of link breakage on global efficiency. Breakage with probability proportional to link length/weight was compared with a null model of random breakage, showing that the fungus maintained a greater efficiency than a randomly-weighted network with the same topology, for a giving level of link breakage.

Our analyses have revealed that the fungal mycelium to be self-organised dynamic network with desirable properties of transport efficiency and resilience. Further investigation of variation in mycelial structure among fungal species may reveal trade-offs between properties such as exploration and resilience, and suggest adaptations to different ecological niches. Network theory provides a new and exciting way of understanding fungal biology and ecology, while the variability and experimental tractability of fungal networks makes them ideal subjects in the study of complex systems.

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## Analysis of IRC (Internet Relay Chat) Networks

Murat Sensoy, Haluk Bingol

*Poster Session 2*

In this study, properties of Internet Relay Chat (IRC) networks are analyzed in terms of complex network characteristics. Two different IRC communities are studied; freenode and unfirc. IRC channels in freenode are mostly dedicated to chatting, whereas IRC channels in unfirc are mostly dedicated to file sharing and warez. In this study, it is shown that those IRC networks have small-world property. Furthermore, degree distribution of freenode's IRC user network and channel network is shown to follow power-law degree distribution. Even though degree distribution of unfirc's IRC channel network follows power-law degree distribution, IRC user network of unfirc does not show power-law degree distribution, because of the nature of unfirc IRC community. IRC user networks can be regarded as a sort of social network. It is shown in the literature that social networks have small-world property and power-law degree distribution. The findings in this study confirm that IRC networks show complex network properties similar to the social networks.

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## Inferring Connectivity from Dynamics on Networks

Max Little, Patrick McSharry

*Poster Session 2*

This paper considers the common problem of inferring the connectivity of a dynamical system operating on a network of nodes, with time series values of the dynamical state variables available from each node. The nodes are connected to their own past state values and to the past state values of any other node. Such a network might represent, for example, a stock exchange of interconnected companies whose stock price influences and is influenced by eachother, neuronal units in a network whose firing rate is interdependent, or a viral infection that spreads through populations in cities connected by transport routes. We show that time-delayed cross-covariance methods, taking each time series in isolation, cannot be used to distinguish node self-causation from causal influence by a node with self-causation, and suggest that all cross-covariances must be considered simultaneously in, for example, a maximum likelihood model framework. Towards that aim, we consider linear and nonlinear dynamics and vector (quasi)-linear prediction. Each node is assumed to have an additive, Gaussian, i.i.d. input term, representing the uncertainty in the dynamics. Then the maximum likelihood solution to the parametric identification problem, where the parameters represent the connectivity of the network, is equivalent to least-squares optimisation, which can be solved analytically arriving at a time-delayed, cross-correlation matrix problem. Inversion of this matrix identifies the network connectivity parameters. We demonstrate the effectiveness of this vector prediction method on a simulated example of the spread of an infection through an interconnected population.

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## Maximum entropy method for the reconstruction of networks

Yohann Grondin, Derek Raine

*Poster Session 2*

A wide variety of real systems can be represented by networks where the nodes are the agents of those systems and the links are the interactions between the agents. Inferring the architecture of such networks is an important step in understanding the formation, the dynamics and the properties of those systems. In the case of genetic networks, numerous methods are used to infer the architecture from mRNA abundances such as Bayesian networks, clustering algorithms or mutual information. All these methods are hindered by imperfect data. Here we show that the maximum entropy method, which has proven elsewhere powerful in reconstructing images composed of millions of pixels from imperfect data, could be used to infer the architecture of genetic networks. We show here how this is possible by reconstructing two networks of different architecture from simulated data.

