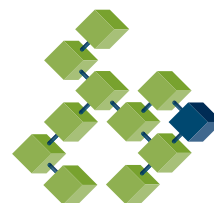




ARC Centre for Complex Systems

annual report 2007



ARC CENTRE FOR
COMPLEX SYSTEMS

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Introduction to the Centre

Complex systems science is an emerging discipline developing new ways of investigating large, highly intricate, dynamically changing systems across diverse areas such as biology, social networks and socio-technological systems, economics, ecology and the environment.

The ARC Centre for Complex Systems (ACCS) was established in 2004 to conduct world-class basic and applied research on questions fundamental to understanding, designing and managing complex systems. The goal is to develop deeper understanding of fundamental phenomena in complex systems, such as how macro-level system properties and behaviours emerge from relatively simple micro-level interactions, what mechanisms enable complex systems to self-organise, and how complex systems can be managed and controlled.

The Centre provides a focus for complex systems science research in Australia, and is developing strong engineering infrastructure for modelling and analysing network-based systems, including high-performance computing and visualisation facilities, to enable the science to be applied to real-world problems. The resulting methods and tools are being used to understand, manage and control complex systems. The Centre applies its research to complex systems in domains including electricity networks, bioscience, IT systems acquisition, and air-traffic control.

The Centre has its headquarters at The University of Queensland in Brisbane, with nodes at Griffith University in Brisbane, Monash University in Melbourne, and The University of New South Wales campus at the Australian Defence Force Academy in Canberra. The Centre is interdisciplinary, involving leading researchers from a range of disciplines including: systems and software engineering, economics, visualisation, human factors, computational mathematics and statistics, and relevant application domains, including aerospace, economics and biology. Funding is provided by the Australian Research Council (ARC) and the universities involved. Industry collaborations and further funding are being established to apply the Centre's research.

What is a complex system?

Complexity is the richness in structure and behaviour often seen in large systems. The property that distinguishes complex systems from systems that are merely large but simple is the emergence of global features from local interactions, as captured in the popular saying 'the whole is greater than the sum of its parts.' For example, a flock of birds emerges when individual birds coordinate their behaviour with each other.

[Quoted from Green, D.G. and Bransden, T.G. 'Complexity theory', in *McGraw-Hill Encyclopedia of Science and Technology*. McGraw-Hill, New York, 2006. pp 507-511.]

Why research complex systems?

What do recombining genes have in common with air traffic control and with farmers irrigating their fields?

The answer is that they are all activities involving agents interacting in networks, which result in systems that have very interesting, and often unexpected, properties. The common thread is that the agents act largely autonomously, and yet the system behaves in an apparently controlled manner.

- ❖ Biologists have discovered that certain sets of genes work together in networks to regulate cell growth, determining for example what kinds of new cells will be produced when cells split and where the new cells will be positioned. The resulting system - a biological organism - can be fascinatingly complex, as we all know.
- ❖ Air travel can be a highly efficient way of travelling from point A to point B. But with the continued growth in air travel, air traffic systems are increasingly coming close to overload. Small changes in traffic flow can lead to large delays further downstream, as the effects propagate through the air traffic network. Fog in Sydney, for example, can cause delays that ripple through the system, resulting in flights being in other parts of Australia, with all the resulting chaos and missed connections.
- ❖ Farmers' use of water and fertiliser can have severe effects on conditions downstream if usage patterns of different farmers happen to combine in unintended ways. Major environmental problems with water quality, salinity and sedimentation have arisen in Australia's major river systems due to measures that have addressed local problems but have failed to take their system-wide impact into account.

In all of these cases there is a need for better understanding of how high-level properties emerge from largely independent system elements acting in networks.

The Centre was established to investigate these kinds of problems and to develop methods and tools to help solve them. The Centre's mission is to conduct world-class basic and applied research on questions fundamental to understanding, designing and managing complex network-based systems. To provide focus to its research program, the Centre has five core application areas - genetic regulatory networks, air traffic control, evolutionary economic systems, electricity networks & energy markets, and dependable computer-based systems - these are described in more detail later in this Report.

Director's Report



Welcome to the 2007 Annual Report of the ARC Centre for Complex Systems (ACCS). As you read the Report you'll see there were many highlights in 2007, but I'd like to bring three particular successes to your attention.

The first is the Complex'07 Conference which was held on the Gold Coast in July. The event was by far the largest and most diverse gathering of complex systems science researchers and industry users ever held in Australia, and attracted many international participants. The event was a great success and showcased many of the Centre's research outcomes. Centre staff played key roles in the organisation and running of the conference. Special thanks are due to Janet Wiles for her role in developing the conference program (with COSNet's Bob Dewar), Carol Stirk, Lyn Greenfield (of HI Events) and Peter Adams for local arrangements and project management, and Virginia Garton and HI Events for financial accounting.

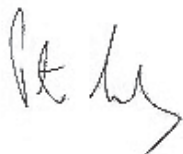
Another highlight was the take-up of the Behavior Trees method by Raytheon Australia, one of Australia's largest systems integration and engineering organisations. The Centre provided training and support, and Raytheon in turn funded trials and helped develop tools for applying the approach. The outcomes demonstrate how enormously effective the method is in enhancing understanding of large complex engineered systems, and the support it provides for defining the problem to be solved. Raytheon expects to save millions of dollars of development costs by improving the quality of systems requirements specifications.

A third highlight of 2007 was the establishment of the research groundwork for coordinated management of technical and financial aspects of Australia's electricity network. The Centre invested effort in bringing together experts with an understanding of economics and market mechanisms, with experts in the power engineering aspects of electricity transmission and distribution. As a result we have developed one of the country's strongest research groups for studying the economic aspects of distributed electricity generation. This capability is of critical importance for future expansion of the electricity network in the face of deregulation and the need to reduce greenhouse gas emissions.

Federation Fellowship success

Looking forward, we have high hopes for 2008. The Australian Research Council extended our funding for 12 months beyond its original 2004-2007 term and the extra time will enable us to consolidate the outcomes of our research programs and to capitalise on their application in industry.

In closing I wish to thank everyone who helped in putting this Annual Report together, but especially Leanne Brandis, Daniel Bradley and Virginia Garton.



Peter Lindsay
Director, ACCS
March 2008

Centre Chief Investigator Professor John Quiggin has been awarded a second Federation Fellowship — a very rare honour. John is Australia's most productive and influential research economist, contributing significantly to our understanding of the economics of uncertainty and the environment. He is a prominent contributor to Australian public debate and was listed among Australia's top 100 public intellectuals in 2005.

John's new research program is entitled 'Climate change: Adaptation and resilience in the face of uncertainty'. He aims to analyse options for adaptation to climate change in Australia and, in particular, the role and management of uncertainty. A central theoretical objective will be an improved understanding of the concepts of resilience and adaptive management and their application to the problems of adaptation to, and mitigation of, climate change.

The research will use simulation modelling of land and water use in the Murray-Darling Basin and other vulnerable areas to predict the effects of climate change under alternative policies. The modelling will yield suggestions for policies designed to promote resilient adaptation and efficient design of property rights and emissions trading schemes.

Professor Quiggin completed his PhD in agricultural economics at The University of New England. He is a Fellow of the Academy of the Social Sciences in Australia and the American Agricultural Economics Association, and a Distinguished Fellow of the Australian Agricultural and Resource Economics Society.

Professor Quiggin has been active in public life through submissions to Parliamentary and public inquiries and as a member of the board of the Queensland Competition Authority from 1998 to 2005.

He was awarded the Academy of the Social Sciences in Australia Medal (1993) and a Thompson ISI Citation award (2004).

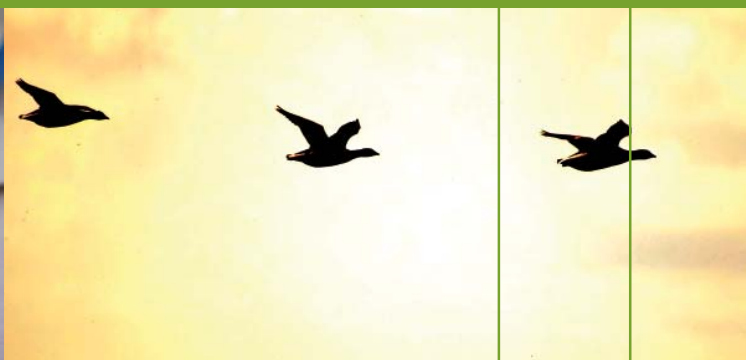
Centre Personnel

The ACCS fosters the emerging discipline of complex systems within Australia by creating a critical mass of researchers. Currently the Centre brings together a strong, interdisciplinary team across four major Australian universities.

Director	School/Unit	Institution
Prof Peter Lindsay	Information Technology & Electrical Engineering	The University of Queensland
Deputy Director		
Prof John Foster	Economics	The University of Queensland
Chief Investigators		
Prof Hussein Abbass	Information Technology & Electrical Engineering	UNSW@ADFA
Prof David Abramson	Computer Science & Software Engineering	Monash University
Prof Peter Adams	Mathematics	The University of Queensland
Prof Kevin Burrage	Mathematics	The University of Queensland
Prof Geoff Dromey	Information & Communication Technology	Griffith University
Prof David Green	Computer Science & Software Engineering	Monash University
Prof Ian Hayes	Information Technology & Electrical Engineering	The University of Queensland
Prof Bernard Pailthorpe	Mathematics	The University of Queensland
Prof John Quiggin	Economics	The University of Queensland
Prof Penelope Sanderson	Psychology/Information Technology & Electrical Engineering	The University of Queensland
Prof Janet Wiles	Information Technology & Electrical Engineering	The University of Queensland
Partner Investigators		
Prof Kalyanmoy Deb	Mechanical Engineering	Indian Institute of Technology, Delhi, India
Mr Julian Robins	Engineering & Mission Assurance	Boeing Australia
Dr Guy Theraulaz	Centre de Recherches sur la Cognition Animale	University Paul Sabatier, Toulouse, France
Centre Admin & Technical Support Staff		
Ms Virginia Garton	Centre Manager	The University of Queensland
Mr Daniel Bradley	Webmaster	The University of Queensland
Ms Leanne Brandis	Education Officer	The University of Queensland
Mr Leighton Brough	Tools Coordinator	The University of Queensland
Ms Natalie Dunstan	Administration	Griffith University
Mr John Hawkins	Webmaster	The University of Queensland
Ms Carol Stirk	Acting Education Officer	The University of Queensland
Collaborators		
Dr Michael Barlow	Information Technology & Electrical Engineering	UNSW@ADFA
Prof Gilbert Baumslag	Center for Algorithms & Interactive Scientific Software	City College, City University of New York, USA
Dr Rodney Beard	Business	University of Alberta, Canada
Dr Christine Beveridge	ARC Centre of Excellence for Integrative Legume Research	The University of Queensland
Dr Mikael Boden	Information Technology & Electrical Engineering	The University of Queensland
Mr Scott Bolland	Key Centre for Human Factors & Applied Cognitive Psychology/ITEE	The University of Queensland
Mr Jim Boston	Senior Project Manager	Raytheon Australia
Dr Lam Bui	Information Technology & Electrical Engineering	UNSW@ADFA
Prof Alan Burns	Computer Science	University of York, UK
Dr Darryn Bryant	Mathematics	The University of Queensland
Dr Colin Campbell	Mathematics & Statistics	University of St Andrews, Scotland
Mr Gerard Champion	Brisbane Operations	Airservices Australia
Dr David Chen	Information & Communication Technology	Griffith University
Prof Marston Conder	Mathematics	University of Auckland, NZ
Assoc Prof Zhao Yang Dong	Information Technology & Electrical Engineering	The University of Queensland
Assoc Prof Diane Donovan	Mathematics	The University of Queensland
Prof Vladimir Estivill-Castro	Information & Communication Technology	Griffith University
Dr Daryl Essam	Information Technology & Electrical Engineering	UNSW@ADFA
Dr Marcus Gallagher	Information Technology & Electrical Engineering	The University of Queensland
Dr Nicholas Geard	Electronics & Computer Science	The University of Southampton, UK
Prof David Goldberg	Mathematics	Purdue University, USA
Prof Peter Gresshof	ARC Centre of Excellence for Integrative Legume Research	The University of Queensland
Assoc Prof Lindsay Groves	Mathematics, Statistics & Computer Science	Victoria University of Wellington, NZ
Dr Lars Grunske	Information Technology & Electrical Engineering	The University of Queensland
Dr Jennifer Hallinan	Centre for Integrated Systems Biology of Ageing and Nutrition	University of Newcastle-on-Tyne, UK
Assoc Prof George Havas	Information Technology & Electrical Engineering	The University of Queensland
Prof David Hill	Research School of Information Sciences & Engineering	Australian National University
Prof Melvin Hinich	Department of Government	The University of Texas at Austin, USA
Prof Michael Jackson	Computer Science	University of Newcastle-on-Tyne, UK
Dr Geoff James	Information & Communication Technologies (ICT)	CSIRO
Prof Cliff Jones	Computing Science	University of Newcastle-on-Tyne, UK
Dr Kung-Kiu Lau	Computer Science	University of Manchester, UK
Prof Peter Liesch	UQ Business School	The University of Queensland
Dr Xue Li	Information Technology & Electrical Engineering	The University of Queensland
Dr Victor Luchangco	Scalable Synchronization Group	Sun Microsystems Laboratories, USA
Prof Jin Ma	Department of Electric Power Engineering	North China Electric Power University, China

Collaborators	School/Unit	Institution
Dr Yuri Makarov	Energy Technology Development group	Pacific Northwest National Laboratory, USA
Mr Greg McDonald	Future Directions Group	Airservices Australia
Dr Stuart McDonald	Social & Information Sciences Lab	California Institute of Technology, USA
Dr Mark Moir	Scalable Synchronization Research Group	Sun Microsystems Laboratories, USA
Dr Andrew Neal	Key Centre for Human Factors & Applied Cognitive Psychology	The University of Queensland
Prof Hon-Wing Ngan	Electrical Engineering	Hong Kong Polytechnic University
Prof Stefano Nolfi	Institute of Cognitive Sciences & Technologies	National Research Council (CNR), Italy
Prof Eamonn O'Brien	Mathematics	University of Auckland, NZ
Dr Tien Duc Pham	Economics	The University of Queensland
Dr Jason Potts	Economics/ARC Centre for Creative Industries	UQ/Queensland University of Technology
Prof Edmund Robertson	School of Mathematics & Statistics	University of St Andrews, Scotland
Dr Peter Robinson	Information Technology & Electrical Engineering	The University of Queensland
Dr Suzanne Sadedin	Information Technology	Monash University
Prof Tapan Saha	Information Technology & Electrical Engineering	The University of Queensland
Dr Ruhul Sarker	Information Technology & Electrical Engineering	UNSW@ADFA
Dr Kumara Sastry	Illinois Genetic Algorithms Laboratory	University of Illinois at Urbana-Champaign, USA
Dr Alla Seleznyova	Palmerston North Research Centre.	Horticulture & Food Research Institute of NZ
Prof Leyuan Shi	Industrial & Systems Engineering	University of Wisconsin-Madison, USA
Mr Lukas Skoufa	UQ Business School	The University of Queensland
Dr Graeme Smith	Information Technology & Electrical Engineering	The University of Queensland
Dr John Steen	UQ Business School	The University of Queensland
Dr Rob Stocker	Information Technology & Electrical Engineering	UNSW@ADFA
Prof Anne Street	Centre for Discrete Mathematics & Computing	The University of Queensland
Dr Terry Stevenson	Chief Technology Officer	Raytheon Australia
Assoc Prof Paul Strooper	Information Technology & Electrical Engineering	The University of Queensland
Prof Chengzheng Sun	Computer Engineering	Nanyang Technological University, Singapore
Assoc Prof Kay Chen Tan	Electrical & Computer Engineering	National University of Singapore
Prof Doug Troeger	Center for Algorithms & Interactive Scientific Software	City College, City University of New York, USA
Dr Miguel Vilaplana	ATM Advanced Trajectory Technologies	Boeing Research & Technology, Europe, Spain
Dr Liam Wagner	Economics	The University of Queensland
Dr Geoff Walker	Information Technology & Electrical Engineering	The University of Queensland
Prof Dianhui Wang	Computer Science & Computer Engineering	La Trobe University
Assoc Prof Youyi Wang	Electrical & Electronic Engineering	Nanyang Technological University, Singapore
Prof Kit Po Wong	Electrical Engineering	Hong Kong Polytechnic University, Hong Kong
Prof Jim Woodcock	Computer Science	University of York, UK
Prof Zhan Xu	Physics	Tsinghua University, China
Prof Yusheng Xue	Nanjing Automation Research Institute (NARI)	State Power Grid Company, China
Dr Pei Zhang	Grid Operation & Planning	Electric Power Research Institute (EPRI), USA
Research Staff		
Mr Sameer Alam	ACCS	UNSW@ADFA
Mr Mark Bowden	ACCS	The University of Queensland
Mr Daniel Bradley	ACCS	The University of Queensland
Mr Clement Chu	ACCS	Monash University
Dr Robert Colvin	ACCS	The University of Queensland
Mr Simon Connelly	ACCS	The University of Queensland
Miss Sheree Driver	ACCS	Monash University
Mr Colin Enticott	ACCS	Monash University
Dr Ken Gray	ACCS	The University of Queensland
Dr Jim Hanan	ACCS	The University of Queensland
Mr John Hawkins	ACCS	The University of Queensland
Ms Diana Kirk	ACCS	Griffith University
Dr Ariel Liebman	ACCS	The University of Queensland
Mr Gary Leishman	ACCS	Monash University
Ms Tania Leishman	ACCS	Monash University
Mr Alex Tee Neng Heng	ACCS	Monash University
Dr Minh Ha Nguyen	ACCS	UNSW@ADFA
Mr Tom Peachey	ACCS	Monash University
Dr Daniel Powell	ACCS	Griffith University
Dr Colin Ramsay	ACCS	The University of Queensland
Mr Jiangjun Tang	ACCS	UNSW@ADFA
Dr James Watson	ACCS	The University of Queensland
Dr Lian Wen	ACCS	Griffith University
Dr Jacqueline Wicks	ACCS	The University of Queensland
Dr Phillip Wild	ACCS	The University of Queensland
Dr Kai Willadsen	ACCS	The University of Queensland
Dr Kirsten Winter	ACCS	The University of Queensland
Ms Nisansala Yatapanage	ACCS	Griffith University
Dr Junhua Zhao	ACCS	The University of Queensland

Research Staff list does not include Summer Students (See page 35)



Management

Management of the Centre involves the Executive, the Research Advisory Committee and the Advisory Board.

The Research Advisory Committee comprises the Centre Chief Investigators and the Chair of the Advisory Board. This Committee meets twice annually to review the Centre's research and research plans. The Chief Investigators also meet on two other occasions throughout the year. A Research Higher Degree (RHD) Committee manages student matters.

Advisory Board

The Advisory Board meets once per year to offer advice regarding the scientific focus and vision of the Centre, its structure and general operating principles, and intellectual property and commercialisation management.

The Advisory Board provides broad representation from the research and end-user communities.

The following people were members of the Advisory Board in 2007:

Dr John Finnigan (Chair)

Director, Centre for Complex System Science, CSIRO, Canberra, ACT

Professor Paul Bailes

Head of School, School of Information Technology & Electrical Engineering, The University of Queensland, St Lucia, Qld

Professor Edwina Cornish

Deputy Vice Chancellor & Vice President—Research, Monash University, Clayton, Victoria

Dr Richard Davis

Head, National Security Science & Technology Unit,

Department of Prime Minister & Cabinet, Canberra, ACT

Professor John Foster

Head of School, School of Economics, The University of Queensland, St Lucia, Qld

Professor Peter Lindsay (Director)

Boeing Professor of Systems Engineering, School of Information Technology & Electrical Engineering, The University of Queensland, St Lucia, Qld

Mr Julian Robins

General Manager, Engineering & Mission Assurance, Boeing Australia, Brisbane, Qld

Professor David Siddle

Deputy Vice Chancellor—Research, The University of Queensland, St Lucia, Qld

Mr Colin Tuckerman

Manager, Capability Planning, Future Directions Division, Airservices Australia, Canberra, ACT

Professor Stephen Walker

Executive Dean, Faculty of Engineering, Physical Sciences & Architecture, The University of Queensland, St Lucia, Qld



Advisory Board members at the meeting on 28 March.
Front row left to right: Julian Robins, Peter Lindsay, John Finnigan
Back row left to right: Richard Davis, Stephen Walker, Paul Bailes

Recognition of Centre personnel

Centre collaborator **Dr Darryn Bryant**, holder of a QEII Research Fellowship in combinatorial mathematics, was awarded the Hall Medal from the Institute of Combinatorics and its Applications. The medal recognises extensive quality research by ICA (Institute for Combinatorics and its Applications) Members in mid-career. "Darryn has solved several very difficult problems in discrete mathematics, especially in design theory and graph theory, and he has collaborated with people involved in drug design, in DNA sequence work, and in other bioinformatics areas." For further details see www.uq.edu.au/news/?article=12748.

Centre Chief Investigator **Professor Ian Hayes** was elected a Fellow of the British Computer Society.

Centre Chief Investigator **Professor Hussein Abbass** was promoted to the position of Professor and Chair of Information Technology at UNSW@ADFA.

Centre PhD students were highly awarded in 2007:

- ❖ **Dr Nicholas Geard** (Advisory team - Janet Wiles and John Mattick) and **Dr Lesley Seebeck** (Advisor - Simon Kaplan) were the recipients of the highly competitive University of Queensland's Dean's List of Commendation for outstanding Research Higher Degree theses in 2006.
- ❖ Nic also won the Australian Computer Society thesis award in 2006.
- ❖ **Ms Xilin Li** was the winner of first place in the Cognitive Engineering and Decision Making Technical Group's contest for student papers accepted for the 51st Annual Meeting of the USA-based Human Factors and Ergonomics Society

(HFES). Her paper was titled 'Convergent measures of situation awareness in a process control simulator setting'.

- ❖ **Ms Anisah Nizar** was awarded the UniQuest Trailblazer Award for an outstanding project.
- ❖ **Dr Lam Bui's** PhD thesis was awarded a prize for the best thesis in Information Technology at UNSW@ADFA.
- ❖ Centre researcher **Dr Jim Hanan**, collaborator **Dr Christine Beveridge** and Kim Nichols (UQ Department of Education) were recently awarded an inaugural UQ Teaching and Learning Large Strategic Grant of \$55 000 for their *My Lab: Supporting UQ Teaching and Learning with Interactive Dynamic Model* project. They aim to create a resource for the development of computational models for UQ undergraduate subjects. The models will provide complex investigative environments suitable for inquiry based learning. Methods for promoting reflective inquiry to increase conceptual understanding of biological phenomena will be refined and rigorously evaluated.

Six of the best paper awards at Complex'07, the 8th Asia-Pacific Conference on Complex Systems went to ACCS staff, students or researchers. For further detail on Complex'07, see page29-31.

In 2007, Centre Researcher Dr Liam Wagner took up a post-doctoral position with Centre Chief Investigator and ARC Fellow, John Quiggin. With Liam's background in Mathematics and John's in Economics, this is a good example of how the Centre has effectively brought together people from different disciplines. Since starting with John Quiggin, Liam has been awarded a UQ post-doctoral research fellowship to examine current issues which affect the National Electricity Market.

Research Program

Through joint applied projects with collaborators, the Centre links existing Australian research strengths and builds new capacity for interdisciplinary, collaborative approaches to address the most challenging and significant research problems.

Through its research program, the Centre explores both the science and the engineering of complex systems.

In the science stream of its research program, the Centre aims to develop a coherent set of theories, computational techniques and modelling tools for network-based systems. The aim is to capture how natural systems self-organise and adapt, and then apply those insights to other areas.

The engineering stream of the Centre's research program is concerned with providing a modelling framework, theory, toolset, and infrastructure to enable complex-systems researchers to build powerful models

and simulations economically and reliably. The aim is to facilitate the application of the theories to real-world systems, and to develop principles for managing (planning and controlling) complex systems.

The Centre's core ARC-funded program is based around a number of application areas:

- ❖ genetic regulatory networks,
- ❖ air traffic control,
- ❖ evolutionary economic systems,
- ❖ electricity networks and energy markets, and
- ❖ dependable computer-based systems.

These programs are supported by projects concerned with improved methods and tools for analysing and developing complex systems. External funding is used to apply Centre results to government and industry problems.



Genetic Regulatory Networks

Program Leader: Janet Wiles

Research in the Genetic Regulatory Networks (GRN) program tackles fundamental questions about growth and form in cellular biology. In this program, computational modelling is used to study how the control of development results from an interaction between each cell's genetic regulatory network and its inputs from neighbouring cells and its environment, and how the process proceeds reliably, while coping with unreliable components, perturbation, injury, and changing environments.

Modelling gene regulatory networks and plant morphology

Project Leader: Janet Wiles

Researcher: James Watson

This project had two primary goals. The first was to analyse a computational model of gene regulation and plant morphology. The second was to develop the modelling techniques that allow the efficient simulation and analysis of such a model. In the model of gene regulation and plant morphology, there were three main components - a genetic sequence, a regulatory network, and plant development. This model was analysed with respect to the constraints these components placed on each other. A software toolkit of common modelling functionality was designed, and a prototype regulatory network model that utilised idle, distributed computing resources to reduce simulation time was developed. Other methods of improving simulation time, such as the use of graphics processing units for simulation calculations, were investigated.

In 2007, the analysis of the GRN and plant morphology software model was extended to investigate the constraints different components placed upon each other.

An analysis of this model was presented at IPCAT'07 in Oxford. A number of research centres, including the San Diego Supercomputer Centre, Calit2, the Centre for Research in Language and the Salk Institute were visited to see first-hand how leading research centres implement and use computational facilities. The software model that utilises idle computing facilities in the student laboratories was outlined in a report to the Queensland Cyber Infrastructure Foundation, and was extended to form a practical parameter sweep tool. This tool was used by researchers from the Institute for Molecular Bioscience, and the results from some of this work were presented at Complex'07 and IPCAT'07. A computational steering workshop (CompuSteer) was attended in Hull, UK, and an overview of this project was presented at the School of Computing, Leeds University.

Recent outputs

Watson, J., Wiles, J., "Modeling the fitness of plant morphologies across three levels of complexity", *Proceedings of the Seventh International Workshop on Information Processing in Cells and Tissues*, August 2007.

Machine learning architectures for biological sequence analysis

Project Leader: Mikael Boden

Researchers: Daniel Bradley, John Hawkins, Janet Wiles

This project contributes a software technique, and concrete implementation that will allow the exploration of the nuclear portion of the proteome, and hence another avenue for exploring gene regulation. The project aims to develop a nascent piece of IP developed within the Centre and see it through to commercial reality.

In this project in 2007, we have developed working relationships with a number of experimental biologists and have published the results of joint projects using

computational biology to generate hypotheses testable in the laboratory. We have recently developed a method for extracting sequence features from Kernel-based machine learning algorithms which will allow us to produce novel predictions regarding the location of functional regions in biological sequences. This technique will form the hub for a series of further joint investigations into the sequence features responsible for the dynamics of assorted nuclear proteins.

Recent outputs

Hawkins, J., Davis, L., Boden, M., "Predicting nuclear localisation", *Journal of Proteome Research*, Vol. 6, No. 4, 2007, 1402-1409.

Hawkins, J., Mahony, D., Maetschke, S., Wakabayashi, M., Teasdale, R.D., Boden, M., "Identifying novel peroxisomal proteins", *Proteins: Structure, Function, and Bioinformatics*, Vol. 69, No. 3, 2007, 606-616.

Modelling regulatory networks at cell, tissue and organism level

Project Leader: Jim Hanan

Researchers: Kevin Burrage, Janet Wiles

Computer-aided models of biological regulatory networks are a cornerstone of systems biology, promising to transform biological research by providing a framework for (1) systematic investigation of hypothesised network structures; (2) management of data on large numbers of system components and interactions; and (3) allowing simulation studies to reveal emergent properties and consequences of hypothesised networks. Development and application of an agent-based generative modelling system will be explored, allowing simulation of regulatory networks within a developing spatial structure at cellular, tissue and organism levels. From a computational standpoint, topological connections of structures within a cell and within a layer of tissue can be treated with the same abstractions. Analysis of the complex system models expressed with this special purpose toolkit will be carried out to extract general software engineering principles, particularly for developing further software methodologies and notations, and for investigation of mechanisms for managing and controlling complex systems for transfer to other domains of application.

In 2007, Jim Hanan supervised Frijtof Heyde, a student intern from Germany who implemented a system for modelling spatial and regulatory aspects of intracellular processes-based on an approach integrating Petri Net and L-system models. He also supervised a student, Michael Rivoire, intern from France, who implemented an individual-based model of competition between trees, based on field of neighbourhood concepts. Also in 2007, models of genetic control of pea branching were analysed using Geoff Dromey's Behavior Tree approach.

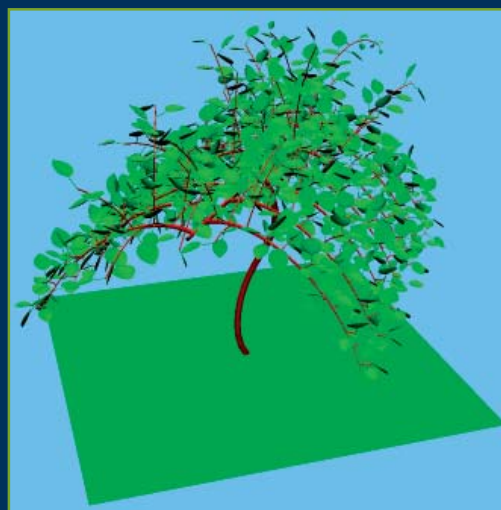
Recent outputs

Birch, C., Hanan, J., Thornby, D., "Architectural modelling of maize under water stress", *Australian Journal of Experimental Agriculture*, Vol. 48, No. 3, 2008, 335-341.

Virtual kiwifruit: Modelling the annual growth cycle

Centre PhD Student Mikolaj Cieslak, along with Centre Researcher Dr Jim Hanan and Collaborator Dr Alla Seleznyova, has studied the complex branching patterns of managed mature kiwifruit vines. Their research has created a 3D virtual plant model of kiwifruit vine shoot growth and development.

By modelling interactions between plant architecture, resource allocation and the environment, the researchers are able to better understand the relationship between the plant and its exploitation of resources throughout its life cycle. The virtual kiwifruit model will be used to further explore the complexity of vine architecture, and to study the effect of canopy structure on light distribution.

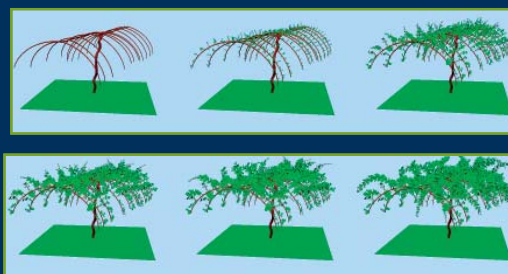


3D visualisation of a virtual kiwifruit

This work has contributed to the development of a collaborative agreement with the Queensland Department of Primary Industries and Fisheries who are starting a new project in 3D modelling of tropical fruit and nut trees.

The poster describing this research was awarded Best Poster at Complex'07, the 8th Asia-Pacific Complex Systems Conference.

Further details on this project are available at www.complex07.org/online-edition/files/241.pdf.



3D visualisation of the growth of a virtual kiwifruit

Dun, E.A., Hanan, J., Beveridge, C., "Hypothesis-driven computational modelling of branching control in pea", *Proceedings of the 5th International Workshop on Functional Structural Plant Models*, November 2007.

Han, L., Gresshoff, P., Hanan, J., "Virtual soybean—a computational model for studying autoregulation of nodulation", *Proceedings of the 5th International Workshop on Functional-Structural Plant Models*, November 2007.

Renton, M., Thornby, D., Hanan, J., "Canonical modelling: an approach for intermediate level simulation of carbon allocation in functional structural models", *Functional-Structural Plant Modelling in Crop Production*, Wageningen UR Frontis Series, Vol. 22, Springer, 2007.

Song, Y., Birch, C., Hanan, J., "Architectural analysis and modeling of maize growth and development under

water stress", *Proceedings of the 5th International Workshop on Functional Structural Plant Models*, November 2007.

Stolk, H., Hanan, J., "Discovering genetic regulatory network models in *Pisum sativum*", *International Congress on Modelling and Simulation (MODSIM 2007)*, December 2007.

Thornby, D., Spencer, D., Hanan, J., Sher, A., "L-DONAX, a growth model of the invasive weed species, *Arundo donax* L.", *Aquatic Botany*, Vol. 87, No. 4, November 2007, 275-284.

Where are they now?

Past researchers from the Centre's Genetic Regulatory Networks program are now employed across a range of institutions demonstrating the value of innovative complex-systems thinking and techniques in many new areas.

Centre Chief Investigator and Program Leader, **Professor Janet Wiles** continues as Director of the Thinking Systems Project: Navigating Through Real and Conceptual Spaces, an ARC Special Research Initiative based at The University of Queensland and jointly funded by the Australian Research Council and the National Health and Medical Research Council. Complex systems theory will underpin the study of fundamental issues in how information is transmitted, received, processed and understood in biological and artificial systems.

Dr Jennifer Hallinan, Centre collaborator and formerly of The University of Queensland, has been awarded a five-year Research Fellowship in Complex Systems from the UK Research Council, starting October 2007, and leading to an ongoing lectureship in Computer Science at the University of Newcastle-Upon-Tyne.

Centre researcher, **Dr Jim Hanan**, who has held joint appointments with the ARC Centre of Excellence for Integrative Legume Research and the ARC Centre for Bioinformatics, will join the UQ Centre for Biological Information Technology to apply complex systems theory to the development of educational models supporting teaching and learning in the BSc degree program.

Dr Nic Geard, formerly a Centre PhD student and researcher, is now Research Fellow in the School of Electronics and Computer Science, University of Southampton. Nic is currently employed on an EPSRC (the UK's Engineering and Physical Sciences

Research Council) funded project developing simulation models to investigate the growth and evolution of communities in large social networks.

Dr Kai Willadsen, also a former Centre PhD student and researcher is now Guest Scientist at the Frankfurt Institute for Advanced Studies in at Johann Wolfgang Goethe University, Frankfurt am Main, Germany. Kai is currently working on understanding biases and weaknesses in measures of causality in simple non-linear systems.

Dr James Watson, a former Centre PhD student, was a postdoctoral researcher with the Centre in 2007. James has recently accepted a Research Fellowship in the School of Computing at the University of Leeds, where he will be developing computational models of biological systems.



Nic Geard & James Watson, two former Centre students and researchers, now both based in the UK.

General GRN publications

Dorr, G., Hanan, J., Adkins, S., Hewitt, A., Noller, B., "Spray deposition on plant surfaces: a modeling approach", *Proceedings of the 5th International Workshop on Functional Structural Plant Models*, November 2007.

Dorr, G., Noller, B., Woods, N., Hewitt, A., Hanan, J., Adkins, S., Ricci, P., "Development of a decision-making tool to minimise environmental and public health risk of pesticide application", *Rational Environment Management of Agrochemicals: Risk Assessment, Monitoring, and Remedial Action*, American Chemical Society, 2007, 53-65.

Geard, N., Wiles, J., "Directed evolution of artificial cell lineages", *Progress in Artificial Life*, Edited by Randall, M., Abbass, H., Wiles, J., December 2007; Lecture Notes in Computer Science, Vol. 4828, 144-155.

Geard, N., Wiles, J., "LinMap: Visualising complexity gradients in evolutionary landscapes", *Artificial Life*, 2008.

Lohaus, R., Geard, N., Wiles, J., Azevedo, R., "A generative bias towards average complexity in artificial cell lineages.", *Proceedings of the Royal Society of London, Series B*, Vol. 274, No. 1619, 2007, 1741-1750.

Stolk, H., Zaluki, M., Hanan, J., "Subpopulation agents emerge from individual agents in simulations of monarch butterflies", *International Congress on Modelling and Simulation (MODSIM 2007)*, December 2007.

Willadsen, K., Wiles, J., "Robustness and state-space structure of Boolean gene regulatory models", *Journal of Theoretical Biology*, Vol. 249, No. 4, 2007, 749-765.

ACCS in the media

Queensland's electricity market

In a boost for the Centre's new Electricity Networks & Energy Markets program, Channel 9 News featured Centre Researcher Ariel Liebman speaking on the *Deregulation of Queensland's retail electricity market*. 6pm, 18 June.

It's not what you know - it's who you know...

The UQ Business School's report on Sam MacAulay's work 'The role of social networks in the innovation process', (see page 14) was picked up by ABC Local Radio, Gold Coast, 21 May, and by Physorg.com (see www.physorg.com/news98375254.html) 14 May.

Clarity of language signals success

In response to a *Courier Mail* front-page article, Centre Chief Investigator Geoff Dromey wrote an article in response claiming that "using technology should not be at the expense of clear language. One wrong instruction in four million lines of Boeing 777 software could be disastrous..." 16 April, *Courier Mail*, Ed: 1, Pg 17, 644 words by Geoff Dromey

Complex'07

For details of media coverage of Complex'07, see page 31.



Air Traffic Control

Program Leader: Peter Lindsay

As more vehicles take to the air, air traffic control will be a constraining factor on the number of aircraft that can be accommodated, and on the paths that they fly. Europe, the USA and Australia are all considering fundamentally new ways of managing air traffic with a view to improving efficiency without compromising safety. We are applying complex systems science to the problem by modelling airspace as networks of aircraft, and developing new approaches to assurance of system-level properties including safety and efficiency. This work builds on the group's existing work in human factors and human-computer interaction in air-traffic control.

Evaluation of future Air Traffic Management concepts

Project Leader: Peter Lindsay

Researchers: Ariel Liebman, Martijn Mooij, Colin Ramsay, Peter Robinson

The aim of this project is to use modelling and simulation to explore new operational concepts for Air Traffic Management (ATM). It builds on the conceptual framework developed in an earlier ACCS project, and uses the ATC simulation toolkit being developed in the Centre. The 2007 Australian ATM Strategic Plan proposes a notion of User Preferred Trajectories, whereby airspace users have more direct influence over the 4D trajectory that they fly which, in turn, is expected to lead to large efficiency gains. The challenge is to understand how to implement this concept, which will involve a fundamental change of conceptual viewpoint, from distance-based air traffic control to time-based trajectory management.

In 2007, two major studies were conducted. The first was a study of sector transit times in Australian airspace based on actual trajectories flown. Three cases were

compared: actual transit times using track data; transit times extrapolated from flight plans using our ATC Simulator software; and transit times from flight plans using agents emulating ATC interventions. The study demonstrated that the simulator is broadly accurate, in as much as the general behaviours were broadly the same in all three cases. The main differences seem to be due to lack of wind modelling in the Simulator, but another issue was timing of interventions, where they occurred in real life, since this information was not available to us. The second study focused on feeder sectors and used agent-based models to investigate the likely effects of increased traffic volumes on delays. A nonlinear relationship between traffic density and airspace capacity emerged where delays and other system level metrics increase suddenly when a certain threshold was reached. The study was repeated with the addition of a simple decision support tool enabling the controller agent to optimise for arrival timing accuracy. It was found that this capability significantly reduced delays without imposing penalties on other system properties such as safety.

Air traffic control workload

Project Leader: Andrew Neal

Researchers: Scott Bolland, Gerard Champion, Graham Halford, Mike Humphreys, Peter Lindsay, Shayne Loft, Martijn Mooij, Penelope Sanderson

The aim of the project is to develop a computational model that can measure the flow of traffic through an air sector, and predict the level of workload that an air traffic controller will experience, as well as the overall risk of breakdowns in separation between aircraft. The purpose is to develop a tool that can be used for risk analysis and scenario planning. This is a multidisciplinary project, integrating recent models of human memory and reasoning, with formal methods for the analysis of human-computer systems. The project is funded jointly by an ARC Linkage grant and Airservices Australia

and administered through UQ's Key Centre for Human Factors and Applied Cognitive Psychology.

In 2007, we completed the collection of data from the operational environment, with a final study being run in Melbourne Centre. Analyses of earlier studies run in Brisbane Centre were completed, and progress was made towards handover of the final workload modelling tool for the industry partner. In the first half of 2008, we will complete the analyses of the data from the Melbourne study and finish debugging of the workload modelling tool. The project will be completed by June 2008.

Recent outputs

Bolland, S., Fothergill, S., Humphreys, M., Neal, A., Lindsay, P., "Modelling the human air traffic controller, Part II: Emulating controller intervention", *Proceedings of the 14th International Symposium on Aviation Psychology*, 2007.

Loft, S., Bolland, S., Humphreys, M., "Modelling the human air traffic controller. Expert-Trainee differences in conflict detection.", *Proceedings of the 14th International Symposium on Aviation Psychology*, 2007.

Loft, S., Sanderson, P., Neal, A., Mooij, M., "Modelling and predicting mental workload in en route air traffic control: Critical review and broader implications", *Human Factors*, 2007.

Neal, A., Mooij, M., Bolland, S., Xiao, T., Lindsay, P., Boag, C., "Using multi-level analysis to model the sources of variability in workload within and between sectors", *Proceedings of the 14th International Symposium on Aviation Psychology*, 2007.