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## Network Disconnectedness: a Novel Robustness Metric for Infrastructure Networks

Alex K. S. Ng, Janet Efstathiou

*Poster Session 2*

Infrastructure networks exist everywhere. This paper proposes that the topology of an infrastructure network is fixed while the flow of an infrastructure network is stationary. This paper reviews that the pre-existing network metrics cannot measure the fragmentation of the infrastructure network so that they are not the best candidate to analyze infrastructure network. This paper proposes a novel network metric, namely network disconnectedness, to measure the connectivity of the network. This paper also develops a methodology, namely scenario-based analysis, to measure the network. Comparing with the existing approach on the study of network robustness, the proposed methodology requires less computation requirement. Case study of Newcastle Metro network showed that both the scenario-based analysis and the network disconnectedness are plausible to measure the impact of the network disruption and hence the network robustness. This metric is applicable to other infrastructure network and further studies will be done to prove the generality of the proposed metric and method to other networks.

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## Towards a unified model of protocell evolution

Anders Eriksson, Olof Görnerup, Martin Nilsson Jacobi, Steen Rasmussen

*Poster Session 2*

Without a central control of genome replication, primitive pre-biotic organisms - self-assembling container aggregates - require coordinated replication of hosted competing template molecules in order to grow and reproduce. In previous work on aggregate dynamics, we have demonstrated that effective evolution on the container level is enabled under certain conditions. However, the model considered bypasses the issue of synchronisation of lipid production and template molecule replication by using relative concentrations. Other of our studies indeed show that there is such synchronisation, although in a purely kinetic context that lacks elements of evolution. In this work we initialise an effort to merge these two results and study evolutionary dynamics of container aggregates and template molecules, in a setting that borrows from the quasi-species framework, and where absolute concentrations are regarded. The outcome of this work is expected to be a significant step towards an understanding of how the molecular dynamics in the protocell metabolism influences the structure of the effective fitness landscape of the template molecules.

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## Study of language evolution and population dynamics of two interacting species on scale free and random networks

Alkiviadis Kalampokis, Kosmas Kosmidis, Panos Argyrakis

*Poster Session 2*

We use Monte Carlo simulations and assumptions from evolutionary game theory in order to study the population dynamics and the evolution of the vocabulary known to the members of a system consisting of two interacting species which initially speak two different languages. The species are characterised by their identity, their vocabulary and their fitness which corresponds to their reproduction capability. Simulations take place in different underlying space configurations. We use scale free networks with $\gamma$ equal to 2, 2.5 and 3, and also random networks with connectivity of 0.1% and 0.2%. The system is followed through time monitoring the number of words known to each member and also the number of individuals belonging to each species. We study the values of initial parameters that lead to the coexistence of both species or to the domination of one, the probability of pattern formation or segregation in the network and the evolution of the vocabulary known by the species. Finally, we compare our results with those of simulations performed on square lattices.

Specific differences are observed in the scale free networks, where the existence of hubs plays an important role, both for the number of words known to each individual, but also for the population dynamics of the model. More specifically hubs seem to add another fitness generating mechanism, and may have a profound and unexpected impact on the evolutionary dynamics of the system.

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## Structural stability, morphogenesis and epigenetic landscape

Sara Franceschelli

*Poster Session 2*

Structural stability, morphogenesis and epigenetic landscape
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The paper "Une theorie dynamique de la morphgenese", written by Rene Thom in 1966 and appeared in 1967 in Towards a theoretical Biology I, published by Conrad Hal Waddington, can be considered as the princeps paper of the catastrophe theory. In this paper Thom declares that embryology and, in particular, Waddington's notions of epigenetic landscape and chreod have been one of his sources in conceiving catastrophe theory. Moreover, Thom tries and shows that embryology, and in particular the problem of cellular differentiation as it was introduced by Max Delbruck in 1949, can be a field of application of Thom's catastrophe theory, i.e. a mathematical theory of morphogenesis, based on the study of the property of structural stability by topology and differential analysis. In the collection of Rene Thom's works Modeles mathematiques de la Morphogenese, published in 1980, the French version of this paper is augmented by a correspondence between Conrad Hal Waddington and Rene Thom (five letters, from the 25th of January till the 23th of February 1967). In my commentary from this correspondence and from other unpublished letters, I will consider two Waddington's criticisms to the first version of Thom's paper and the debate between the two scientists that followed these Waddington's criticisms. The first commentary concerns the paternity of the notion of cellular differentiation. The second criticism concerns the use of alternative steady states instead of time extended chreods. A first interpretation of this lack of agreement between the two scientists can be based on the taking into account of their cultural differences. To use the expression introduced by Evelyn Fox Keller in "Making Sense of Life", they do not share the same epistemological culture and they do not have the same explanatory needs. Rene Thom himself introduces this correspondence as an example of the difficulties in communication between a mathematician and a biologist because of the differences in their exigencies of mathematical rigour. However, following some Waddington's remarks on the peculiarity of the variable "time" in biology, I suggest another interpretation of their disagreement. This second interpretation is based on the Waddington's unsatisfied need of representing, thanks to the metaphor of epigenetic landscape, different time scales in the process of the organism development.

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## The effect of network mixing patterns on contact tracing efficacy

Istvan Kiss, Rowland Kao

*Poster Session 2*

"The effect of network mixing patterns on contact tracing efficacy"

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In many networks nodes tend to be connected to other nodes that are like (or unlike) them in some way (Newman 2002). The mixing properties of networks are known to have marked influence on network resilience to random or targeted removal (e.g. highest degree nodes removed first) of nodes (Newman 2002, 2003). In scale-free networks, Boguñá et al. (2003) have shown that, independent of the mixing pattern, an infinite variance of the degree distribution of the nodes can sustain an epidemic outbreak on the network, even for infinitesimally small transmission rates.

Throughout an epidemic contact tracing aims to identify and isolate individuals that have been in contact with infectious individuals. The efficacy of contact tracing has been shown to depend on the levels of clustering in the network (Eames & Keeling (2002), Kiss et al. (2005)) as well as on the underlying degree distribution of the nodes in the network (Kiss et al. (2006)). However, these studies did not explicitly consider the effect of mixing patterns in networks. Building on the method used by Newman (2003), networks with assortative and disassortative mixing patterns are generated. Using individual-based stochastic simulations of an SITR (susceptible, infected and infectious, traced and removed) epidemic model on the generated networks, the effect of the mixing pattern on contact tracing efficacy is demonstrated.

Depending on the mixing properties of the network, the removal of nodes impacts differently on epidemic control. In the case of large epidemics, contact tracing performs better on assortative networks, even though these are more resilient to node removal when compared to disassortative networks. This is a direct consequence of the early tracing of highly connected nodes on assortative networks. For smaller epidemics, however, on assortative networks, the control of disease via contact tracing is negated by the fast epidemic spread and has a limited effect.

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## Epidemiological Theory, Social Networks and the Basic Reproduction Ratio

Rowland Kao, Istvan Kiss

*Poster Session 2*

Recent developments in the theory of social networks have led to the considerable interest in its application to disease transmission problems. Many of these ideas can be linked to concepts in standard epidemiological theory. In particular the basic reproduction ratio or R0 is the central threshold quantity of modern epidemiological theory and can be interpreted as a network percolation threshold. Despite its central role, there remains considerable confusion over what R0 is in the network context. Here, we discuss the definition of R0 in a contact matrix setting, and illustrate how some of these problems can be resolved.

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## Defense Strategies against Network Worms: Formulation, Evaluation, and Comparison

Zoran Nikoloski

*Networks 5*

Devising control strategies for worms that employ random and local propagation strategies is the first step towards a comprehensive network-security solution. While deployment of distributed control strategies imposes many practical challenges, we demonstrate here that the analysis of such strategies can be carried by means of epidemiological models and their simulation on real-world and synthetically generated networks. We design five novel control strategies, and evaluate their performance with respect to the final fraction of removed nodes. We derive rigorous results about the final fraction of removed (immunized or quarantined) nodes and estimate its effects on the functionality of the network. Moreover, we arrive at a sufficient condition for the success of a near-optimal control strategy with respect to the losses to the population. In addition, we present a classification of static and dynamic control strategies.