Sanderson, P., Mooij, M., Neal, A., "Investigating sources of mental workload using a high-fidelity ATC simulator", *Proceedings of the 14th International Symposium on Aviation Psychology*, 2007.

Propagation of uncertainty in trajectory computations

Project Leader: Peter Lindsay

Researchers: Ariel Liebman, Greg McDonald, Colin Ramsay, Miguel Vilaplana

The ability to accurately predict the 4D trajectory that an aircraft intends to follow is important for a wide range of ATM applications such as conflict detection and traffic planning. This project is developing a theoretical framework for modelling of uncertainties associated with the trajectory prediction process. Important factors include environmental conditions such as wind, aircraft performance characteristics, and operational decisions such as the precise time at which a pilot takes an action. Improved understanding of the nature and amount of error involved in trajectory prediction is important in determining the viability of new tools and procedures in ATM.

This project was started with funding from Boeing Research and Technology Europe (BR&TE) in late 2007. This is a collaborative effort also involving Airservices Australia under the BR&TE-Airservices research

collaboration initiative. A review was undertaken of existing literature in the field of uncertainty effects in trajectory prediction. We also familiarised ourselves with Boeing's prototype formal language used to describe aircraft trajectories (known as the Aircraft Intent Description Language or AIDL). The goal is to develop a theoretical framework for the qualitative and quantitative analysis of the effects of stochastic factors, such as those above, on trajectories expressed in AIDL. A preliminary literature review and project plan was produced and delivered to Boeing RTE in Madrid, Spain.

Recent outputs

Lindsay, P., Liebman, A., Ramsay, C., "Project plan and preliminary literature review", *Industry Report Submitted to Boeing Research & Technology Europe*, December 2007.

Swarm intelligence for conflict detection and resolution in free-flight environments

Project Leader: Hussein Abbass

Researchers: Sameer Alam, Michael Barlow, Peter Lindsay, Minh Ha Nguyen

Free flight is a revolutionary concept that will enable greater traffic volume and operational flexibility by distributing some of the functionality, including conflict detection and resolution, to airborne systems and pilots. Swarm intelligence is the study of computations in social insects (such as ants, termites and some types of bees and wasps). It is a new branch of distributed artificial intelligence, where computations are carried out by a group of agents working cooperatively to achieve a task. Ant colony optimisation is an optimisation technique inspired by the behaviour of real ants. In this project, we are developing safe conflict detection and resolution algorithms for free-flight inspired by natural computations and navigations in colonies of ants. The advantages of such algorithms include being adaptive in a dynamic environment, and being fully distributed.

In 2007, work proceeded on a fully distributed version of the Air Traffic Operations and Management Simulator (ATOMS) toolset. An evolutionary-based scenario assessment approach was developed, where advanced ATM concepts can be tested and validated. The ATOMS tool was also adapted for use in a study for Airservices Australia to investigate possible benefits of different ATM strategies (including free-flight) on greenhouse gas emissions and noise.

Recent outputs

Alam, S., Abbass, H., Barlow, M., "ATOMS: Air traffic operations and management simulator", *IEEE Transactions on Intelligent Transportation*, 2008.

Alam, S., Nguyen, M., Abbass, H., Barlow, M., "Ants guide future pilots", *Progress in Artificial Life*, December 2007; Lecture Notes in Computer Science, Vol. 4828.

Alam, S., Nguyen, M., Abbass, H., Barlow, M., "The architecture design and validation of the air traffic

It's not what you know - it's who you know...

ACCS and UQ Business School PhD student, Sam MacAulay says the old cliché - it's not what you know; it's who you know - might be true after all. Sam said the informal relationships people developed at work were often critical to their effectiveness.

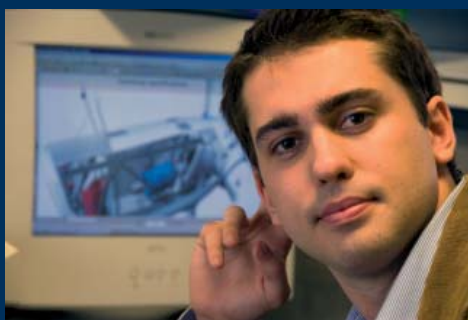
He said, "Most people would probably agree that the average organisational chart doesn't begin to capture the complexity of relationships developed by employees to get things done."

"Instead of the formal organisational structure, effective workers develop their own 'knowledge networks' as they build relationships with other staff in the course of their work. These knowledge networks have been shown to be critical in the innovation process."

MacAulay will work with the world's leading producer of wind power systems, the Danish wind turbine manufacturer Vestas, and with Rio Tinto, a world leader in finding, mining and processing the earth's mineral resources, to discover how knowledge networks enable the companies to keep innovating.

MacAulay said he was also planning to examine how knowledge networks change over time and in response to particular events such as the emergence of new technical capabilities within the industry or the entry or exit of critical team members.

(From UQ Business School News, 14 May, www.business.uq.edu.au/display/news)



Sam MacAulay

operations and management simulator (ATOMS)", *Proceedings of the 2007 SimTecT*, June 2007.

Alam, S., Shafi, K., Abbass, H., Barlow, M., "Evolving air traffic scenarios for the evaluation of conflict detection models", *Proceedings of the 2007 EUROCONTROL Innovative Research Workshop*, December 2007.

Chen, K., Dam, H., Lindsay, P., Abbass, H., "Biasing XCS with domain knowledge for planning flight trajectories in a moving sector free-flight environment", *Proceedings of the 1st IEEE Symposium on Artificial Life*, 2007.

Greenwood, G., Abbass, H., "A new local search algorithm for continuous spaces based on army ant swarm raids", *Proceedings of the 2007 IEEE Congress on Evolutionary Computation*, September 2007; 1097-1102.

Nguyen, M., Alam, S., Abbass, H., "Dynamic weather avoidance in a traffic constrained airspace", *Proceedings of the 2007 EUROCONTROL Innovative Research Workshop*, December 2007.

Ziauddin, U., Sarker, R., Abbass, H., "Improving the performance of genetic algorithm in capacitated vehicle routing problem using self imposed constraints", *Proceedings of the 2007 IEEE Symposium on Computational Intelligence in Scheduling*, April 2007.

General ATC publications

Connelly, S., Lindsay, P., Gallagher, M., "An agent based approach to examining shared situation awareness", *12th International Conference on Engineering of Complex Computer Systems (ICECCS 2007)*, July 2007, 138-147.



Photo by Juha Blomberg



Evolutionary Economic Systems

Program Leader: John Foster

We are applying complex systems and network theory in economics and business to understand how evolutionary change occurs. There are strong connections with earlier approaches taken in evolutionary economics and in dealing with the economics of innovation. Consistent with other programs in the Centre, multi-agent modelling and associated simulation and calibration techniques are core components of the methodology that we are using. With regard to the economic statistics available to us, we are developing new ways of testing for complex patterns in high frequency data. For example, we have been studying trade-by-trade data in stock markets and in electricity markets and seeking 'pattern matches' in artificially generated agent based modelling data. We are also developing new ways of dealing with spatial complexity in several contexts. Also visualisation techniques, rarely used in economics, are being applied in a range of data-rich contexts to better understand the architecture and complex dynamics of systems. Although a key goal in this program is to make fundamental theoretical and empirical advances, care has been taken to work within several applied areas: induction is viewed as very important in the development of new theories, particularly in emergent research fields. In this regard, we feel that it is essential that theories are 'historically friendly' in complex adaptive system settings. This has necessitated the development of new methodological perspectives not previously used in economic research.

Nonlinear econometric modelling: A complex systems perspective

Project Leader: John Foster

Researchers: Melvin Hinich, Phillip Wild

Complexity in real world systems is intrinsically generated by nonlinear interactions amongst system components

that generate unanticipated emergent behaviour commonly associated with complex systems. In this project we have developed statistical techniques that can identify underlying emergent complexity in time series data. This involves applying a battery of nonlinear tests to both confirm the existence and identification of nonlinear interactions. This has been principally based on using relative power of different nonlinearity tests to identify and categorise different types of nonlinear generating mechanisms and confirming complexity through rejections of tests of time reversibility.

In 2007, we finalised work on the software including the trispectrum and have worked on applications to electricity price and load data with a view to generating an assortment of publications over the period 2008-09. This research effort will dovetail with the continuing research on electricity markets in the Centre project 'Optimal allocation of embedded renewable electricity sources throughout the distribution network'.

Recent outputs

Foster, J., Hinich, M., Wild, P., "Randomly modulated periodic signals in Australia's national electricity market", *The Energy Journal*, Vol. 29, No. 1, 2008, 105-130.

Complex networks and the world trade web

Project Leader: John Steen

Researchers: John Foster, Tim Kastle, Peter Liesch, Jason Potts, Sam MacAulay

The study of complex networks is a growing part of the complexity literature that is characterised by the use of statistical mechanics to examine the network properties of a variety of biological, technological, social and economic systems (see Newman 2002 for detailed review). While some work has been done showing that complex network properties exist in directorship networks (Davis 2003), banking investment syndicates (Baum,

Rowley and Shapilov 2004) and inter-firm alliances (Verspagen and Duysters 2004), little has been done in terms of understanding what these properties actually mean for the functioning of these systems. To this extent, the study of world trade networks is still at an embryonic stage that is ripe for theory building and empirical testing. Essentially, we will be using network parameters as independent variables that affect other performance-related variables such as system robustness, information flow and economic growth.

In 2007, the research team has investigated the use of probabilistic methods to analyse the dynamics of the world trade web. These statistical techniques and associated software such as PNet and SIENA are able to determine the mechanisms that drive the evolution of the world trade web as a complex system. For example, applying SIENA to the world trade dataset over the last 100 years has revealed that preferential attachment (i.e. the rich get richer) can partly explain the most recent evolution of the world trade web. It is possible that these longitudinal analyses can be applied to the mechanisms behind the evolution of complex networks more generally.

Eutrophication of the Great Barrier Reef marine ecosystem

Project Leaders: Rodney Beard, Liam Wagner

Researchers: Leighton Brough, John Foster, John Quiggin, Stuart McDonald

The Great Barrier Reef stretches along the continental shelf of the north-east coast of Australia forming a shallow lagoon between the reef and the coast. Human activity along the coast appears to have led to an accumulation of sediments, fertiliser, pesticides and herbicides in the marine environment with unforeseen consequences. The primary driving force behind this has been economic in nature. Integrated socio-economic and environmental modelling is needed to address scientific and community concern about the possible impact of the coastal agriculture on the eutrophication of the Great Barrier Reef lagoon. Complex systems methodology such as non-linear dynamics and self-organised criticality and network modelling is likely to prove useful in analysing possible impacts of human economic activity on a complex marine ecosystem.

In 2007, a generalised model for catastrophe management and the placement of marine reserves was developed by Liam Wagner. This model examines the optimal spacing between marine reserves for maximizing the viability of a species occupying a reserve network. The closer the networks are placed together, the higher the probability of colonisation of an empty reserve by an occupied reserve, thus increasing population viability. However, the closer the networks are placed together, the higher the probability that a catastrophe will cause extinction of the species in both reserves, thus decreasing population viability. Using a simple discrete-time Markov chain model for the presence or absence of the species in each reserve we have determined the distance between

the two reserves which provides the optimal trade-off between these processes, resulting in maximum viability of the species.

Recent outputs

Wagner, L., Ross, J., Possingham, H., "Catastrophe management and inter-reserve distance for marine reserve networks", *Ecological Modelling*, Vol. 201, No. 1, February 2007, 82-88.

Water usage modelling for the Murray-Darling Basin

Project Leader: John Quiggin

Researcher: Liam Wagner

The object of the modelling project is to build a multicatchment model of land and water use in the Murray-Darling Basin, incorporating flexible producer responses to uncertain availability of water for agricultural production. The aim is to provide insights on the implications of alternative specifications for irrigation water rights, environmental flow regimes and other policy. The basic building blocks of the model are catchment-specific farm level models, based on activity analysis, with parameters derived from published gross margin models.

Recent outputs

Adamson, D., Mallawaarachchi, T., Quiggin, J., "Climate change and climate uncertainty in the Murray-Darling Basin", *51st Australian Agricultural and Resource Economics Society Conference*, February 2007.

Adamson, D., Mallawaarachchi, T., Quiggin, J., "Water use and salinity in the Murray-Darling Basin: A state-contingent model", *Australian Journal of Agricultural and Resource Economics*, Vol. 51, No. 3, September 2007, 263-281.

Quiggin, J., "Complexity, climate change and the precautionary principle", *Environmental Health*, Vol. 7, No. 3, 2007, 15-21.

Venn, T., Quiggin, J., "Accommodating indigenous cultural heritage values in resource assessment: Cape York Peninsula and the Murray-Darling Basin, Australia", *Ecological Economics*, Vol. 61, No. 2-3, 2007, 334-344.

Simulation studies of social networks

Project Leader: David Green

Researchers: Sheree Driver, Gary Leishman, Tania Leishman, Suzanne Sadedin

Links between people form networks by which ideas, opinions and attitudes can disseminate throughout societies. This project uses simulation models of social networks to investigate questions such as the formation of social groups, the role of peer influence in marketing, and the effects of economic and resource issues on social behaviour.

In 2007, we investigated the role in social networks of a process, Dual Phase Evolution (DPE), which is a widespread mechanism that underlies self-organisation in many systems. The process occurs in systems that

switch between two phases: a balance phase and a variation phase. Using simulation experiments we showed how DPE may play a role in creating cliques, clusters, modules and other kinds of order within social networks.

Recent outputs

Leishman, T.G., Green, D., "Dual phase evolution - a mechanism for self-organisation and optimisation", *Proceedings of the 11th Asia-Pacific Workshop on Intelligent and Evolutionary Systems*, Edited by Namatame, A., December 2007.

Green, D., Leishman, T.G., Sadedin, S., "The emergence of social consensus in boolean networks", *Proceedings of the 2007 IEEE Symposium on Artificial Life*, April 2007.

Computational game theory

Project Leaders: Stuart McDonald, Liam Wagner

Researchers: Rodney Beard, John Foster

This project is examining the potential for applying global optimisation techniques, based on directed search and machine learning algorithms, for use in computing the equilibria of both static and dynamic non-cooperative games. The emphasis is on designing algorithms that converge on a sample Nash equilibrium that is a Nash refinement and assessing potential gains in computational efficiency from using these algorithms. From this perspective, the focus of this project is on using these algorithms to increase the likelihood of game theory being used as a modelling tool for large, complicated multi-agent systems.

In 2007, research undertaken by Liam Wagner has led to a game theoretical model for electricity pricing on the National Electricity Market (NEM) for the pending National Emissions Trading Scheme (NETS). This dominant firm with competitive fringe model allows for market participants to examine the impacts of carbon trading on wholesale electricity spot prices. This work examines the impact of NETS on market power and whether generators will be able to recover their carbon cost from the wholesale market under perfect and imperfect competition scenarios.

Recent outputs

Menezes, F., Quiggin, J., "Games without rules", *Theory and Decision*, Vol. 63, No. 4, October 2007, 315-347.

Wagner, L., McDonald, S., "Finding traitors in secure networks using Byzantine agreements", *International Journal of Network Security*, 2007.

General EES publications

Bell, P., "Adaptive interactive profit expectations and small world networks", *Journal of Evolutionary Economics*, 2008.

Bowden, M. "Confirmatory bias and the sharing of information within social networks", In: Arabnia A, Yan M and Yang J (Eds), *Proceedings of the 2007 International Conference on Artificial Intelligence*. 2007, 62-70.

Bowden, M., McDonald S "The impact of interaction and social learning on aggregate expectations" *Computational Economics*, 2008.

Earl, P., Peng, T., Potts, J., "Can speculative decision-rule cascades explain asset price inflation?", *Journal of Economic Psychology*, 2007.

Foster, J., Raine A., Potts, J., "The new entropy law and the economic process", *Ecological Complexity*, 2007.

Ghoneim, A., Barlow, M., Abbass, H., "Rounds effect in evolutionary games", *Progress in Artificial Life*, 12 2007; Lecture Notes in Computer Science, Vol. 4828, 72-83.

Ghoneim, A., Abbass, H., Barlow, M., "The critical point when prisoners meet the minority: local and global dynamics in mixed evolutionary games", *Proceedings of the 2007 IEEE Congress on Evolutionary Computation*, September 2007; 3711-3718.

Ghoneim, A., Abbass, H., Barlow, M., "Investigating alliance dynamics using a co-evolutionary iterated prisoner's dilemma with an exit option", *Proceedings of the 2007 IEEE Congress on Evolutionary Computation*, September 2007; 4065-4072.

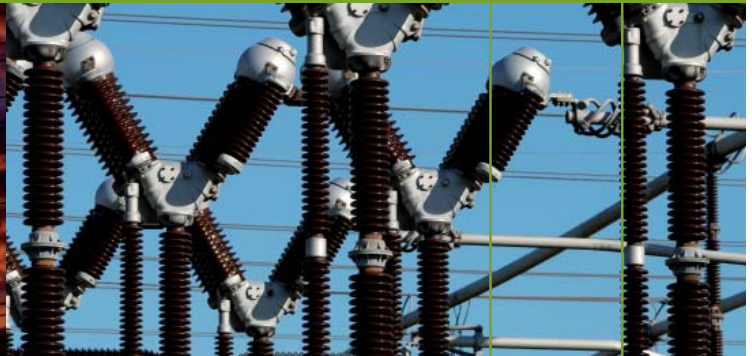
Ghoneim, A., Abbass, H., Barlow, M., "Information sharing in the iterated prisoner dilemma game", *2007 IEEE International Symposium on Computational Intelligence in Games*, April 2007.

Neal, M., "Estimating complex production function: the importance of starting values", *51st Australian Agricultural and Resource Economics Society Conference*, February 2007.

Potts, J., "Can a better theory of rules make for a better theory of institutions?", *Journal of Economics Issues*, 2007.

Potts, J., "Exchange and evolution", *Review of Australian Economics*, 2007.

Potts, J., Morrison, K., "Meso comes to markets", *Journal of Economic Behavior and Organization*, 2007.



Electricity Networks and Energy Markets

Program Leaders: Zhao Yang Dong, John Foster & Ariel Liebman

With the introduction of deregulation, the national electricity network has emerged as an excellent example of a complex system in need of an inter-disciplinary approach to modelling and design. This program investigates how to integrate technical and market aspects of power system and price dynamics to provide key insights into planning expansion of the power transmission network. It also aims to apply modern computational modelling techniques to the interface between the physical properties of the electricity system and its economic considerations. A particular focus is placed on the impacts of the transmission network and power station operation on electricity price behaviour and its influence on infrastructure investment decisions. It also looks into the importance of customer-load impact on system and market operations.

Optimal allocation of embedded renewable electricity sources throughout the distribution network

Project Leader: Ariel Liebman

Researchers: David Abramson, Ngoc Dinh, Zhao Yang Dong, John Foster, Tien Duc Pham, Phillip Wild

The study requires the simulation of the Australian electricity network down to the level of the distribution sub-station where we assume that generation resources are connected at the sub-station and the total amount of generation is less than 30MW (the level below which generators have to be registered with the National Electricity Market). The study will be formulated as a combinatorial optimisation problem where the total generation at each substation is composed of several units of renewable and low emission generation

resources selected from the following set of generation technologies: wind turbines, solar photovoltaic, solar thermal, biomass, micro-turbine (gas-fired), and geo-thermal. Each of these different types of generating technologies has different capital costs, fixed maintenance costs, and variable operation costs. Additionally, the rate at which the capital costs decrease over the long term is different for each technology, with each rate being uncertain and having different degrees of uncertainty. Additional uncertainties exist in the long term forecasts for demand growth, fuel costs (e.g. coal, gas, distillates and bio-fuels such as bio-diesel).

In order to perform the simulation required by this project, the Plexos electricity market simulation software needs to be used. As Plexos is highly computationally intensive it requires the Nimrod grid computing engine. In 2007 a software development effort began to diversify Nimrod for the Windows platform which is currently the only platform on which Plexos operates.

Recent outputs

Cao, G., Dong, Z., Wang, Y., Zhang, P., "A SVC controller design for power systems with FACTS devices", *IEEE Power Engineering Society General Meeting*, 2007.