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## Computing Clustering Coefficients in Data Streams

Luciana Salete Buriol, Gereon Frahling, Stefano Leonardi, Alberto Marchetti-Spaccamela, Christian Sohler

*Networks 5*

We present random sampling algorithms that with probability at least $-\delta$ compute a $(1 \pm \epsilon)$-approximation of the clustering coefficient and of the number of bipartite cliques in a graph given as a stream of edges. Our algorithm for estimating the clustering coefficient uses space that is inversely related to the clustering coefficient of the network itself. Our algorithm for computing the number $K_{3,3}$ of bipartite cliques uses space that is proportional to the ration between the number of $K_{1,3}$ and $K_{3,3}$ in the graph.

Since the space complexity depends only on the structure of the input graph and not on the number of nodes, our algorithms scale very well with increasing graph size and so they provide a basic tool to analyze the structure of dense clusters in large graphs. They have many applications to the discovery of Web communities, the analysis of the structure of large social networks and to the discovery of frequent patterns in large graphs.

We implemented both algorithms and evaluated their performance on networks from different application domains. The sizes of the considered input graphs varied from about 8,000 nodes and 40,000 edges about 135 million nodes and more than 1 billion edges. For both algorithms we run experiments with a sample set size varying from 100,000 to 1,000,000 to evaluate running time and approximation guarantee. Both algorithms appear to be time efficient for these sample sizes.

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## Statistics of cycles in large networks

Konstantin Klemm, Peter F. Stadler

*Networks 5*

The occurrence of self-avoiding closed paths (cycles) in networks is studied under varying rules of wiring. As a main result, we find that the dependence between network size $N$ and typical cycle length is algebraic, $\langle h \rangle \propto N^{\alpha}$, with distinct values of $\alpha$ for different wiring rules. The Barabasi-Albert model has $\alpha = 1$, while various preferential and non-preferential attachment rules yield $\alpha < 1$. Computation of the statistics of cycles at arbitrary length is made possible by the introduction of an efficient sampling algorithm.

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## Self-Organized Criticality and Co-evolution of Network Structure and Dynamics

Piotr Fronczak, Agata Fronczak, Janusz Holyst

*Networks 5*

We investigate, by numerical simulations, how the avalanche dynamics of the Bak-Tang-Wiesenfeld (BTW) sandpile model can induce emergence of scale-free (SF) networks and how this emerging structure affects dynamics of the system.

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## Cooperation: popularity or cliquishness ?

David Chavalarias

*Networks 5*

We propose an analytical and computational insight about the role of endogenous networks in emergence and sustainability of cooperation and exhibits an alternative to the choice and refusal mechanism that is often proposed to explain cooperation.

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## Modelling the future of cities

Denise Pumain, Anne Bretagnolle, Benoit Glisse
*Social and Economic Systems 5*

As urban systems are complex systems, their further evolution cannot be merely a linear projection of the most recent trends, nor can it be taken for granted that the future will replicate what happened in the past. Nor can we reliably predict the evolution of European cities by looking at those in North America. The 21st century opens a new stage in the history of system of cities: the urban transition which in two hundred years completely transformed our way of inhabiting the planet, from a scattered and rather homogeneous rural settlement system into a very concentrated, hierarchical and heterogeneous urban system, is now over. What future can be expected for cities in developed countries, where there is no longer migration from rural areas or local demographic growth for sustaining the cities development? Will population and activities continue to concentrate in the largest metropolises? Are the small and medium size towns condemned to decline and disappear, as did so many villages in the past?