Electricity market price analysis and risk management with advanced data mining techniques

Project Leader: Zhao Yang Dong

Researchers: Ke Meng, Dianhui Wang, Kit Po Wong, Xia Donna Yin, Junhua Zhao, Xun Zhou

This project aims to develop methodologies and tools for market analysis and system security assessment from a complex system's point of view using data-mining based methods. The electricity network as a complex system exhibits economical as well as physical characteristics. This research will look into two of the most important aspects about an electricity network in a

market environment, namely market price and system security. Specifically, the objectives of this project are to investigate the complex and highly volatile price spikes in an electricity market, and to develop advanced tools to correctly model and predict the price spike. At the same time, the power system behind the electricity market must maintain a secure state to ensure the functionality of the market. System security/stability is the primary responsibility of the system operator (usually also the market manager). This project will also investigate the features of an electricity network with respect to its stability/security. The aim is to identify the major factors that contribute to possible system failure, and to predict instability events which may lead to system blackouts.

In 2007, a framework for power system transmission and expansion to allow flexibility of planning options was developed. This framework explores the market as well system analysis methods in planning area. It includes techniques developed earlier as well as proposed new research methodologies. An ARC Discovery Project application was lodged in 2008 based on research into this framework. As part of this general framework, previous research in electricity market forecasting, in power system security assessment and in decision making are also included. Four journal papers were published. A paper was published with SIGKDD, the premier conference in data mining area. The research has lead to a comprehensive approach for price spike analysis, and for power system contingency assessment to prevent cascading failure.

Recent outputs

Luo, Y., Xue, Y., Dong, Z., "Composite optimisation of generation capacity adequacy", *Automation of Electric Power Systems*, 2007.

Nizar, A., Dong, Z., Zhao, J., Zhang, P., "Empirical study on NTL analysis references", *IEEE Power Engineering Society General Meeting*, 2007.

Wang, H., Xue, Y., Dong, Z., "Adaptive optimal restoration control for interconnected grids", *Automation of Electric Power Systems*, 2007.

Xu, N., Wen, F., Huang, M., Dong, Z., "Optimal parameter setting of performance based regulation with reward and penalty", *Proceedings IEEE Congress on Evolutionary Computing*, 2007.

Xue, Y., Lu, H., Li, B., Lu, J., and Dong, Z., "On interruptible load participation in the power system in standby", *Automation of Electric Power Systems*, 2007.

Zhao, J., Dong, Z., Li, X., "An improved Naive Bayesian classifier with advanced discretisation method.", *International Journal Intelligent Systems Technologies*, Vol. 3, No. 3/4, 2007, 241-256.

Zhao, J., Dong, Z., Li, X., "Electricity market price spike forecasting and decision making", *IET Generation, Transmission & Distribution*, Vol. 1, No. 4, July 2007, 647-654.

Zhao, J., Dong, Z., Li, X., Wong, K., "A framework

for electricity spike analysis with advanced data mining methods", *IEEE Transactions on Power Systems*, Vol. 22, No. 1, February 2007, 376-385.

Zhao, J., Dong, Z., Zhang, P., "Mining complex power networks for blackout prevention", *Proceedings of the 13th ACM International Conference on Knowledge Discovery and Data Mining*, August 2007, 986-994.

Zhao, J., Li, X., Dong, Z., "Online rare events detection", *Proceedings of Pacific-Asia Conference on Knowledge Discovery and Data Mining (PAKDD'07)*, 2007, Vol. 4426, 1114-1121.

Impacts and risk of emissions trading on electricity generation companies and projects

Project Leader: Ariel Liebman

Researchers: John Foster, Fabio Barelli, Lukas Skoufa

This project develops and applies a stochastic model for the assessment of the impacts of a CO₂ emissions trading scheme on Australian and international power generation entities. These entities could be new investments in power generation plant or existing power generation companies or utilities. Particular focus is placed on the statistical nature of key economic factors affecting the profitability of a power generation entity. These include input fuel costs and electricity outputs. Careful attention needs to be paid to the correlations between the input costs (particularly coal or gas market prices), the emission permit prices, which need to be postulated since no such scheme exists in Australia yet, and electricity market prices. The quantities to be analysed to assess risks and opportunities to the generation entities are the Profit and Loss probability distributions.

In 2007, a comprehensive investment model for a variety of generation technologies was developed with an annual resolution. The technologies the model can assess include, coal fired (from old to next generation ultra-critical power stations), gas fired, wind, solar and others. The simulation is on Microsoft Excel spreadsheets but uses monte-carlo simulation engines built by commercial third parties. This model can easily be deployed in a commercial setting. The model currently enables the comparison of the risks of various new ventures and the trade-off between investment costs and running costs can be explored. Preliminary results have been presented at industry forums and have received favourable feedback.

Recent outputs

Wang, H., Xue, Y., Dong, Z., Yin, X., "Start power supply service in power markets", *Automation of Electric Power Systems*, 2007.

Vehicle-2-Grid

Project Leader: Ariel Liebman

Researchers: Geoff Walker, Zhao Yang Dong, Tapan Saha

This project aims to determine the feasibility of the use of hybrid wheeled vehicles (car) connected to an electricity grid. These are also known as plug-in-hybrid technologies

to enable the introduction of large-scale renewable energy and at the same time produce significant improvements in the performance of power systems and markets in a changing global energy environment with a special focus on enabling the growth of renewable generation. Specifically the concept involves the modelling of the effects of the use of batteries installed in electric powered or hybrid cars to supply the grid or offset the local demand. Proof of concept connections of hybrid car (Toyota Prius) already exist (www.acpropulsion.com/white_papers.htm). The motivating aspect of the use of these technologies is the potential benefit of having a large amount of distributed energy storage on the grid at all times in order to be able to respond to various short-term events on the system. In particular events, such as a sudden increase or drop in supply or demand on a timescale of minutes, the possible benefits are economic, environmental and physical.

In 2007, this project has taken on three final year engineering students in order to assess various aspects of the technology. The students have performed literature reviews of battery technology development as well as impacts on transmission expansion costs and impacts on renewable energy deployment. This enables the research to move on to a stage where an integrated view of the impact of V2G on the electricity system can be thoroughly explored.

Impacts of climate change on the Snowy Hydro system

Project Leader: Liam Wagner

Researchers: Rohan Alexander, John Quiggin, Ariel Liebman, Lukas Skoufa

This project aims to analyse the impacts of climate change on the generation profile of the Snowy Hydro scheme by evaluating natural inflow of water from snow melts and rain fall into the three dams which provide the fuel source for power generation. Furthermore, analysis will also need to be performed on the internal demand of the SNOWY1 region on the National Electricity Market (NEM), which may indicate pumping of water for reuse.

Snowy Hydro's generation performance has been significantly affected during 2007 due to declining inflows into their dam storage network. This project has been performing analysis of electricity production by Snowy Hydros units, its Bid Stacks and use of pump storage during off peak hours of operation. The results from this investigation currently indicate that Snowy's future viability as a generator of clean renewable electricity for peak demand is under question.

Electricity network expansion planning in a market environment

Project Leader: Zhao Yang Dong

Researchers: David Hill, Ariel Liebman, Yateendra Mishra, Jennie Miao Lu, John Zhe Lu, Ke Meng, Anisah Nizar, GuangYa Yang, Xia Donna Yin, Xun Zhou

This project is investigating how to integrate technical and market aspects of power system dynamics and price dynamics in order to provide key insights into planning expansion of the power transmission network. This project aims to apply modern computational modelling techniques to the interface between the physical properties of the electricity system and its economic considerations. A particular focus is placed on the impacts of the transmission network and power station operation on electricity price behaviour and its influence on infrastructure investment decisions. It also looks into the importance of customer load impact on system and market operations.

Research work in electric power and networks continued to generate many outcomes in 2007. These included new computational methods for electricity market and power system analysis; load modelling and its impact on system dynamic characteristics and planning; and risk management in electricity markets and its impact on power system planning.

Recent outputs:

Ali, M., Dong, Z., Zhang, P., Li, X., "Probabilistic transient stability analysis using grid computing technology", *IEEE Power Engineering Society General Meeting*, 2007.

Liu, Q., Xue, Y., Dong, Z., "Nondeterministic analysis for transient stability based on transient stability domain and conditional probability", *Automation of Electric Power Systems*, 2007.

Liu, Q., Xue, Y., Dong, Z., "The abnormal effects of line fault location on the transient stability and its mechanism", *Automation of Electric Power Systems*, 2007.

Lu, M., Dong, Z., "A probabilistic load flow method considering transmission network contingency", *IEEE Power Engineering Society General Meeting*, 2007.

Ma, J., Dong, Z., He, R., Hill, D., "Measurement-based load modelling using genetic algorithms", *Proceedings of IEEE Congress on Evolutionary Computing*, 2007.

Ma, J., Han, D., He, R., Dong, Z., Hill, D., "Research on identifiability of equivalent motor in composite load model", *Proceedings of Power Tech*, 2007.

Ma, J., Han, D., He, R., Dong, Z., Zhang, P., "Reducing identified parameters of measurement-based composite load model", *IEEE Transactions on Power Systems*, Vol. 23, No. 1, February 2008, 76-83, 2008.

Ma, J., Hill, D., Dong, Z., He, R., "System energy analysis incorporating comprehensive load characteristics", *IET Generation, Transmission & Distribution*, Vol. 1, No. 6, 2007, 885-863.

Makarov, Y., Dong, Z., Hill, D., "On convexity of power flow feasibility boundary", *IEEE Transmission on Power Systems* (letter), 2007.

Makarov, Y., Ma, J., Dong, Z., "Determining static stability boundaries using a non-iterative method", *IEEE Power Engineering Society General Meeting*, 2007.

Makarov, Y., Ma, J., Dong, Z., "Non-iterative method to determine static stability boundaries", *IEEE Power Engineering Society General Meeting*, 2007.

Sampepajung, H., Lu, Z., Dong, Z., Zhang, P., "Investigation into the Indonesia power industry for implementation of a competitive generation market", *IEEE Power Engineering Society General Meeting*, 2007.

Wong, K., Dong, Z., "Differential evolution, an alternative approach to evolutionary algorithm", *Modern Heuristic Optimization Techniques: Theory and Applications to Power Systems*, Edited by Lee, K., El-Sharkawi, M., Wiley, 2007.

Xue, Y., Xu, W., Dong, Z., "A review of wide area measurement system and wide area control system", *Automation of Electric Power Systems*, 2007.

Yang, G., Dong, Z., Wong, K., "A modified differential evolution algorithm with fitness sharing for power system planning", *IEEE Transactions on Power Systems*, 2007.

Yang, G., Hovland, G., Dong, Z., "TCSCs allocation based on line flow equations via mixed-integer programming", *IEEE Transactions on Power Systems*, Vol. 22, No. 4, December 2007, 2262-2269.

Yang, G., Mishra, Y., Dong, Z., Wong, K., "Optimal power system stabiliser tuning in multi-machine system via an improved differential evolution", *IEEE Transactions on Power Systems*, November 2007.

Agent based modelling for electricity price simulation

Project Leader: Ariel Lieberman

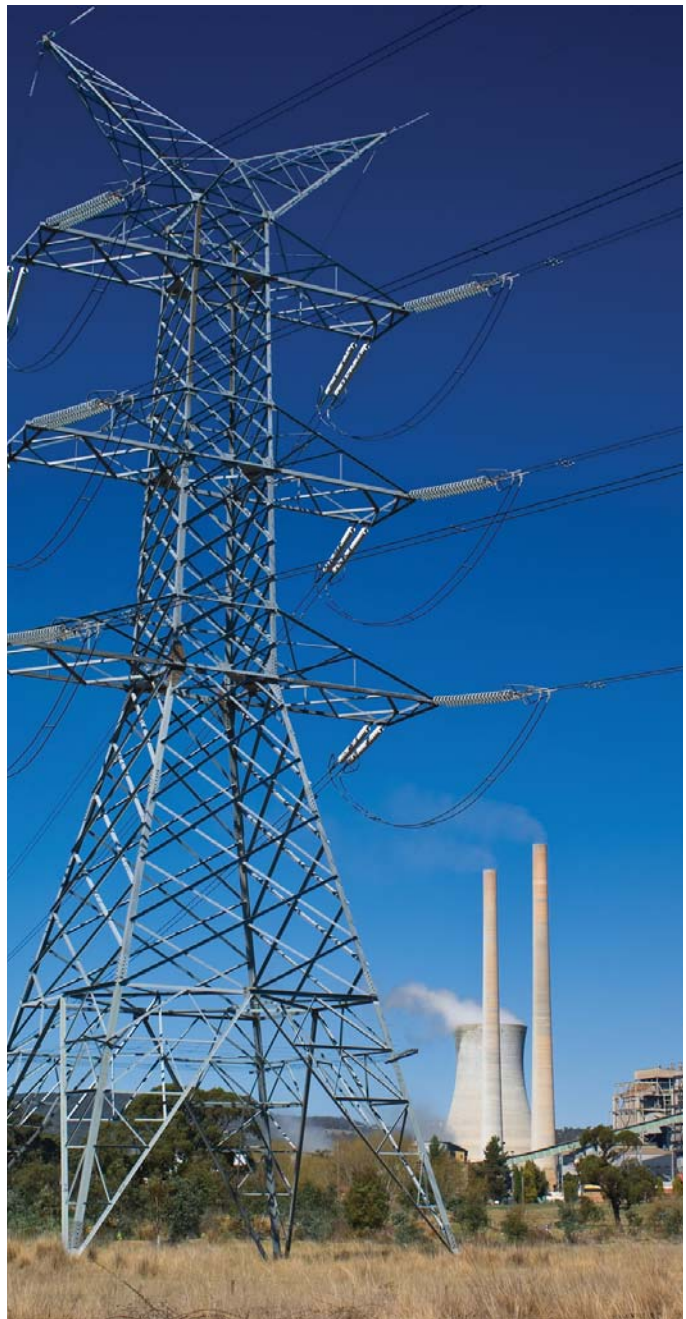
Researchers: Mark Bowden, Zhao Yang Dong, John Foster

Electricity markets have developed around the world over the past 15 years. However, these markets are mostly still in a maturing phase and data is not reliable or at best not representative of the full range of outcomes possible. This project aims to develop an agent based simulation model which can reproduce the sort of price statistics that are seen in a variety of markets. The innovative approach of this project is to incorporate both physical electricity trading and trading in secondary markets (futures and forward markets). The results of the simulation will be electricity prices across both markets and could be used to test the sensitivity of electricity price behaviour to changes in market structure and number of participants.

In 2007, a new software tool was developed to implement the model developed in the previous year. Currently the software is able to simulate an electricity system consisting of a number of electricity generator agents bidding into a gross pool market. The prices emerging from the simulation bear some resemblance to prices seen in Australia's electricity markets. Future work includes agents responding to profit outcomes and forward market trading through a small-world network of trading partners.

General NEM publications

Memisevic, R., Sanderson, P., Wong, W., Choudhury, S., Li, X., "Investigating human-system interaction with an integrated hydropower", *IEEE Transactions on Power Systems*, 2007





Dependable Computer-Based Systems

Program Leaders: Geoff Dromey, Ian Hayes, Peter Lindsay

The rapid pace of advances in Information and Communications Technology (ICT) has led to technological systems of ever increasing complexity and sophistication. Many of these systems - in areas such as transport, health and finance - need to be safe, reliable and generally dependable. There is a constant need for new methods and tools to enable engineers to ensure that such systems meet society's demands for dependability. This program is concerned with the development of modelling and analysis tools to ensure that dependability is designed into complex computer-based systems.

Analysing the requirements for large-scale software-integrated systems

Project Leaders: Danny Powell, Terry Stevenson

Researchers: Jim Boston, Geoff Dromey, John Seagrott

This project has been designed to assess the effectiveness of using the analysis method we have developed using Behavior Trees and Composition Trees for modelling and finding major defects in acquisition and functional performance requirements documentation for large-scale, nationally critical Defence projects. The requirements documentation for six large projects were analysed, each involving approximately 1000 requirements. In each case the analysis was carried out after normal reviews and inspections had been conducted and after the defects found by these methods had been corrected. The project is largely funded by Raytheon Australia.

A major outcome of this work in 2007 has been that across all projects we found on average an additional 130 major (confirmed) defects/1000 requirements after normal reviews and corrections had been made. The early detection and resolution of such defects translates into substantial cost savings on a project — without this analysis intervention these defects would have flowed through to later stages of the project where their impact would have escalated project costs. What is also important is that the cost of finding a defect is roughly \$70 and it takes only about 100 hours to analyse 1000 requirements. Feedback from one project manager was as follows: "I see it as a key risk mitigation strategy, of use in both solution development and as a means of advising the customer on problems with the acquisition documentation. Our team now has a strong understanding of the FPS, at the cost of a relatively small investment. Whilst similar results could have been achieved using conventional processes, the cost and time involved would have been far greater". These industry trial results provide strong evidence for the scalability and effectiveness of the method.

Raytheon Australia has provided the funding to develop an industrial strength modelling tool based on the DCS team's prototype. This tool became available in January 2008. Raytheon Australia is moving to adopt the method as part of their standard process. Raytheon Company (73 000 employees) is about to start evaluation trials with use of the method and Raytheon Australia will be employing the method on one of Australia's largest projects. Currently we are also conducting trials with other companies and the Queensland Education Department.

Recent outputs

Powell, D., "Requirements evaluation using Behavior Trees – Findings from industry", *Australian Software Engineering Conference (ASWEC'07)*, Melbourne, April, 2007.

Taming complexity: Building large-scale systems



Information and communications technology underpins all modern infrastructure. This has created a need to construct software-intensive and software-integrated systems of unprecedented scale and complexity.

Two recent international reports imply existing approaches to developing such systems are struggling to cope with this complexity.

Existing approaches are struggling to cope with this complexity

One report estimates that US\$290 billion per annum is attributable to wastage arising from IT project failures across the United States and the European Union (RAE/BCS Report, April 2003). A second report documents recent high-profile project failures (Charrett, IEEE Spectrum, 2005).

Proportionally, the level of project wastage and project failure in Australia is likely to be no better than in Europe or North America — it must therefore be costing Australia at least hundreds of millions of dollars each year.

Failure to control complexity poses a great risk to project success in building large-scale systems. Thousands of requirements written in natural language are initially used to describe the needs for a combat system for a modern destroyer or an integrated transportation system for a city and many other such systems.

Typically these systems cost hundreds of millions of dollars to implement and they carry with them a high risk of unacceptable project wastage, cost blowouts and schedule overruns — and even outright failure in some cases, such as the Sydney public transport smartcard project.

The thousands of requirements used to design such systems, contain many ambiguities, inconsistencies and defects simply because no individual has the memory capacity to see the system as a whole or comprehend all the potential interactions and problems among such large sets of requirements. As a consequence many defects end up being built into large-scale systems reducing their dependability and causing high development and maintenance costs.

No individual has the memory or capacity to see the system as a whole

The Centre has developed and has been trialling with industry a very different way of handling requirements complexity and removing defects from large sets of requirements - the Behavior Engineering method.

System engineers initially turn each individual requirement into a Behavior Tree. They then integrate the Behaviour Trees in a manner similar to the way a set of jigsaw puzzle pieces are put together.

The integrated picture allows us to understand the behaviour of the system without overflowing our short-term memory. It can be refined to create first a design and then an implementation for the system. Substantial productivity gains flow from this simpler development method.

Further details of the method can be found at www.behaviorengineering.org

Quantitative modelling and analysis with Behavior Trees

Project Leader: Lars Grunske

Researchers: Robert Colvin, Kirsten Winter

Complex systems often exhibit real-time and stochastic behaviour. To analyse requirements of such systems a modelling notation is needed to capture timing and probabilistic constraints. This also needs to be supported by tools for automated analysis.

In 2007, the Behavior Tree notation was extended to express both real-time and probabilistic behaviour. An existing tool was also extended with an interface supporting the use of the graphical notation of Behavior Trees. We applied our approach to case studies that were derived from the requirements of medical equipment.

Recent outputs

Colvin, R., Grunske, L., Winter, K., "Probabilistic timed Behavior Trees.", *Proceedings of 6th International Conference on Integrated Formal Methods (IFM 2007)*, 2007; Lecture Notes in Computer Science, Vol. 4591, 156-175.

Grunske, L., Winter, K., Colvin, R., "Timed Behavior Trees and their application to verifying real-time systems", *Proceedings of 18th Australian Conference on Software Engineering (ASWEC 2007)*, April 2007.

Model-based development of safety-critical systems

Project Leader: Peter Lindsay

Researchers: Robert Colvin, Geoff Dromey, Lars Grunske, Kirsten Winter, Nisansala Yatapanage, Saad Zafar

The use of model-driven software engineering is steadily growing. In this paradigm engineers work directly with models, and computer programs are generated automatically from the models. However, the evidence required for system safety assurance currently still has to be derived by hand. This project aims to develop new methods for automated evaluation of safety properties from models. Specifically the project is developing encapsulated models for computer-based systems. The project is funded in part by the Boeing Chair grant.