We have developed a new theory, at a conceptual level, which can not yet be entirely formalised in a mathematical way but which can be experimented with agent based simulation models. Based on historical observations, we have built a general computer model ("SIMPOP2", see Bura et al., 1996) to help explore the fundamental process of urban self-organization and growth, and to derive predictions about the future of urban systems. In our model, we represent urban systems as subsets of cities involved in a multiplicity of exchanges, through the different networks that use them for a variety of economic, political and social functions of operation, management or control. For instance, a city supplies services to its surrounding region and produces manufactured goods which are sold to other cities in a broader network. The city innovates by creating a new function of by deciding to adopt one by imitation. The model suggests that the spontaneous appearance of new innovation, which can be a new technology (the tramway in 19th century, the automobile in 20th century) as well as a new social behaviour (the invention of tourism at the end of 19th century, its democratisation during the second half of 20th) have a particularly strong influence on how cities grow and evolve. The model will be calibrated on urban systems from different countries in the world. Results of simulation will help to understand how the urban hierarchy is linked to the hierarchical diffusion of innovations, as well as to the improvement of transportation technologies, and to make scenarios configuring the future cities hierarchies and networks according to the growing impulses of globalisation and European integration.

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## Binding Social and Semantic Networks

Camille Roth
*Social and Economic Systems 5*

Social and semantic networks have mostly been studied separately. We provide a theoretical framework to bind these two networks, suggesting that the analysis of knowledge community structure and underlying agent-based dynamics requires to take into account the reciprocal influence of both networks. We show how to characterize meaningful cultural communities using Galois lattices and briefly explain how models could render the coevolution of socio-semantic networks, building upon a generalized understanding of preferential attachment. This should enable the comprehension of stylized facts proper to knowledge networks, in particular how the social and semantic structures affect each other.

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## Semiotic Dynamics in Online Social Communities

Ciro Cattuto, Vittorio Loreto, Luciano Pietronero
*Social and Economic Systems 5*

A distributed classification paradigm known as collaborative tagging has been successfully deployed in large-scale web applications designed to organize and share diverse online resources. Communities of web users categorize resources by associating metadata with them, in the form of freely chosen text labels, or tags. Here we regard tags as basic dynamical entities and study the semiotic dynamics underlying collaborative tagging. We collect data from a popular system, focusing on tagging data associated with a given resource, and report our experimental findings. Remarkably, we observe a universal power-law behavior for the dynamics of tag accumulation. On studying the frequency distribution of tags, we find a generalized Zipf's behavior and quantitatively describe the observed distributions in terms of a previously introduced Yule-Simon process with heavy-tailed memory.

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## Conceptual Representations: What do they have to say about the Density Classification Task by Cellular Automata?

Manuel Marques, Ruli Manurung, Helen Pain
*Concepts and Methods 5*

In this paper, Aitana, a Developmental Cognitive Artifact developed by Marques (2006), is used to produce "conceptual" representations of the best known Cellular Automata (CA) rules that perform the Density Classification Task (DCT) (see e.g. Packard, 1984, 1988; Mitchell et al., 1993). The resulting redescriptions are then analysed from the viewpoint of their similarity, in terms of their cell state-update functions. We show that these new conceptual representations can reveal knowledge about these rules that is not accessible on the implicit level (CA in their look-up table form). We also show how the resulting abstractions can be considered suitable for the formation of "Conceptual Spaces", wherein rules that perform similar computations are positioned in close proximity.

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## Computational Complexity of Some Enumeration Problems About Uniformly Sparse Boolean Network Automata

Predrag Tosic

*Concepts and Methods 5*

We study the computational complexity of counting the fixed point configurations (FPs), the predecessor configurations and the ancestor configurations in certain classes of network automata viewed as discrete dynamical systems. Some early results of this investigation are presented in our prior work [ECCC05-1, ECCC05-2]. In particular, we prove in [ECCC05-2] that both exact and approximate counting of FPs in the two closely related classes of Boolean network automata, called Sequential and Synchronous Dynamical Systems (SDSs and SyDSs, respectively), are computationally intractable problems when each node is required to update according to a monotone Boolean function. In the present paper, we further strengthen those results by showing that the intractability of exact enumeration of FPs of a monotone Boolean SDS or SyDS still holds even when (i) the monotone update rules are restricted to linear threshold functions, and (ii) the underlying graph is uniformly sparse. By uniform sparseness we mean that every node in the graph has its degree bounded by $c = O(1)$ for a small value of constant c. In particular, we prove that exactly enumerating FPs in such SDSs and SyDSs remains NP-complete even when no node degree exceeds $c = 3$. Among other consequences, we show that this result also implies intractability of determining the exact memory capacity of discrete Hopfield networks with uniformly sparse and nonnegative integer weight matrices. We also show similar intractability results for the problems of enumerating (i) predecessors and (ii) all ancestors of an arbitrary SDS, SyDS or Hopfield network configuration.

Keywords: Cellular and network automata, sequential and synchronous dynamical systems, discrete Hopfield networks, fixed point configurations, predecessor configurations, computational complexity, NP-completeness

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## How to Cluster Evolving Graphs

Marco Gaertler, Robert Görke, Dorothea Wagner, Silke Wagner

*Concepts and Methods 5*

Clustering is a frequently used tool in the analysis and evaluation of large and complex networks. Most such networks result from or model dynamic processes, thus clustering techniques need to be adapted. We provide a model for clustering graphs that are subject to changes. More precisely, we address the update problem, i.e., maintaining the clustering while nodes and edges can be inserted and deleted, as well as the issue of clustering graph sequences. Furthermore, we give some illustrating examples and point out several pitfalls. This work is a first step towards a sound foundation for clustering on evolving graphs.

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## Generating Significant Graph Clusterings

Daniel Delling, Marco Gaertler, Dorothea Wagner

*Concepts and Methods 5*

Many applications such as experimental evaluations of clustering algorithms require the existence of a significant reference clustering. This task is dual to finding significant clusterings of a given graph. We present several generators for pre–clustered graphs based on perturbation and geometry. In an experimental evaluation we confirm the applicability of our generators. Furthermore, the presented results lead to a better understanding of the correlation between the degree of perturbation and significance.

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## Multi-assets artificial stock market with heterogeneous interacting agents

Silvano Cincotti, Linda Ponta, Stefano Pastore

*Social and Economic Systems 6*

In this paper, an information-based multi-assets artificial stock market is presented. The market is populated by heterogeneous agents that are seen as nodes of sparsely connected graphs. The market is characterized by different types of stocks and agents trade risky assets in exchange for cash. Beside the amount of cash and of stocks owned, each agent is characterized by sentiments. Moreover, agents share their sentiments by means of interactions that are determined by graphs. A central market maker (clearing house mechanism) determines the price processes for each stock at the intersection of the demand and the supply curves. Within this framework, stock price processes exhibit volatility clustering and fat-tailed distribution of returns. Moreover, the cross-correlations between returns of different stocks is studied using methods of random matrix theory. The probability distribution of eigenvalues of the cross-correlation matrix shows the presence of outliers, similar to those recently observed on real data for business sectors. These results suggest a significant structural influence on statistical properties of multi-assets stock market.

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## The Geography of Scientific Productivity: Scaling in U.S. Computer Science

Rui Carvalho, Michael Batty

*Social and Economic Systems 6*

Here we extract the geographical addresses of authors in the Citeseer database of computer science papers. We show that the productivity of research centres in the United States follows a power-law regime, apart from the most productive centres for which we do not have enough data to reach definite conclusions. To investigate the spatial distribution of computer science research centres in the United States, we compute the two-point correlation function of the spatial point process and show that the observed power-laws do not disappear even when we change the physical representation from geographical space to cartogram space. Our work suggests that the effect of physical location poses a challenge to ongoing efforts to develop realistic models of scientific productivity. We propose that the introduction of a fine scale geography may lead to more sophisticated indicators of scientific output.