In 2007, we have created an automatic approach for probabilistic FMEA based on probabilistic model checking. This approach has been applied to the case study of an ambulatory infusion pump (medical device). Furthermore, we developed an outline of an architecture-based method for optimising dependability attributes of software-intensive systems.

Recent outputs

Grunske, L., Colvin, R., Winter, K., "Probabilistic model-checking support for FMEA", *Proceedings of 4th International Conference on the Quantitative Evaluation of SysTems (QEST 2007)*, 2007, 119-128.

Grunske, L., Lindsay, P., Bondarev, E., Papadopoulos, Y., Parker, D., "An outline of an architecture-based

method for optimising dependability attributes of software-intensive systems", *Architecting Dependable Systems IV, Lecture Notes in Computer Science*, Vol. 4615, Springer, August 2007, 188-209.

Smith, G., Winter, K., "Model checking action system refinements", *Formal Aspects of Computing*, 2007.

Zafar, S., Colvin, R., Winter, K., Yatapanage, N., Dromey, R.G., "Early validation and verification of a distributed role-based access control model", *14th Asia-Pacific Software Engineering Conference (APSEC2007)*, December 2007, Japan, 2007; 430-437.

Foundations of Behavior Trees

Project Leaders: Geoff Dromey, Ian Hayes

Researcher: Robert Colvin

Behavior Trees are a new framework which allows the functional behaviour of a system to be constructed out of its requirements. Behavior Tree notation is easy to learn and use, and can be used to model a wide range of complex systems, including large software systems and biological and chemical processes. This project is developing a formal semantics for the Behavior Tree framework, which will help to precisely define and compare systems, and allow automated tool support for the development of software in the framework. The project will also extend the Behavior Tree language and semantics to handle real-time and stochastic specifications.

In 2007, progress was made with developing a framework with enough expressive power to formalise the complex relational behaviour that is often found in large-scale real-world systems. A framework was developed and applied in representing complex behaviour in six large-scale projects. The framework provides a way of structuring and decomposing complex behaviour into fragments that can be individually formalised and then composed. This development should provide a basis for the formalisation necessary to support simulation and model-checking.

Recent outputs

Colvin, R., Hayes, I.J., "A semantics for Behavior Trees", *ACCS Technical Report*, No. ACCS-TR-07-01, ARC Centre for Complex Systems, April 2007.

Grunske, L., Winter, K., Yatapanage, N., "Defining the abstract syntax of visual languages with advanced graph grammars - A case study based on Behavior Trees.", *Journal of Visual Languages and Computing*, 2008.

Collaborative software engineering based on Behavior Trees

Project Leader: Geoff Dromey

Researchers: David Chen, Kevin Lin

A Real-time Collaborative Genetic Software Engineering system (CoGSE) allows a group of users to view and edit the same Behavior Tree representation at the same time from different sites. To develop CoGSE, we have been investigating constraint maintenance in collaborative

systems. Constraint maintenance is an important issue in single-user CAD and CASE tools. In collaborative systems, constraint maintenance becomes even more complicated due to the generation and execution of various combinations of concurrent and dependent operations. In CoGSE, constraint maintenance is required to maintain Behavior Tree structure and to resolve conflicts. Tasks include multi-user editing of Behavior Trees, visualisation methods and collaborative computing methods.

In 2007, an editing tool for Behavior Trees was designed and a collaborative facility was implemented. The resulting tool was used for developing many of the case studies used by other sub-projects in this research stream.

Recent outputs

Lin, K., Chen, D., Dromey, R.G., Sun, C., "Maintaining constraints expressed as formulas in collaborative systems", *3rd International Conference on Collaborative Computing: Networking, Applications and Worksharing*, November 2007.

Lin, K., Chen, D., Dromey, R.G., Xia, S., Sun, C., "API design recommendations for facilitating conversion of single-user applications into collaborative applications", *3rd International Conference on Collaborative Computing: Networking, Applications and Worksharing*, November 2007.

Lin, K., Chen, D., Sun, C., Dromey, R.G., "Leveraging single-user Microsoft Visio for multi-user real-time collaboration", *Proceedings 4th International Conference Cooperative Design, Visualization, and Engineering, CDVE 2007*, September 2007; Lecture Notes in Computer Science, Vol. 4674, 353-360.

Wen, L., Colvin, R., Lin, K., Seagrott, J., Yatapanage, N., Dromey, R.G., "Integrare, a collaborative environment for behavior-oriented design", *Proceedings 4th International Conference on Cooperative Design, Visualization, and Engineering*, September 2007; Lecture Notes in Computer Science, Vol. 4674, 122-131.

Verification of lock-free algorithms

Project Leader: Robert Colvin

Researchers: Brijesh Dongol, Lindsay Groves, Ian Hayes, Victor Luchangco, Mark Moir

Computer systems are increasingly being used to tackle problems involving interactions between hundreds of independent processes, all competing for access to some central data store. The algorithms underlying such complex computer systems can be implemented using a new technique, called a 'lock-free' approach, which provides significant improvements in efficiency over existing implementation techniques. However the benefits come at the cost of increased complexity of the algorithms involved. This project will investigate effective strategies for verifying lock-free algorithms, building on earlier work using I/O Automata and simulation techniques.

In 2007, existing research links with Sun Laboratories in Boston, USA, and Victoria University of Wellington, NZ, were strengthened when Dr Colvin visited Sun Laboratories in October. This resulted in expanding the collaboration to include researchers at MIT, Naval Research Laboratories, and a private company, whose specification and verification tools will be used by the project in 2008.

Recent outputs

Colvin, R., Dongol, B., "Verifying lock-freedom using well-founded orders", *The 4th International Colloquium on Theoretical Aspects of Computing*; Lecture Notes in Computer Science, Vol. 4711, 2007, 124-138.

Colvin, R., Groves, L., "A scalable lock-free stack algorithm and its verification", *Fifth IEEE International Conference on Software Engineering and Formal Methods (SEFM 2007)*, September 2007, London, UK, 339-348.

Groves, L., Colvin, R., "Derivation of a scalable lock-free stack algorithm", *Electronic Notes Theoretical Computer Science*, Vol. 187, 2007, 55-74.

Change management: Formalising the impact of requirements change on design

Project Leader: Geoff Dromey

Researchers: Toby Myers, Lian Wen

This project involves using Behavior Trees to model requirements change. One aspect is the investigation of a formal process to map the changes from the functional requirements into the software design, which includes the component architecture, the component behaviours and the component interfaces. The other aspect is the investigation of the impact of change of functional requirements on the component architecture, and how this impact may be reduced or prevented, thereby making the software system more stable and easier to maintain.

In 2007, we submitted a paper on evolutionary change of systems to the journal *ACM Transactions of Software Engineering*.

Recent outputs

Wen, L., Kirk, D., Dromey, R.G., "A tool to visualize behavior and design evolution", *International Workshop on Principles of Software Evolution (IWPSE2007)*, 114-115, 2007.

General DCS publications

Jones, C., Hayes, I.J., Jackson, M., "Deriving specifications for systems that are connected to the physical world", *Formal Methods and Hybrid Real-Time Systems*, Lecture Notes in Computer Science, Vol. 4700, Springer, 2008.



Photo by Mateusz Atroszko

Complex Systems Theory and Applications

In addition to the research programs described above, the ACCS includes a number of projects addressing key problems for complex systems. The projects are concerned with the application of theory to solve issues in the design and operation of complex socio-technological systems, and with the development of new analysis techniques for complex systems.

Application of Grid computing to complex systems modelling

Project Leader: David Abramson

Researchers: Colin Enticott, Slavisa Garic, Tom Peachey

Over the last several years, combinations of super-computers, or Grids, have been developed which couple geographically distributed resources such as high-performance computers, workstations, clusters of computers, and scientific instruments. Grids such as the US-based TeraGrid have begun to provide the infrastructure to support global collaboration in science and engineering in ways that were not previously possible. Many complex systems models have enormous resource requirements. In this project we investigate the application of Grid computing to these complex systems models, and illustrate the utility of this approach. In particular, we shall apply and further develop a number of Grid specific methodologies and tools.

In 2007, we explored the use of Grid computing in designing optimal energy management strategies. This has resulted in a new project devoted to this activity (see page 18 - 'Optimal allocation of embedded renewable electricity sources throughout the distribution network'). We are currently implementing the necessary infrastructure to allow us to run an industry energy modelling package on distributed Windows-based computers.

Recent outputs

Ayyub, S., Abramson, D., "GridRod - a service oriented dynamic runtime scheduler for Grid workflows", *Proceedings of the 21st ACM International Conference on Supercomputing*, June 2007.

Ayyub, S., Abramson, D., Enticott, C., Garic, S., Tan, J., "Executing large parameter sweep applications on a multi-VO testbed", *Proceedings of the Seventh International IEEE Symposium on Cluster Computing and the Grid*, May 2007.

Zheng, C., Katz, M., Papadopoulos, P., Abramson, D., Ayyub, S., Enticott, C., Garic, S., Goscinski, W., Arzberger, P., Lee, B., Phatanapherom, S., Sriprayoonsakul, S., Uthayopas, P., Tanaka, Y., Tanimura, Y., Tatebe, O., "Lessons learned through driving science applications in the PRAGMA grid", *The International Journal of Web and Grid Services*, Vol. 3, No. 3, 2007, 287-312.

Distributed computing for interactive modelling research

Project Leader: Janet Wiles

Researchers: Jon Kloske, Bernard Pailthorpe, James Watson

The goal is to develop a system to test the viability of using undergraduate laboratories for real-time research. The motivation for this project is that in complex systems modelling (1) the interactive exploration of large parameter spaces is fundamental to understanding system dynamics, and (2) the simulation development process involves iterative testing and refinement cycles. A single trial of one of our complex systems models typically takes several minutes to run. Therefore it is feasible to test a small number of options within a session on a single machine, but batched runs must be performed to analyse larger parameter sets and systems. When macro-scale effects need to be tested

over large parameter sets, using batched runs slows the identification of interesting results and the refinement of the computational models. Distributed computing is a solution that enables interactive exploration of parameter spaces where the computational load is the limiting factor. This project is part-funded by the Queensland Cyber Infrastructure Foundation (QCIF).

In 2007, a software prototype for interactive distributed computing was developed by James Watson in collaboration with Jon Kloske. A software prototype was developed and tested in the IT&EE student labs at The University of Queensland, which successfully demonstrated the feasibility of interactive, distributed computing for complex systems models. The software continues to run in those labs. A summary report is published on the QCIF website at: www.qcif.edu.au/research/Reports/InterModelFinalReport. This work was presented at Oxford at the Seventh International Workshop on Information Processing in Cells and Tissues.

Recent outputs

Watson, J., Maetschke, S., Wiles, J., "Dsweep: A lightweight tool for distributed parameter sweeps", *Proceedings of the Seventh International Workshop on Information Processing in Cells and Tissues*, August 2007.

Watson, J., Wiles, J., "QCIF report: An on-site survey of high performance computing", *Queensland Cyber Infrastructure Foundation Technical Report*, November 2007.

High performance complex systems simulation project

Project Leader: David Abramson

Researchers: Colin Enticott, Tom Peachey

In-silico experimentation is increasingly being used to understand the behaviour of complex systems when it is not possible to perform real world experiments. For example, a computer simulation of an electrical distribution grid, a genetic regulatory network, an air traffic control system or a healthcare system, might model the behaviour of that system under particular conditions that cannot be tested in the real. Running this model might show what happens when certain input conditions are present. However, to fully understand the dynamics of the system, it is necessary to explore what happens when many inputs change. Moreover, to get results that are statistically significant, it might be necessary to run the model many times with different initial conditions. This can require enormous amounts of computing time. Recently, combinations of super-computers, or Grids, have been developed which couple geographically distributed resources such as high-performance computers, workstations, clusters of computers, yielding potentially very large distributed supercomputers. In previous research we have developed a methodology (parametric modelling) and software environment (Nimrod [1]) for performing very large in-silico experiments of the

type discussed using Grids. In this project we will apply parametric modelling to a range of ACCS supported complex systems modelling experiment; and augment Nimrod with new capabilities for exploring complex systems.

Factorial and fractional factorial designs are the most commonly used experimental designs, but have been under used in computer experiments. To facilitate these techniques, in 2007 we have developed tools that automatically generate fractional factorial designs, perform the experiment, and then provide an analysis of the results. The tools interface with an existing tool called Nimrod/G, which is used to organise the execution of the model using the parallelism offered by a computational grid. The new system, known as Nimrod/E, augments the existing Nimrod tool chain.

Experimental design

Project Leader: Anne Street

Researchers: Diane Donovan, Ken Gray, George Havas, Colin Ramsay

Experimental designs can be thought of as arrangements of elements of a set into subsets with pre-determined properties desirable for particular applications in particular situations. Such arrangements are characterised and described by various factors, including: their current and potential fields of application, such as in cryptographic protocols, or in planning sample surveys or clinical experiments or marking schemes for tests, and so on; their properties; their size and complexity; and their origins, possibly from algebraic structures or from finite geometries or from computer search, or from some combination of these. Each such factor is a potential subject of interest in its own right, but the research proposed in this case aims to identify and address problems and complexities that arise when several, if not all, of these factors are in play. These arrangements are often conveniently represented by graphs, involving us in graph theory for many examples and applications.

In 2007, we have continued with earlier work on secret sharing schemes, especially on problems with the use of minimal defining sets for secret sharing; Sudoku squares; critical sets in Latin squares; applications of partitions of full designs of triples into small planes; and computational techniques for investigating simple groups which are likely to be applicable in these areas.

Recent outputs

Gray, K., Street, A., "Defining sets", *Handbook of Combinatorial Designs*, Edited by Colbourn, C., Dinitz, J., 2nd Edition, Chapman & Hall/CRC, Taylor & Francis Group, 2007, 382-385.

Gray, K., Street, A., "On defining sets of full designs and of designs related to them", *Journal of Combinatorial Mathematics and Combinatorial Computing*, Vol. 60, 2007, 97-104.

Mathon, R., Street, A., Gamble, G., "Classification of partitions of the set of all triples on ten points into copies of Fano and affine planes", *Discrete Mathematics*, 2007.

Street, D.J., Street, A., "Partially balanced incomplete block designs", *Handbook of Combinatorial Designs*, Edited by Colbourn, C., Dinitz, J., 2nd Edition, Chapman & Hall/CRC, Taylor & Francis Group, 2007, 382-5.

Software architecture and scale-free networks

Project Leader: Geoff Dromey

Researcher: Lian Wen

This project studies the evolution and topological structure of large software systems and their relationships with scale-free networks. We have found that the component architecture of all the tested Java packages is scale-free, and that a close relationship exists between optimised sorting algorithms and scale-free networks. This will lead to practical methods by which to control and manage the architecture of large software systems, as well as encouraging further research into their evolution.

We have built a tool to study software systems as complex networks. In our paper we suggest ways of controlling and changing how systems evolve to make them easier to understand and maintain. We are also currently revising a paper titled 'Software engineering and scale-free networks' for publication in *IEEE Transaction on Systems, Man and Cybernetics*.

Recent outputs

Wen, L., Kirk, D., Dromey, R.G., "Software systems as complex networks", *The 6th IEEE International Conference on Cognitive Informatics*, 106-115, 2007.

Multi-objective optimisation

Project Leader: Hussein Abbass

Researchers: Lam Bui, David Green

When solving many real life problems, one is usually faced with two or more objectives that are in conflict, requiring the need for a compromise between the conflicting objectives. Multi-objective optimisation is about solving problems with conflicting objectives. In this project, we develop robust multi-objective optimisation techniques for decomposing and solving complex problems with many constraints and variables in the existence of noise.

In 2007, we have succeeded in introducing a distributed framework of local models using explicit niching as an overarching umbrella to solve multi-objective optimisation problems (MOPs). The concept behind the framework is for the search to be decomposed and to be conducted locally in different areas of the decision search space (creating local models), which allows the local models to be distributed on different processing nodes. The interaction among models is controlled and utilised by simple rules inspired from well-known paradigm: Particle Swarm Optimisation. The framework has been validated in both noisy and noise-free environments. Several important parts of the obtained results have been published (or accepted) by two Springer journals with high ISI impact factors. Dr Lam Bui successfully completed his PhD and his PhD thesis was awarded a prize for the best thesis in Information Technology at UNSW@ADFA.

Recent outputs

Bui, L., Soliman, O., Abbass, H., "A modified strategy for the constriction factor in particle swarm optimisation", *Progress in Artificial Life*, December 2007; Lecture Notes in Computer Science, Vol. 4828, 333-344.

Emerging applications of advanced computational methods and discrete mathematics

Project Leader: Peter Adams

Researchers: Darryn Bryant, Barbara Maenhaut

Combinatorial computing plays an important role in visualising, modelling and solving a variety of important practical problems, particularly in the field of complex systems. In this project, we are investigating approaches such as grid computing, evolutionary algorithms and refined theoretical approaches in order to enhance combinatorial searches. These are being used in a variety of problems, ranging from searches for combinatorial designs to applications in bioinformatics. Future developments in combinatorial computing techniques may have broader applications including understanding network-based systems in biology, engineering and economics.

In 2007, we focused on development and application of computational tools in graph decomposition problems. There were two journal articles accepted for publication during 2007, representing advances in the knowledge of several classes of graph decompositions. One paper presents a comprehensive survey of existence results for small-order G-designs along with some new results, and the other considers a class of equitably 2-colourable small-order cycle decompositions.

Recent outputs

Adams, P., Bryant, D., Waterhouse, M., "Some equitably 2-colourable cycle decompositions", *Ars Combinatoria*, Vol. 85, 2007, 49-64.

Adams, P., Buchanan, M., Bryant, D., "A survey on the existence of G-designs", *Journal of Combinatorial Designs*, 2008.

Adams, P., Eggleton, R., MacDougall, J., "Taxonomy of graphs of Order 10", *Congressus Numerantium*, 2007.

Adams, P., "Sequencing aided by mutagenesis facilitates the De Novo sequencing of megabase DNA fragments by short read lengths", *New High Throughput Technologies for DNA Sequencing and Genomics*, Elsevier, 2007.

Computational group theory

Project Leader: George Havas

Researchers: Gilbert Baumslag, Colin Campbell, Marston Conder, Eamonn O'Brien, Colin Ramsay, Edmund Robertson, Doug Troeger

Group theory is a fundamental part of pure mathematics with diverse applications. Computational group theory addresses many problems. In this project, we study computationally-based proofs in groups given by presentations. As an integral part of the research we will design, implement, test, analyse and apply new

algorithms for groups. We will also develop metrics for evaluating the quality of proofs, with a view to addressing Hilbert's '24th' problem which is finding criteria for determining simplest proofs.

During 2007, work focused on the solution of problems related to the efficiency of infinite simple groups, on problems associated with an infinite family of groups related to trivalent graphs, and on the Andrews-Curtis conjecture. Progress was made on converting proofs obtained by machine computation to more conventional human proofs.

Recent outputs

Campbell, C.M., Havas, G., Ramsay, C., Robertson, E.F., "On the efficiency of the simple groups with order less than a million", *Experimental Mathematics*, Vol. 16, 2007, 347-358.

Campbell, C.M., Havas, G., Robertson, E.F., "Addendum to an elementary introduction to coset table methods in computational group theory", *Groups St Andrews 1981 (revised edition)*, 2007; *London Mathematical Society Lecture Note Series*, Vol. 71, 361-364.

Havas, G., Lawrence, J.L., Ramsay, C., Street, A., Yazici, E., "Defining set spectra for designs can have arbitrarily large gaps", *Utilitas Mathematica*, Vol. 75, March 2008, 65-79, 2008.

Havas, G., Ramsay, C., "On proofs in finitely presented groups", *Groups St Andrews 2005, 2007*; *London Mathematical Society Lecture Note Series*, Vol. 340, 457-474.

Havas, G., Vaughan-Lee, M.R., "Computing with 4-Engel groups", *Groups St Andrews 2005, 2007*; *London Mathematical Society Lecture Note Series*, Vol. 340, 475-485.

General CAS publications

Abbass, H., Baker, S., Bender, A., Sarker, R., "Anticipating future army supply chain fleet capabilities", *Proceedings of the 2007 SimTecT*, June 2007.

Barlow, M., Yang, A., Abbass, H., "A temporal risk assessment framework for planning a future force structure", *Proceedings of the 2007 IEEE Symposium on Computational Intelligence for Security and Defense Applications*, April 2007.

Dam, H., Lokan, C., Abbass, H., "Evolutionary online data mining: an investigation in a dynamic environment", *Evolutionary Computation in Dynamic and Uncertain Environments, Studies in Computational Intelligence*, Vol. 51, Springer, 2007.

Kurniawan, D., Abramson, D., "A WSRF-compliant debugger for Grid applications", *Proceedings of the IEEE International Parallel and Distributed Processing Symposium*, March 2007.