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## Modelling an Innovative Industry with Agent-based Simulation

Klaus Wersching
*Social and Economic Systems 6*

This paper encourages the usage of agent-based simulation models for economic analysis. Apart from the formulation of market interaction an agent-based simulation model allows a simple representation of geographical and technological space and the examination of learning through knowledge spillovers. An example of such a model is employed to analyze the profits of co-located firms in contrast to firms that choose isolation.

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## Open Source Teams, Firm Size and Wealth Distribution: An agent based model approach

Vijay Dakshinamoorthy
*Social and Economic Systems 6*

An agent based model of team formation and wealth distribution is studied. Based on previous work, two incentive structures, one resembling a firm and the second resembling an open source team are used to study the dynamics of team formation. I found that there exist ranges for the number of such teams when agents find it beneficial to join one of the open source teams and when not to. The effects of this behavior on the size of firms, total effort, compensation and wealth distribution are analyzed. Results are presented with some directions for future work.

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## Small cluster statistics and Levy size distributions

Oleg Bakunin

*Concepts and Methods 6*

Small cluster statistics and Levy size distributions

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There exists a large variety of models describing cluster growth [1]. In the present paper, we consider the statistical properties of small cluster system. There are several conventional methods to describe aggregation, but at the same time, it is difficult to find a suitable equation to describe properties of small cluster system. Thus, the Smoluchowski aggregation equation appears to be the well-known method to analyze the kinetics of growth processes. However, the character of its solution depends significantly on the form of integral equation kernel. Another drawback of this equation is the neglect of density fluctuations [1]. These fluctuations can be considerable on the initial stage of growth in the system with rare growth centers. The same reasons prevent to use the diffusive Zeldovich approximation [1]. The initial stage of growth has the fluctuation character, hence in such a system the number of "events" can be small, and the diffusion form of the equation is often incorrect. In anomalous transport theory it was suggested [2,3] a number of modifications of the conventional diffusive equations to describe the non-diffusive character of a process in terms of fractional differential equations and scalings [4]. In the framework of this approach, it is possible to obtain the power form distribution based on statistical properties of a system. The new functional equation is obtained from the probabilistic consideration of the transition to cluster-cluster aggregation in small cluster systems. The solution of this equation is based on using the model correlation functions [5]. In the Poisson dependence, the new nontrivial solution for cluster size distribution is obtained as follows:

This function is non-analytical with . Therefore, it cannot be obtained by the asymptotic technique from the Fokker-Planck type equations. The fluctuation character of the model is related to using the waiting time distribution approach. The transformation of equations for the case of large number of growth centers is analyzed. It was demonstrated that the dependence for cluster size distribution in the Levy form with a=3/2 could be found [5]. The difference between the Levy solution of the non-local Einstein-Smoluchowski equation and randomization approach is discussed.

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## Stability of Attractor Cycles in Random Boolean Networks

Steffen Schober

*Concepts and Methods 6*

Random Boolean networks (RBNs) were proposed as a model of genetic regulatory networks by Kauffman in 1969. This paper addresses the stability of cycles of RBNs and Boolean networks. In particular we define the error probabilities of cycle states as the probability of leaving a cycle after a randomly occurring error. Therefore, we introduce the weight distributions, which are usually used to analyse error probabilities of error-correction codes, and show that these completely determine the error probabilities of the cycles. By simulations of RBNs with 20, 17 and 15 state bits and bias of 0.5 we found that networks with connectivity 2 show less stable attractor cycles compared to RBNs with higher K, namely K $>$ 3,4,5,6.

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## Random Numbers in Distributed Systems

Heiko Bauke, Stephan Mertens

*Concepts and Methods 6*

Monte Carlo simulations are one of the major tools in complex system science, and an increasing number of these simulations is run on distributed systems like clusters or grids. This raises the issue of generating random numbers in a parallel, distributed environment. In this contribution we demonstrate that multiple linear recurrences in finite fields are an ideal method to produce high quality pseudorandom numbers in sequential and parallel algorithms. Their known weakness (failure of the spectral test in high dimensions) can be overcome by an appropriate delinearization that provably preserves all desirable properties of the original linear sequence.

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