Kurniawan, D., Abramson, D., "An integrated Grid development environment in Eclipse", *Proceedings of the 3rd IEEE International Conference on e-Science and Grid Computing*, December 2007.

Researchers win best paper awards

UQ Business School researchers and ACCS participants, have taken out two of the ten best paper awards on offer at the 8th Asia-Pacific Complex Systems Conference.

A paper written by PhD student Sam MacAulay, and co-authored by academics Dr John Steen and Dr Tim Kastle, won best paper for the economics and business track at the conference, while another paper written by Dr Kastle was voted best paper in one of the general tracks.

Dr Steen said the conference, held last week on the Gold Coast, was regarded as the key complex systems event in Australia and the Asia-Pacific region. He said the event had a multidisciplinary focus attracting economists, psychologists, physicists, engineers, sociologists and IT and information systems experts.

"The conference is about analysing all systems as complex systems that evolve," Dr Steen said. "Some researchers might be looking at ecosystems, while others are examining biochemistry and the interaction inside cells. But we can also use this branch of science to look at the evolution of organisations and economic systems."

Mr MacAuley's paper examined the problems encountered and mistakes that can be made when interpreting economic networks.

Dr Kastle's paper was on the evolution of the world trade system. The paper examined globalisation from a network perspective tracing the evolution of the network over the course of 80 years.

(From UQ Business School News, 31 July, see www.business.uq.edu.au/display/news)

Nguyen M.H., Abbass H.A., McKay R. "Analysis of CCME: Co-evolutionary dynamics, automatic problem decomposition and regularization, *IEEE Transactions on Systems, Man, Cybernetics*, Part C, Vol. 38, No. 1, 100-109, 2008.

Shafi, K., Abbass, H., "Biologically-inspired complex adaptive systems approaches to network intrusion detection", *Information Security Technical Report*, Vol. 12, No. 4, 2007, 209-217.

Soliman, O., Bui, L., Abbass, H., "The effect of a stochastic step length on the performance of the differential evolution algorithm", *Proceedings of the 2007 IEEE Congress on Evolutionary Computation*, September 2007; 2850-2857.

The 8th Asia-Pacific Complex Systems Conference

2-5 July 2007
Surfers Paradise
Queensland, Australia

Complex'07 was a joint activity between the prominent complex systems science organisations in Australia:

- ❖ ARC Centre for Complex Systems (ACCS)
- ❖ ARC Complex Open Systems Research Network (COSNet)
- ❖ ARC Centre of Excellence for Mathematics and Statistics of Complex Systems (MASCOS)
- ❖ CSIRO Complex Systems Science Emerging Science Area

Complex'07 was the key complex systems event in Australia and the Asia-Pacific region for the year. The conference sought to bring together those in the region who are actively involved in complex systems research and practice. It also aimed to provide an introduction to specialised topics for people seeking to know more about the theoretical and practical aspects of research in complex systems.

The conference featured one day of pre-conference workshops and tutorials, followed by three days of keynote presentations, panel discussions, contributed papers and poster sessions. Participants heard the latest information from industry experts who have gained their knowledge from hands-on experience, developed important new contacts, and left with practical advice to achieve maximum outcomes.

Complex limericks

One of the winning limericks from the conference dinner competition...

I came here to learn of complexity
With a feeling of anguished perplexity
They spoke of links between nodes
And the sex partners they chose
So I'm eyeing the one sitting next to me
John Hawkins



Conference Chair & Centre Director, Peter Lindsay; Dinner Speaker & Science Journalist and Broadcaster, Robyn Williams; Centre Advisory Board Chair & Director CSIRO CSS, John Finnigan

The conference attracted 267 delegates from 13 countries. There were 13 plenary speakers and 13 conference tracks, with a total of over 200 presentations. Overwhelmingly positive feedback has been received. To the best of our knowledge this has been the most successful of the Asia-Pacific Complex Systems Conferences since the series inception.

Centre personnel contributed significantly to the organisation of the conference:

- ❖ Centre Director, Peter Lindsay was Conference Chair
- ❖ Centre Chief Investigator, Janet Wiles, was Program Committee Co-Chair, along with Robert Dewar from COSNet;
- ❖ Centre Chief Investigator, Peter Adams, was Local Organising Chair
- ❖ The Centre also provided web and project management services by Centre staff Daniel Bradley, Virginia Garton and Carol Stirk.

Illustrative of the nature of Complex Systems is the quality of the program of speakers and their diversity. Tracks included:

- ❖ Anomalous diffusion
- ❖ Business & economics
- ❖ Complex systems challenges in health care
- ❖ Complex systems engineering
- ❖ Complex systems in the earth sciences
- ❖ Complexity in energy, water & urban development
- ❖ Computational modelling for biology & chemistry
- ❖ Defence & security
- ❖ Social networks & epidemiology
- ❖ Social science & management
- ❖ Turbulence
- ❖ General

Further details of the conference and links to some of the presentations are on the conference website www.complex07.org



Complex'07

Media coverage

Science journalist and broadcaster Robyn Williams was the after-dinner speaker at the conference. Robyn gave a far-reaching talk covering the importance of complex systems science research and the need for interdisciplinary approaches to big scientific problems such as climate change. Robyn also interviewed a number of the scientists attending the conference; transcripts of some of these interviews are available on the ABC website:

- ❖ Peter Lindsay, *The Science Show*, 'The growth in air traffic', ABC Radio National, 7 July 2007
- ❖ Ian Enting, *The Science Show*, 'Study of climate sceptics', ABC Radio National, 14 July 2007
- ❖ Roger Bradbury, *In Conversation*, ABC Radio National, 19 July 2007

Peter Lindsay was also interviewed by Ingrid Just, ABC Radio Queensland on 13 July at 3:10pm.

In 'Complex'07: Making sense out of chaos' Beverley Head reported on the Conference for *The Sydney Morning Herald* (Technology - Next, 3 July), *The Age* (Technology - Next, 3 July) and *The Brisbane Times* (Technology, 3 July). This article was subsequently picked up by a number of Internet news and blog sites.

The ARC included an article on Complex'07 in their Winter 2007 *Discovery* magazine (see www.arc.gov.au/pdf/discovery_winter07.pdf)

Best paper awards

ACCS participants featured prominently in the Complex'07 Best Paper Awards:

- ❖ Software: Alex TN Heng & David Green, *VLAB Poster*
- ❖ Poster: Mikolaj Cieslak, Alla Seleznoya & Jim Hanan. *Virtual kiwifruit*
- ❖ Business and Economics: Sam MacAulay, John Steen & Tim Kastle. *Discovering small worlds in potentially biased nets*
- ❖ Complexity in Energy, Water and Urban Development: Ariel Liebman & Geoff Walker. *Impacts of V2G tech on electricity markets*
- ❖ General: Mark Bowden. *Information contagion and financial prices*
- ❖ General: Tim Kastle. *The evolution of the World Trade Web as a complex system*

The UQ Business School reported on the best paper awards, see page 29.

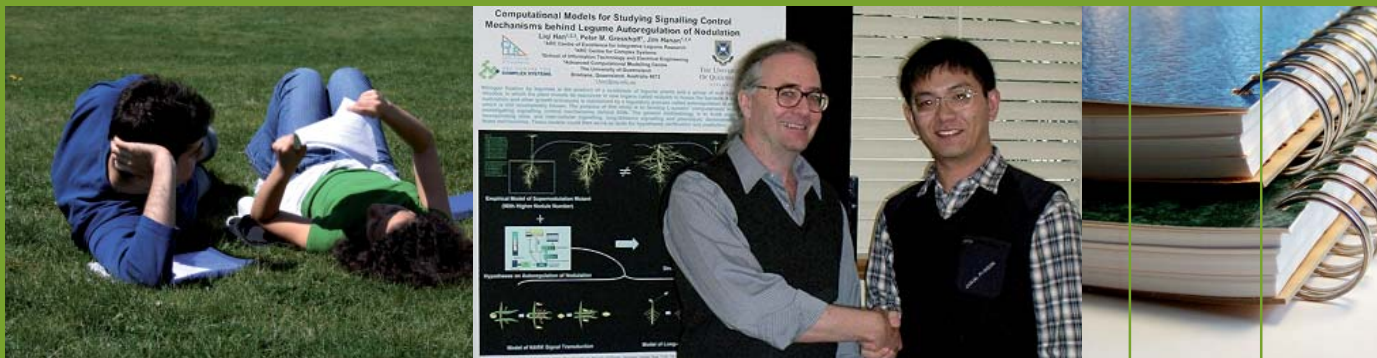


Photo by Gozde Otman

Peter Lindsay & Liqi Han

Research Students

Research by postgraduate research students under the supervision of Centre staff contributes significantly to the Centre's longer-term research goals. By providing high quality training environments, the Centre actively aims to retain Australia's best young complex systems researchers within the country. In 2007, scholarship or top-up funding was awarded to 13 students at UQ and 3 at Griffith. Centre funding also enables students to attend conferences and workshops, to present their work and to gain a wider perspective on research and technical innovation.

Research Degrees Awarded

Lam Bui (UNSW@ADFA) - PhD

'The role of explicit niching and communication messages in distributed multi-objective optimisation'

Advisors: Hussein Abbass, Daryl Essam, David Green & Kalyanmoy Deb

Junhua Zhao (UQ) - PhD

'Electricity market management and analysis using advanced data mining and statistical methods'

Advisors: Zhao Yang Dong & Xue Li

Stefan Maetschke (UQ) - PhD

'Topological models of transmembrane proteins for subcellular localisation prediction'

Advisors: Marcus Gallagher, Geoff McLachlan & Mikael Boden

Andrew Rae (UQ) - PhD

'A behaviour-based methodology for fault tree generation'

Advisor: Peter Lindsay

Aaron Searle (QUT) - PhD

'Automatic relative debugging'

Advisors: John Gough & David Abramson

Ang Yang (UNSW@ADFA) - PhD

'A networked multi-agent combat model: Emergence explained'

Advisor: Hussein Abbass, Ruhul Sarker & Neville Curtis (DSTO)

PhD Students

Sameer Alam (UNSW@ADFA)

'Evolutionary scenario planning for evaluating advanced Air Traffic Management concepts'

Advisors: Hussein Abbass, Michael Barlow & Peter Lindsay

Ardiaty Arief (UQ)

'The application of fuzzy logic controller for frequency control ancillary services in competitive electricity market'

Advisors: Zhao Yang Dong & Marcus Gallagher

Shane Arnott (UQ)

'The impact of advanced technologies in support of decision making in complex environments'

Advisors: Peter Lindsay & Richard Davis

Jennifer Badham (UNSW@ADFA)

'The role of social network properties on the impact of direct contact epidemics'

Advisor: Hussein Abbass & Robert Stocker

Paul Bell (UQ)

'Simulating the process of profit expectations formation using an agent based model'

Advisors: John Foster, Phillip Wild, Rodney Strachan & Jason Potts

Mark Bowden (UQ)

'Can the interaction of heterogeneous agents explain price fluctuations in financial markets?'

Advisors: Jason Potts, Stuart McDonald & John Foster

Kuang Yuan Steven Chen (UQ)

'An approach for the architecture of a "multi-agent system" environment'

Advisors: Peter Lindsay & Hussein Abbass

Xia Chen (UQ)

'Data mining and statistical methods for electricity market analysis'

Advisors: Zhao Yang Dong & Dianhui Wang (LaTrobe University)

Mikolaj Cieslak (UQ)

'Modelling carbon allocation in kiwifruit vine'

Advisors: Jim Hanan, Christine Beveridge & Alla Seleznyova

Simon Connelly (UQ)

'Use of agent based modelling to investigate shared situation awareness: how it is defined, established and measured'

Advisors: Peter Lindsay & Marcus Gallagher

Brijesh Dongol (UQ)

'Formal reasoning about progress in concurrent programs'

Advisors: Ian Hayes & Robert Colvin

Elizabeth Dun (UQ)

'Computational analysis of branching and flowering in pea plants'

Advisors: Christine Beveridge & Jim Hanan

Ezekiel Golan (UQ)

'Individual-based modelling of insect behaviour'

Advisor: Jim Hanan

Liqi Han (UQ)

'Mathematical and computational methods for modelling control of plant development and function'

Advisors: Jim Hanan & Peter Gresshoff

John Hawkins (UQ)

'Machine architectures for biological sequence classification'

Advisors: Mikael Boden & Janet Wiles

Geoffrey Jones (UQ)

'General belief theory: Toward an integrated framework for the general analysis of socioeconomic phenomena'

Advisors: Tom Mandeville & John Foster

Ashok Kanagarajah (UQ)

'Characteristics, strategies and trend for health sector supply chain in Australia'

Advisors: Peter Lindsay & David Parker

Tim Kastle (UQ)

'Analysing the evolution of international trade: A complex networks approach - measuring globalisation in the international trade network from 1938-2003'

Advisors: Peter Liesch, John Steen & Jason Potts

Xilin Li (UQ)

'Visualisation and adaptation in complex systems: hydropower system case study'

Advisors: Penelope Sanderson & Zhao Yang Dong

Kai Lin (Griffith)

'Collaborative editing of Behavior Trees'

Advisors: David Chen, Chengzhen Sun & Geoff Dromey

A student's take on Complex'07

Centre PhD student, Liqi Han, reports on his experiences at Complex'07.

The 8th Asia-Pacific Complex Systems Conference was the key event on complex systems in the Asia-Pacific region this year, covering the design, development and application of complex systems for different purposes. Differing from traditional mathematical modeling, which tries to find answers by simplifying complexity, complex systems is a systematic approach to study how the interactions between a system's parts and its environment lead to emergent system behaviours. For example, the regulatory systems of plant development and function are complex systems that involve signaling mechanisms inside and outside plants, giving rise to the emergent phenotypes or behaviours.

Day one of the conference provided a set of tutorial programs, of which I attended 'Non-linear dynamics: From chaos to fractals to fractional calculus' and 'How might biological learning relate to machine learning?'. On day two I attended a series of keynote talks and

other presentations about current research on complex systems. On the third day I presented my project within a poster highlight talk and a poster session. Some audience members were interested in the general methodology and modeling approaches of this work. But the most interesting question I received was about the practical application of the soybean supernodulation mutant: how farmers could use the mutant to improve agricultural production and whether the weeds can have mutants with nodulation to fertilise the fields. Another interesting question was whether the plant signaling systems can offer ideas to social network regulation.

Four days of learning and talking have greatly enhanced my understanding of complex systems. Furthermore it bolstered my belief that systematic modeling would surely lead to a better investigation of the complexity involved in plant signaling mechanisms.

Jennie Miao Lu (UQ)

'Probabilistic transmission expansion planning in competitive electricity market'

Advisor: Zhao Yang Dong

John Zhe Lu (UQ)

'Electricity market planning and management'

Advisors: Zhao Yang Dong & Penelope Sanderson

Sam MacAulay (UQ)

'The division of labour and innovation in communities of practise: Insights from an analysis of problem solving networks'

Advisors: Lars Håkanson (Copenhagen Business School)
John Steen & Tim Kastle

Michelle McPartland (UQ)

'Evolutionary techniques in complex environments'

Advisors: Marcus Gallagher & Janet Wiles

Jason Ke Meng (UQ)

'Intelligent fault diagnosis approach to high voltage transmission line'

Advisors: Zhao Yang Dong & David Hill

Yateendra Mishra (UQ)

'Stability studies in a deregulated power system'

Advisors: Zhao Yang Dong & Pei Zhang (EPRI)

Kate Morrison (UQ)

'The value of markets'

Advisors: Peter Earl & John Foster

Toby Myers (Griffith)

'Model driven engineering using the Behavior Engineering methodology'

Advisors: Geoff Dromey & Vladimir Estivil-Castro

Greg Paperin (Monash)

'The role of extrinsic disturbances and phase changes in the evolution of natural and artificial complex systems'

Advisor: David Green

Anisah Nizar (UQ)

'Data Mining techniques and technologies in customer information billing system to predict, forecast and estimate the customer behaviour in electricity market'

Advisors: Zhao Yang Dong & Penny Sanderson

Alan Raine (UQ)

'On growth, property and energy transformation'

Advisors: John Foster, Jason Potts & Tom Mandeville

Ella Reeks (UQ)

'Agent coordination in emerging markets'

Advisors: Tom Mandeville, John Foster & Peter Earl

John Seagrott (Griffith)

'Investigating potential productivity improvements through a systematically constructive requirements engineering approach'

Advisor: Geoff Dromey

Kamran Shafi (UNSW@ADFA)

'Multi agent based early warning system for Internet threats'

Advisors: Hussein Abbass & Weibing Zhou

Morgan Smith (UQ)

'Learning agents to model air traffic control systems'

Advisor: Ariel Liebman & Peter Robinson

Philip Valencia (UQ)

'Can practical distributed robotic solutions be automatically generated for real world applications'

Advisors: Peter Lindsay, Peter Corke & Mikhail Prokopenko

Lian Wen (Griffith)

'Mapping requirements changes to design changes'

Advisor: Geoff Dromey

GuangYa Yang (UQ)

'Electricity market management and planning'

Advisors: Zhao Yang Dong & David Hill

Nisansala Yatapanage (Griffith)

'Formal verification of system designs'

Advisor: Geoff Dromey

Yu-Hei Flora Yeh (UQ)

'Model selection in machine learning using computational statistics'

Advisors: Marcus Gallagher, Hussein Abbass & Janet Wiles

Donna Xia Yin (UQ)

'Artificial intelligence and data mining techniques in electricity market forecasting'

Advisors: Tapan Saha & Zhao Yang Dong

Saad Zafar (Griffith)

'Integrating safety and security requirements into the design of large systems'

Advisor: Geoff Dromey

Xuelin Zheng (Griffith)

'A model for characterising requirements and design defects'

Advisor: Geoff Dromey

Xun Zhou (UQ)

'Investigation of distributed generation and its impact on power grid as a complex system'

Advisor: Zhao Yang Dong & CSIRO

Masters Students

Andres Sanin

'Reimplementing a model of goal-directed navigation based on theta oscillations'

Advisor: Janet Wiles

Du Li (UQ)

'Data mining method for power system data analysis'

Advisor: Zhao Yang Dong

Kin Ho Pong (UQ)

'(Carbon) Emissions trading and distributed generation in an electricity market'

Advisor: Zhao Yang Dong

Honours Students**Heath Manning (UQ)**

'Perturbing flight trajectories to emulate uncertainty in air traffic control'

Advisor: Peter Lindsay

Ernest Wong Kwok Wai (UQ)

'Evaluating performance properties with SysML (UML 2.0) parametric diagrams'

Advisors: Lars Grunske & Kirsten Winter

Ann Kee Hui (UQ)

'Electricity market and network impacts of plug-in-hybrid vehicles connected to the electricity grid'

Advisor: Ariel Liebman

Gee Ci-Yan (UQ)

'Electricity market and network impacts of plug-in-hybrid vehicles connected to the electricity grid'

Advisor: Ariel Liebman

Ng Tze Chia (UQ)

'Electricity market and network impacts of plug-in-hybrid vehicles connected to the electricity grid'

Advisor: Ariel Liebman

Sarah Hilley (UQ)

'Review of the contribution to power system damping from the Blackwall SVC power oscillation damper control (PowerLink)'

Advisor: Zhao Yang Dong

Yongyi Fu (UQ)

'Supporting transmission and distribution systems with distributed generation'

Advisor: Zhao Yang Dong

Yoong Low (UQ)

'National electricity market constraint analysis'

Advisor: Zhao Yang Dong

Timothy McKey (UQ)

'Calculation of noise levels in high voltage Substations (Ergon)'

Advisor: Zhao Yang Dong

Muhammad Modh Amin (UQ)

'Investigating distributed generation impacts on the power system'

Advisor: Zhao Yang Dong

Tao Zhang (UQ)

'Load modelling and its impact on power system stability'

Advisor: Zhao Yang Dong

Chuan Zhao (UQ)

'Power system stability assessment'

Advisor: Zhao Yang Dong

Shanming Zhou (UQ)

'Advanced techniques for demand forecasting of a distribution company'

Advisor: Zhao Yang Dong

Summer Student Projects

To encourage students to pursue research careers, the Centre funded the following summer student projects at the Brisbane node. The 2006/07 summer student projects were reported in the 2006 Annual Report.

2007/2008 Projects**Rohan Alexander (UQ)**

'Impacts of climate change on the Snowy Hydro system'

Supervisor: Liam Wagner

(See page 20)

Kin Ho Pong (UQ)

'Distributed generations impact on the national electricity market'

Supervisor: Zhao Yang Dong

Rui Zhang (UQ)

'Data mining methods for electricity market analysis'

Supervisor: Zhao Yang Dong

International Student Linkages

Jian Ma, a Centre PhD student supervised by Zhao Yang Dong and Yuri Makarov, spent more than six months at Pacific NorthWest National Laboratory (PNNL) in the USA, working closely on a number of projects in power system stability. His initial visit has now been extended and he plans to complete his PhD there. PNNL is a leading power engineering research institute in USA - there are over 300 researchers/engineers just in power engineering.

Centre visitor **Tangtang Xie** is a student at the International Institute for Software Technology, Southwest University in China. She visited the Centre from July until October to undertake work on her project with Peter Lindsay, Lars Grunske and Kirsten Winter.

Guang Ya Yang, a PhD student advised by Zhao Yang Dong and David Hill, was invited to visit Nanyang Technological University in Singapore to conduct research on power station stability and control. This further develops existing collaborations between Centre researcher Prof Dong and Prof Wang of Nanyang Technological University.



John Foster, Ariel Liebman, Liam Wagner & Zhao Yang Dong



Craig Saddler & Peter Lindsay

Outreach, Links and Service to Community

Keynote and Invited Addresses at International Conferences

Hussein Abbass, Track Keynote Speaker, Defence and Security Track, 8th Asia-Pacific Complex Systems Conference (Complex'07). Gold Coast, 2-5 July, 'Signatures of game dynamics for intelligence and information operation'.

David Abramson, Invited Speaker, International Workshop on Advanced Computing and Applications, Ho Chi Minh City, Vietnam, March, 'Robust science and engineering using parametric computing on the Computational Grid' (Khoa Học Công Nghệ Bền Vững với Tính Toán Đa Tham Số trên Lưới Tính Toán).

David Abramson, Invited Speaker, PRAGMA 13 meeting NCSA, Urbana-Champaign, USA., September, 'Grid enabling 'real' science and engineering using the Nimrod tool set'.

Darryn Bryant, Invited Speaker, British Combinatorial Conference, UK, July, 'Cycle decompositions of complete graphs'.

David Green, Keynote Speaker, Intelligent and Evolutionary Systems workshop, Defence Force Academy, Yokosuka, Japan, December, 'Dual phase evolution'.

George Havas, Invited Speaker, Groups in Galway, Galway, Ireland, May, 'Perfect palindromic presentations'.

Penelope Sanderson, Keynote Speaker, Third International Conference on Information Technology in Healthcare-Sociotechnical Systems. Sydney, 28-30 August, 'Designing and evaluating healthcare ICT innovation: A cognitive engineering view'.

Penelope Sanderson, Plenary Keynote Speaker, 8th Asia-Pacific Complex Systems Conference (Complex'07). Gold Coast, 2-5 July, 'Controlling complex resources over different timeframes in process control'.

Janet Wiles, Plenary Speaker, International Conference on Complex Systems (ICCS), Boston, USA, October, 'Complex systems from DNA to development'.

Janet Wiles, Keynote Speaker, European Conference on Artificial Life (ECAL). Portugal, September, 'Complex systems from DNA to development'.

Janet Wiles, Invited Speaker, Dynamics of Development workshop, Portugal, September, 'Issues in the computational modelling of evolution and development'.

Serving the Research Community

Centre participants served on a considerable number of conference program committees and editorial boards.

Centre participants took a leading role in organising the 8th Asia-Pacific Complex Systems Conference (Complex'07), held on the Gold Coast in July. A considerable number of Centre participants were also involved in organising the Third Australian Conference on Artificial Life also held on the Gold Coast in December.

David Abramson was Vice Program-Committee Chair for the 5th Australasian Symposium on Grid Computing and e-Research, Ballarat, Vic 2007. David was also on the Program Committee for 16th IEEE International Symposium on High-Performance Distributed Computing, Monterey, CA, June; 16th Heterogeneous Computing Workshop (HCW'07), Long Beach, California, March (co-located with IPDPS 2007); International Symposium on Parallel Algorithms, Architectures, and Networks, Sydney 2008; IEEE Supercomputing, Reno, Nevada, November 2007; 14th International Conference on High Performance Computing (HiPC), India; and the 13th



David Carrington & Len Bass

Tangtang Xie & Kirsten Winter

Andy Ford & Ariel Liebman

International Conference on Parallel and Distributed Systems (ICPADS'2007), December at National Tsing Hua University, Hsinchu, Taiwan. David was Publicity Chair for CCGrid 2007, Rio de Janeiro, May; and ICCS 2007, the 7th International Conference on Computational Science, Graduate University of the Chinese Academy of Sciences, Beijing, China, May.

Hussein Abbass was the technical Co-Chair for the IEEE Congress on Evolutionary Computation in Singapore; and Program Co-Chair for the IEEE International Conference on Artificial Life, Honolulu, USA, April.

Hussein was a Program Committee member for the 2007 IEEE symposia on Computational Intelligence and Scheduling (CIS'07), on Computational Intelligence in Multi-Criteria Decision-Making (MCDM 2007), and on Computational Intelligence for Security and Defense Applications (CISDA 2007), all in April, Hawaii, USA.

Hussein was also a Program Committee member: Evolutionary Multi-Criterion Optimisation 2007 (EMO 2007), Matsushima, Japan, 5-8 March; the 2nd International Symposium on Intelligence Computation and Applications (ISICA 2007), China University of Geosciences, Wuhan, China, 6-8 April; and the 2007 IEEE International Symposium on Data Mining and Information Retrieval (IEEE DMIR-07), Ontario, Canada, 21-23 May.

Hussein was on the editorial boards of the *International Journal of Applied Systemic Studies* (IJASS), the *International Journal of Intelligent Computing and Cybernetics*, and the *Advances in Data Warehousing and Mining* Book Series.

Darryn Bryant was the Secretary of the Combinatorial Mathematics Society of Australasia, Editor of the *Journal of Combinatorial Designs*, and Associate Editor of the *Australasian Journal of Combinatorics*.

Zhao Yang Dong was Technical Chair and funding committee member for the Symposium of Electric Energy Evolution in China and Australia. PhD Student **Xia Donna Yin** also assisted with the symposium. Zhao Yang Dong is Vice Chair of the Queensland section of the IEEE.

Geoff Dromey was on numerous Program Committees including that for the Theoretical Aspects of Software Engineering Conference (TASE 2007).

David Green was a Reader with the ARC, Editor of *Complexity International*, a member of the Editorial Advisory Board for the journal *Ecological Informatics*, and for the *Journal of Economic Interaction and Coordination* (JEIC).

Jim Hanan was Co-Chair of the 5th International Workshop on Functional Structural Plant modelling, Napier, New Zealand, November.

Ian Hayes was on the Program Committee for the Mathematics of Program Construction (MPC) to be held in Marseille, 15-18 July 2008; Verified Software: Theories, Tools, Experiments (VSTTE), to be held in Toronto, 6-9 October 2008; Symposium on Unified Theories of Programming (UTP) to be held in Dublin 8-10 September 2008; IEEE International Conference on Engineering of Complex Computer Systems; (ICECCS), to be held in Belfast 31 March - 4 April 2008; International Colloquium on Theoretical Aspects of Computing (ICTAC) to be held in Istanbul, 1-3 September 2008, and also the 2007 Colloquium; 5th Workshop on Quantitative Aspects of Programming Languages (QAPL 2007); International Conference on Engineering Complex Computing Systems (ICECCS'07); and a member of the Formal Methods Symposia Series. Ian is also on the editorial board of BCS/Springer journal *Formal Aspects of Computing*.

Peter Lindsay was Conference Chair for the 8th Asia Pacific Complex Systems Conference (Complex'07), a



Peter Fritzson and participants in a Modelica tutorial



Centre visitor, Peter Fritzson & Centre Director, Peter Lindsay

member of the program committee for the 3rd International Conference on Research in Air Transportation (ICRAT 2008); 12th & 13th IEEE International Conference on Engineering of Complex Computer-based Systems (ICECCS'07 & '08); 6th IEEE Conference on Software Engineering & Formal Methods (SEFM'08); 2nd IFIP Conference on Biologically Inspired Collaborative Computing (BICC 2008); the 1st International Workshop on Formal Methods for Interactive Systems; 1st IFAC Workshop on Dependable Control of Discrete Systems (DCDS'07); and the Uninhabited Airborne Systems special stream of Information, Decision and Control (IDC). Peter was also on the editorial board of the *Science of Computer Programming* journal.

Sam MacAulay was a reviewer for DRUID (Danish Research Unit on Industrial Dynamics) Summer Conference 2007.

Professor Quiggin is on the editorial boards of numerous Australian and international journals, including *Journal of Risk and Uncertainty*; *Australian Journal of Agricultural and Resource Economics*; *Economic and Labour Relations Review*; and *Journal of Economic and Social Policy*.

Penny Sanderson is Consulting Editor for the *Journal of Experimental Psychology: Applied*, on the Editorial Board for *Human Factors*, and the *Journal of Cognitive Engineering and Decision Making*, and Regional Editor for *Cognition Technology and Work*.

James Watson was on the program committee for Complex'07 (Co-Chair of the Computational Modelling for Biology and Chemistry track), and reviewer for the Co-evolution of GECCO 2007.

Janet Wiles was Program Committee Co-Chair, 8th Asia-Pacific Complex Systems Conference, Gold Coast, July; and Co-Chair, Third Australian Conference on Artificial Life, Gold Cost, December.

Kirsten Winter was on the program committee of the International Conference IFM, and was an anonymous reviewer for the *Journal of Universal Computer Science* (JUCS).

Visitors to the Centre

The Centre conducts an international visitor program and other networking activities that engage allied researchers who might not be formally associated with the Centre.

Prof Barry Boehm

Centre for Software Engineering, University of South California, USA
December

Prof Keith Clark

Dept of Computing, Imperial College, London, UK
May

Prof Gene Cooperman

Director, Institute for Complex Scientific Software, Northeastern University, Boston, USA
June

Prof Roger Eggleton

Dept of Mathematics, Illinois State University, USA
June, July-August

Prof Andrew Ford

Environmental Science & Regional Planning, Washington State University, MIT Sloan School of Management, USA
February

Prof Peter Fritzson

Dept of Computer and Information Science, Linköping University, Sweden
July-onwards

Prof Robert Glass

Indiana University, USA
January-December

Dr Jennifer Hallinan

Centre for Integrative Systems Biology of Ageing and Nutrition, University of Newcastle-upon-Tyne, UK
December

Prof Melvin Hinich

Dept of Government, University of Texas at Austin, USA,
July

Prof Ian Hiskens

University of Wisconsin-Madison, USA
March

Dr Michael Hoffman

Dept Computer Science, University of Leicester, UK
April-July

Prof John Hogan

Bristol Centre for Complexity Sciences, University of Bristol, UK
December

Dr Kung-Kiu Lau

School of Computer Science, University of Manchester, UK
November

Prof Jin Ma

North China Electric Power University, Beijing, China
February-March

Dr Chee Kiang Pang

Titachi Ltd Central Research Laboratory, Japan
December

Dr Alla Seleznyova

The Horticulture and Food Research Institute of New Zealand Ltd., New Zealand.
February

A/Prof Kaychen Tan

National University of Singapore, Singapore
December

Prof Fushuan Wen

South China University of Technology, Guangzhou, China
February-March

Ms Tangtang Xie

International Institute for Software Technology, Southwest University in China, United Nations University, China
July-October

Prof Yusheng Xue

Principle Engineer, Nanjing Automation Research Institute of the State Grid Corporation, China
March & December

Modelica - a tool for modelling complex systems

Centre participants benefitted from an extended visit from Professor Peter Fritzson during 2007. Peter is professor at Linköping University, Sweden; Director of PELAB - the Programming Environment Lab; and Vice chairman of the Modelica Association. During the period 1997-2007, he was chairman of the Scandinavian Simulation Society, and Secretary of EuroSim.

During his time with the Centre, Peter presented a number of seminars and tutorials on Modelica. Modelica is being trialled in a number of the Centre's projects and is proving to be a powerful tool for modelling physical aspects of many complex systems.

According to the Modelica website (www.modelica.org) 'the object-oriented modeling language Modelica is designed to allow convenient, component-oriented modeling of complex physical systems, e.g., systems containing mechanical, electrical, electronic, hydraulic, thermal, control, electric power or process-oriented subcomponents.

The free Modelica language, free Modelica libraries and Modelica simulation tools are available, ready-to-use and have been utilised in demanding industrial applications, including hardware-in-the-loop simulations. The development and promotion of Modelica is organised by the non-profit Modelica Association.

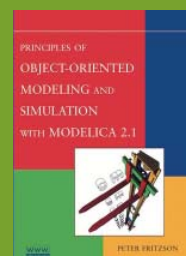
Peter recently (December 2007) created an organisation, the Open Source Modelica Consortium, currently with seven company members and four university members, for the long-term open source development and cooperation regarding open source implementation of OpenModelica and associated tools for model-driven development.

Further details are at :

- ❖ www.ida.liu.se/~pelab/modelica/
- ❖ www.modelica.org
- ❖ www.openmodelica.org

Principles of Object-Oriented Modeling and Simulation with Modelica 2.1,

Peter Fritzson, 944 pages,
ISBN: 978-0-471-47163-9,
Wiley-IEEE Press January 2004,
www.mathcore.com/products/mathmodelica/book.php



Visits to International Institutions

Visits by Centre participants to leading international laboratories aim to develop relationships and build networks to help achieve global competitiveness and recognition for Australian complex systems research.

Of these visits, 12 are of particular note because of the high standing of the laboratories visited in the complex systems field:

Darryn Bryant visited colleagues at the University of Reading, UK and the University of Otago, NZ.

Mikolaj Cieslak visited The Horticulture and Food Research Institute of New Zealand Ltd. He attended the 5th International Workshop on Functional-Structural Plant Modelling in Napier, NZ, and visited Dr. Alla Seleznyova in Palmerston North research centre.

Robert Colvin visited Sun Laboratories, Boston, USA to further existing collaborations.

Simon Connelly visited the University of Auckland, NZ.

Zhao Yang Dong met with colleagues with the North China Electric Power University (NCEPU) in China to discuss joint research work in power system load modelling supported by an ARC project. This visit also facilitated the formal agreement between The University of Queensland and NCEPU on international development for collaboration in teaching and student recruitment.

Ken Gray visited the Slovak Academy of Sciences in Bratislava, Slovakia, and Koç University, Istanbul, Turkey.

Liqi Han visited New Zealand to attend the 5th International Workshop on Functional-Structural Plant Modelling.

George Havas visited the School of Mathematics and Statistics, and the Centre for Interdisciplinary Research in Computational Algebra, both at the University of St Andrews in Scotland. George also visited the National University of Ireland, Galway, Ireland, the Center for Algorithms and Interactive Scientific Software at the City College of the City University of New York and the Algebraic Cryptography Center, Stevens Institute of Technology, both in the USA.

Ian Hayes visited the University of Newcastle-upon-Tyne, UK, meeting with collaborators Professors C.B. Jones and M.A. Jackson; University of York, UK, meeting with

collaborators Professors A. Burns and J. Woodcock; University of Southampton, UK; Carnegie-Mellon University, Pittsburgh, USA; and Software Engineering Institute, Pittsburgh, USA

Peter Lindsay, The Forum for European-Australian Science and Technology cooperation (FEAST) sponsored Peter Lindsay's visit to Italy for an international forum to discuss ICT R&D cooperation between Australia and Europe in the area of managing complexity. While there, Peter also visited: Politecnico di Torino, Turin; Istituto Superiore Mario Boella, Turin; and Bocconi University, Milan.

Sam MacAulay visited Tanaka Business School, Imperial College, and Oxford University, both in England. Sam also visited Copenhagen Business School and Vesta Wind Systems in Denmark.

Jason Potts visited the Imperial College London, UK. He was there for six months funded by the ARC Centre for Creative Industries at QUT.

John Quiggin visited University of California, San Francisco; University of Maryland, Washington DC; and Rice University, Houston, Texas, all in the USA in January.

Anne Street visited Auburn University, USA, the Slovak Academy of Sciences in Bratislava, Slovakia, and the University of Reading, UK.

James Watson visited former Centre PhD student and researcher, Nic Geard at the University of Southampton in September. James presented the distributed computing/plant modeling work to the Science and Engineering of Natural Systems Group there. While in the UK, James also visited the University of Hull, and worked with Netta Cohen at the University of Leeds. In October, James visited the San Diego Supercomputer Centre, the Salk Institute, Calit2: California Institute for Telecommunications and Information Technology, and the Centre for Research in Language, all in the USA.

Janet Wiles visited NSF Temporal Dynamics of Learning Centre at UCSD, USA; and the University of Newcastle-upon-Tyne, the University of Leeds, both in the UK; and the Fundação Calouste Gulbenkian, Portugal.

Kirsten Winter visited the Technical University of Berlin in Germany.

Seminars

Centre seminars, organised by Ariel Liebman, are held by videoconference at 11am most Thursdays. Details of past and future seminars in the series are available on the ACCS website (www.accs.edu.au). Anyone is welcome to join the ACCS mailing lists to receive regular announcements of seminars and other Centre activities. Simply email the Director with your request and your preferred email address.



David Abramson, Peter Lindsay & Geoff Dromey

Seminars presented by Centre visitors in 2007 included:

16 February

Mr Len Bass - Carnegie Melon University, USA
'The Architectural Expert (ArchE) tool'

22/3 February

Prof Andrew Ford - Washington State University, USA
'Boom and bust in power plant construction: Lessons from the California electricity crisis' and
'System dynamics and the electric power industry'

8 March

Mr Paul Ormerod - Volterra Consulting, UK
'Cascades of failure and extinction in evolving complex systems'

15 March

Mr Greg McDonald - Future Directions Division, Airservices Australia
'Airservices' perspective on tailored arrivals'

22 March

Dr Yucang Wang - Earth System Science Computational Centre, The University of Queensland
'Earthquake as a complex phenomenon: Some recent developments about earthquake occurrence, modelling and forecasting'

3 May

Prof Gerard Milburn - Physics, The University of Queensland
'Quantum complex systems'

24 May

Dr Lukas Skoufa - UQ School of Business
'Strategic options facing generation firms in restructured electricity industries: Some implications from recent Australian experience'

26 June

Prof Gene Cooperman - Northeastern University, Boston, USA
'Using parallel disk-based computing: A new record for computer-generated solutions to Rubik's cube'.

12 July

Dr Reid Porter - Los Alamo National Labs, New Mexico, USA
'Digital neural networks in image and video analysis'

2 August

Dr Rodney Beard - University of Alberta, Canada
'Simplifying complexity'

25 October

Mr Miika Valtonen - Tampere University of Technology, Finland
'Pervasive measurement systems for intelligent environments'

Professional Courses

Centre participants benefitted from participation in a range of professional courses and special training seminars. In addition, there were weekly Personal Software Engineering Discussion Groups organised by Daniel Bradley and Leighton Brough, aimed at developing Centre participants' skills and understandings of software engineering issues.

Eclipse - Advanced Usage and Plugin Development

This year the ACCS hosted a two-day Eclipse training course at The University of Queensland in July. Donny Kurniawan and Kam Man Chu, two experienced Eclipse plug-in developers from the Monash node of the ACCS, presented the course to 23 participants.

Introduction to Object-Oriented Modelling and Simulation with Modelica.

Tutorials with hands-on exercises presented by Peter Fritzson, Centre visitor from Linköping University in Sweden. The tutorials provided a basic introduction to the concepts of modeling and simulation, as well as the basics of object-oriented component-based modeling. The level of interest was such that the course was presented three times: 18 September, 16 October and 15 November.

Centre participant, Zhao Yang Dong presented a Special Training Seminar for Centre personnel in October on **Optimisation Methods for Power System Planning and Operations**.

Dr. Paul Sernia, a Commercialisation Associate with UniQuest Pty Ltd at The University of Queensland presented a Special Training Seminar for Centre participants in November entitled **How to Generate Income from Intellectual Property Arising from your Research**.



Sam MacAulay undertook a course in the Longitudinal Analysis of Social Networks at Oxford University in UK.

James Watson attended a CompuSteer Workshop in September at the University of Hull. Computational steering is a mechanism for scientific investigation in which the parameters of a running program can be altered and the results visualised immediately (see compusteer.dcs.hull.ac.uk)

Workshops

Centre participants organised a number of workshops to enhance education and training, collaboration, and excellence in research.

Eclipse Training Course

Centre personnel participated in a two-day Eclipse workshop. Eclipse is an open source community whose projects are focused on building an open development platform comprised of extensible frameworks, tools and runtimes for building, deploying and managing software across the lifecycle. It is widely used for software development in the ACCS.

Other Workshops

In addition, Centre participants contributed a complex systems perspective to a range of other workshops.

Centre Director, Peter Lindsay, presented at the **Technical workshop on managing complexity** in Italy in October. This workshop formed part of the Australian-European ICT Days in Piemonte, an international cooperative R&D forum. Peter was sponsored by the Forum for European-Australian Science & Technology Corporation (FEAST).

David Green and Janet Wiles presented at a one-week short course on **Complex systems beyond the metaphor: Your mathematical toolset**. Held at The University of New South Wales in Sydney in February, the course was sponsored by COSNet, MASCOS and AMSI. "Aiming at a mathematically literate audience, leading Australian experts presented intensive introductions to the essential topics of complex systems theory, including self-organisation, nonlinear dynamical systems, cellular automata, networks and statistical learning".

Geoff Dromey presented the course **Engineering large scale software intensive systems** over five days to US and Australian Raytheon personnel. Geoff also presented versions of this course at Complex'07 and SEPG (Software Engineering Process Group). Similar training was provided for Boeing, and for KJ Ross personnel.

Ariel Liebman and Phil Wild presented **The mathematics of electricity supply and pricing** workshop at the Australian Mathematical Sciences Institute (AMSI) Industry Workshop in Surfers Paradise.

Diane Donovan presented a series of **Workshops on combinatorial mathematics** (Designs in April, Graph Decompositions in July, and Trades in November).

Anne Street presented a workshop on **Sequential arrays** in April.

Centre Chief Investigator, John Foster, jointly presented a workshop **Brisbane Club: Innovation and complexity 1** at IV Convegno STOREP 2007, June, Pollenzo, Turin, Italy.

Centre Chief Investigator John Quiggin presented a workshop **Games without rules**, at the 25th Australasian Economic Theory Workshop, Australian National University, Canberra in February.

Government, Industry and Business Briefings

The briefings listed are illustrative of how the Centre feeds ideas, discoveries and techniques to government and industry to improve their current practices and seed innovation. A number of Centre personnel have been invited to join advisory or expert panels, recognising their expertise in the relevant areas.

Geoff Dromey presented to the Australian Computer Society on 8 November on 'Engineering complex

software-intensive systems, Composition Trees and Behavior Trees'.

Sam MacAulay made a number of visits to Vestas Wind Systems in Denmark including the presentation of a project proposal and collection of data.

Peter Lindsay briefed Prof Peter Andrews, Queensland Chief Scientist, and also Dr Mark Matthews, Executive Director, Forum for European-Australian Science and Technology (FEAST) cooperation, on his visit to Italy.

Peter Lindsay was an invited speaker at two Skilling Australia conferences:

- ❖ 3rd Annual Australian Financial Review Skilling Australia Summit, August, Melbourne; and
- ❖ 3rd ADM Defence Skilling Summit in Brisbane in September.

Peter Lindsay and **Geoff Dromey** are on Defence Materiel Organisation's (DMO's) Expert Advisory Panel on systems and software engineering. They presented a briefing entitled 'Engineering large systems' to DMO.

Daniel Powell provided an internal briefing to Raytheon in Sydney on 'Engineering large systems'. Centre student, **Toby Myers**, demonstrated the use of Behavior Trees in the design of field programmable gate arrays (FPGAs) to Raytheon.

Ariel Liebman was invited to speak at the Electricity and Carbon Price Outlook, IIR Conference, September in Melbourne; at the Energy Leaders Forum, October in Sydney; at Energy Trading and Risk Management, October in Sydney, and at the IBR Future Clean Coal Conference in November in Brisbane.

Kirsten Winter presented developments in the Behaviour Tree and Behaviour Engineering methodology to NICTA, National ICT Australia, an Australian Government body that works in close collaboration with industry and other research institutions to solve problems and make breakthroughs in ICT which can be put to use for public benefit.

John Quiggin prepared a feature article on Water Management for CEDA which considered, among other aspects of water management, issues related to the Murray-Darling basin. CEDA is the Committee for Economic Development of Australia and is a think-tank that aims to promote Australia's economic development in a sustainable and socially balanced way.

John Quiggin presented 'Urban water: markets and planning', at the conference dinner of the Australian Academy of Science's 2007 Fenner Conference on the Environment on 'Water, population and Australia's urban future', in Canberra in March.

Industry Visitors

Visits by the following industry representatives served to strengthen ties with the Centre and promote communication of discoveries and techniques.

Mr Matt Ashford, Defence Materiel Organisation
 Dr Holger Becht, System Safety Manager, Boeing Australia
 Mr Francisco Garcia de Blanes, ATM Advanced Trajectory Technologies, Boeing Research & Technology Europe, Madrid, Spain
 Mr Jim Boston, Raytheon Australia
 Mr Alex Eksir, Vice President, Raytheon USA
 Nic Gerard, Boeing Australia
 Mr Joel Gray, International Business Development, Boeing USA
 Dr Geoff James, CSIRO
 Mr Ross Lawson, Connell Wagner
 Dr Bill Lyons, Boeing USA
 Mr Greg McDonald, Future Directions Group, Airservices Australia
 Mr Gary Morris, Boeing USA
 Mr Paul Omerod, Volterra Consulting, UK
 Mr Shawn Parr, Calytrix Technologies
 Mr Adrian Pitman, Defence Materiel Organisation, Australia
 Ms Isabel del Pozo de Poza (IdP), ATM Advanced Trajectory Technologies, Boeing Research & Technology Europe, Madrid, Spain
 Mr Craig Saddler, President, Boeing Australia
 Dr Paul Simhauser, Babcock & Brown Power
 Dr Terry Stevenson, Chief Technology Officer, Raytheon Australia
 Mr Dean Webb, International Business Development, Boeing USA
 Dr Miguel Vilaplana, ATM Advanced Trajectory Technologies, Boeing Research & Technology Europe, Madrid, Spain

Technology Transfer and Commercialisation Activities

Our technology transfer and commercialisation activities are aimed at encouraging end users to adopt Centre ideas, methods and tools to enable them to better understand, design and manage complex systems. One of the measures of our success is the degree to which our methods and tools are taken up and used by others. There is broad interest in the work we are doing. Amongst others, we have collaborations with:

- ❖ Centre of Excellence in Integrative Legume Research (CILR) and ARC Centre in Bioinformatics (see page 9, 'Modelling regulatory networks at cell, tissue and organism level'),
- ❖ Horticulture & Food Research Institute of New Zealand (see highlight box on page 9) Airservices Australia (see page 12, 'Air traffic control workload').
- ❖ US-based 'TeraGrid' (see page 26, 'Application of Grid computing to complex systems modelling').
- ❖ Institute for Molecular Bioscience (IMB) (see page 8, 'Modelling gene regulatory networks and plant morphology').
- ❖ Vestas and Rio Tinto (see highlight box on page 14)

- ❖ Queensland Department of Primary Industries and Fisheries (see highlight box on page 9).
- ❖ Boeing (see page 12, 'Evaluation of future Air Traffic Management concepts'; and page 13, 'Propagation of uncertainty in trajectory computations'; and page 24, 'Model-based development of safety-critical systems').
- ❖ Raytheon (see pages 22-25; 'Dependable computer-based systems' program).
- ❖ Sun Microsystems Laboratories (see page 25, 'Verification of lock-free algorithms').
- ❖ Queensland Cyber Infrastructure Foundation QCIF (see page 26, 'Distributed computing for interactive modelling research').

The Centre has developed an Intellectual Property (IP) Register to assist with management of the identification, protection and commercialisation of Centre IP and to help ensure compliance with restrictions on third-party Background IP introduced into the Centre. The IP Register consists of a database of IP information cross-linked with project information, with a web-based user interface accessible to Centre participants. UniQuest, the commercialisation arm of The University of Queensland, has identified commercial potential for the IP register and is proposing to develop the tool into a commercial product.

Public Awareness Programs

Through Public Awareness Programs the Centre aims to raise awareness of complex systems in Australia, and its importance in innovation and international competitiveness. In 2007, the Centre's main activity in this area was the organisation of Complex'07 (see page 30).

The Centre maintains a website (www.accs.edu.au) and mailing list to assist in its task of raising public awareness of complex systems.



The Centre has supported the development of Monash University's Artificial Life Virtual Lab (www.complexity.org.au/vlab). VLAB is a web-based resource for research and education about complex systems. It presents simulations to help people understand how complex organisation and behaviour emerges in living systems. See page 45 for details.



Geoff Dromey and the DCS research team maintain the Behavior Engineering website at www.behaviorengineering.org. It provides details of their revolutionary new approach to engineering complex systems. The team has prepared half, one, two, five and ten day versions of a course suitable for presentation in a range of industry and public forums.

Centre personnel presented at the following conferences

1st IEEE Symposium on Artificial Life
 3rd Australian Conference on Artificial Life, Gold Coast, Qld, December, [David Abramson, Invited Speaker, 'Simulated life wasn't meant to be easy: Applications of high performance computers to A-life']
 3rd International Conference on Collaborative Computing: Networking, Applications and Worksharing
 3rd IEEE International Conference on e-Science and Grid Computing
 4th International Conference Cooperative Design, Visualisation, and Engineering (CDVE 2007)
 4th International Conference on the Quantitative Evaluation of SysTems (QEST 2007)
 4th International Colloquium on Theoretical Aspects of Computing (ICTAC)
 5th IEEE International Conference on Software Engineering and Formal Methods (SEFM 2007)
 5th International Workshop on Functional-Structural Plant Models
 6th IEEE International Conference on Cognitive Informatics
 6th International Conference on Integrated Formal Methods (IFM 2007)
 7th International IEEE Symposium on Cluster Computing and the Grid
 7th International Workshop on Information Processing in Cells and Tissues
 11th Asia-Pacific Workshop on Intelligent and Evolutionary Systems
 12th International Conference on Engineering of Complex Computer Systems (ICECCS 2007)
 13th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining
 14th International Symposium on Aviation Psychology
 18th Australian Conference on Software Engineering (ASWEC 2007) [Geoff Dromey, Keynote Speaker]
 21st ACM International Conference on Supercomputing
 51st Australian Agricultural and Resource Economics Society Conference (AARES)
 Bioinformatics Australia 2007 Conference
 British Combinatorial Conference
 eResearch Australasia 2007 [David Abramson, Invited Speaker, 'Grid enabling 'real' science and engineering']
 EUROCONTROL Innovative Research Workshop
 IEEE Power Engineering Society General Meeting
 IEEE Symposium on Computational Intelligence in Scheduling
 IEEE Congress on Evolutionary Computation (CEC 2007)
 IEEE International Parallel and Distributed Processing Symposium
 IEEE International Symposium on Computational Intelligence in Games
 IEEE Symposium on Computational Intelligence for Security and Defense Applications
 International Congress on Modelling and Simulation (MODSIM 2007)
 International Workshop on Principles of Software Evolution (IWPSE2007)
 Meeting of the Society of Crystallographers in Australia and New Zealand (SCANZ 2007) [David Abramson, Invited Speaker, 'High throughput monte-Carlo modelling using the Computational Grid']
 Pacific-Asia Conference on Knowledge Discovery and Data Mining (PAKDD'07)
 Power Tech, 2007
 Progress in Artificial Life
 Simulation Technology Conference (SimTecT 2007)

Undergraduate & Postgraduate Courses

Centre participants presented aspects of complex systems science and engineering in the following undergraduate and postgraduate courses:

Advanced Algorithms & Data Structures

(UQ COMP4500)

Coordinator: Brijesh Dongol

Level: Undergraduate

Functional Plant Biology

(UQ BOTN2002)

Presenter: Jim Hanan (Guest lectures)

Programming in the Large / Advanced Software Engineering

(UQ CSSE2002/7023)

Coordinator: Graeme Smith

Presenters: Paul Strooper, Kirsten Winter

Level: Undergraduate/Postgraduate

Research Methods

(UQ COMP4809/7809)

Coordinator: Janet Wiles/Jane Hunter

Guest lecturer: Peter Lindsay

Level: Undergraduate/Postgraduate

Software Engineering

(Griffith 2509ICT)

Presenter: Geoff Dromey

Level: Undergraduate

Systems Engineering

(UQ ENGG4000/7000)

Coordinators: Peter Lindsay, Lars Grunske

Level: Undergraduate/Postgraduate

System Safety Engineering

(UQ ENGG7020)

Presenters: Peter Lindsay (Coordinator), Lars Grunske, Ariel Liebman

Level: Postgraduate, also offered as a public course to industry. Included dependability analysis for complex engineered systems.

Melbourne University, and anecdotally other institutions, are teaching Behavior Tree and Behavior Engineering methodology as part of their Software Engineering courses. This methodology is being developed by Centre Chief Investigator Geoff Dromey and his DCS research team.

High School Awareness Events

Jim Hanan participated in the Siemens Science Experience for year nine students. Models were integrated into a scenario-based package using UQs CBIT developed software called PBLi to expose year nines to the use of mathematics and computer science approaches in the study of complex biological systems.

John Quiggin presented the keynote address 'Can economists save the planet?' to the year ten students participating in UQ Economics Schools Day at The University of Queensland in July.

Complex theory

Scientists are moving beyond the laboratory to create computer simulations using flocks of birds and the flu epidemic to show the relationship between humans, machines and animals.

They have developed an online resource to test a range of complex scenarios and in a rare move, are sharing that intellectual capital with colleagues and the public. Computers have been part of life and scientific research for decades but it's only recently they have had the capacity to mimic the complexity of nature and our community.

"One of the insights that complex systems science has given us is that what seem like trivial local interactions can have staggering global consequences," says Professor David Green, a researcher with the Faculty of Information Technology. "A flock of birds flows and changes based on the behaviour of individual birds.

One of the insights that complex systems science has given us is that what seem like trivial local interactions can have staggering global consequences

An epidemic emerges from seemingly random contact between people. Social trends emerge from similar human behaviours; and economic strain in one country can sweep across the globe," he said.

In our modern world, we are surrounded by complex systems rich in inter-reaction, Professor Green said. "Imagine the impact of a computer virus on one computer -- it is devastating for the user, but if a virus attacks a network, the problems which follow can be catastrophic. It's all part of a field known as Complexity Theory, where the whole is greater than the sum of its parts."

Monash IT Faculty researchers are creating highly sophisticated computer models, known as the virtual laboratory (VLAB), that can analyse and predict complex systems and outcomes. Their latest achievement is an online laboratory designed to study the consequences of complexity in a range of systems.

"How does the media affect public opinion? What is the influence of social interactions on law and order in society? How do we understand the reasons behind large scale behaviour, such as a stock market crash? These

are all obvious examples of complex networks," he said. "It is an area of research which is growing rapidly, as our society becomes increasingly dependant on networks," Professor Green said. "The more we can understand how complex systems work, how they evolve and how to control them, the better we will be in understanding our own personal, environmental, social and technological environments and the better able we will be to manage them."

In the spirit of collaboration, VLAB is open for anyone across the world to access and use (www.complexity.org.au/vlab). Professor Green said it was important for his global colleagues to be able to easily trial their theories and for the general public to learn more about this emerging science.

He says it's an exciting future, predicting the next generation of complexity theory models will be able to not only map scenario outcomes, but also warn of negative consequences and suggest alternatives.

Story by Samantha Blair, Monash Magazine, Issue 20, Spring/Summer 2007



David Green
(Photography by Greg Ford & Melissa Di Ciero)

Publications

2007

Papers published in publications that The University of Queensland considers to be the top ten percent of journals and conferences in their field, are starred ✦.

Chapters in books

Adams, P., "Sequencing aided by mutagenesis facilitates the De Novo sequencing of megabase DNA fragments by short read lengths", *New High Throughput Technologies for DNA Sequencing and Genomics*, Elsevier, 2007.

Baker, S., Bender, A., Abbass, H., Sarker, R., "A scenario-based evolutionary scheduling approach for assessing future supply chain fleet capabilities", *Evolutionary Scheduling, Studies in Computational Intelligence*, Vol. 49, Springer, 2007.

Dam, H., Lokan, C., Abbass, H., "Evolutionary online data mining: an investigation in a dynamic environment", *Evolutionary Computation in Dynamic and Uncertain Environments, Studies in Computational Intelligence*, Vol. 51, Springer, 2007.

Dorr, G., Noller, B., Woods, N., Hewitt, A., Hanan, J., Adkins, S., Ricci, P., "Development of a decision-making tool to minimise environmental and public health risk of pesticide application", *Rational Environment Management of Agrochemicals: Risk Assessment, Monitoring, and Remedial Action*, American Chemical Society, 2007, 53-65.

Gray, K., Street, A., "Defining sets", *Handbook of Combinatorial Designs*, Edited by Colbourn, C., Dinitz, J., 2nd Edition, Chapman & Hall/CRC, Taylor & Francis Group, 2007, 382-385.

Grunske, L., Lindsay, P., Bondarev, E., Papadopoulos, Y., Parker, D., "An outline of an architecture-based method for optimising dependability attributes of software-intensive systems", *Architecting Dependable Systems IV, Lecture Notes in Computer Science*, Vol. 4615, Springer, August 2007, 188-209.

Renton, M., Thornby, D., Hanan, J., "Canonical modelling: an approach for intermediate level simulation of carbon allocation in functional structural models", *Functional-Structural Plant Modelling in Crop Production*, Wageningen UR Frontis Series, Vol. 22, Springer, 2007.

Street, D.J., Street, A., "Partially balanced incomplete block designs", *Handbook of Combinatorial Designs*, Edited by Colbourn, C., Dinitz, J., 2nd Edition, Chapman & Hall/CRC, Taylor & Francis Group, 2007, 382-5.

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Complex'07 Publications

The following presentations were made by Centre participants at the 8th Asia-Pacific Complex Systems Conference, held on the Gold Coast in July 2007.

'Controlling complex resources over different timeframes in process control'

Penelope Sanderson

'Discovering' small worlds in potentially biased networks: A methodological critique'

Sam MacAulay, John Steen, Tim Kastle

'The emergence of new markets'

Ella Reeks

'Architecture trade-off analysis and multi-objective optimisation strategies'

Lars Grunske

'Simulation engine for strategic planning of health services using Agent Based Modelling'

Ashok Kanagarajah, Peter Lindsay, David Parker

'Towards a complex systems model of Australian Air Traffic Management'

Ariel Liebman, Peter Lindsay, Colin Ramsay, Martijn Mooij

'Impacts of Vehicle-to-Grid (V2G) technologies on electricity market operations'

Ariel Liebman, Geoff Walker

'Optimal GENCO's bidding strategies under price uncertainty with bilateral contracts'

Xia Yin, Zhao Yang Dong, Tapan Saha

'Interactively exploring distributed computational models of biology'

James Watson, Janet Wiles

'Modelling the import of nuclear proteins'

John Hawkins, Mikael Boden

'Signatures of game dynamics for intelligence and information operation'

Hussein Abbass

'Boolean networks as models of social behaviour'

Tania Leishman, David Green

'Advanced data analysis methods to detect and predict the non-technical losses based on customer behaviour changes for power utilities'

Anisah Nizar, Zhao Yang Dong

'Complexity in speciation: Effects of disasters on adaptive radiation in a dual phase evolution model'

Greg Paperin, David Green, Suzanne

Sadedin, Tania Leishman

'Information contagion and financial prices'

Mark Bowden

'The evolution of the World Trade Web as a complex system'

Tim Kastle

'Computational models for studying signalling control mechanisms behind legume autoregulation of nodulation'

Liqi Han, Peter M. Gresshoff, Jim Hanan

'A computational model of *C. elegans* locomotion dynamics and motor control circuitry'

Mark Wakabayashi, David Carrington, Janet Wiles

'Computational techniques for modelling complex biological systems'

James Watson, Mark Wakabayashi, Jared Moore, Andres Sanin Montoya, Kai Willadsen, Nic Geard, Daniel Bradley, Janet Wiles

'Electricity market planning and management'

John Lu

'Optimal active learning in Gaussian process regression: an empirical study'

Flora Yu-Hui Yeh, Marcus Gallagher

'Reinforcement learning in complex computer game environments'

Michelle McPartland, Marcus Gallagher

'Robots and the evolution of spatial language'

Ruth Schulz, David Prasser, Mark Wakabayashi, Janet Wiles

'Searching concept spaces using physical navigation strategies'

Paul Stockwell, Andrew Smith, Janet Wiles

'Simulkit: a software toolkit aiming towards a unified network-based view of complex systems'

Daniel Bradley, Ariel Liebman, Leighton Brough

'Virtual kiwifruit: Modelling annual growth cycle'

Mikolaj Cieslak, Alla N. Seleznyova, Jim Hanan

'LiveGraph - a tool for data visualisation, analysis and logging in complex systems simulations.'

Greg Paperin

'VLAB - An online virtual laboratory for complexity and artificial life'

Alex Tee Neng Heng, David Green

Performance Indicators Report

P1. Research findings			
Description	2007 Actual	Details	2007 Target
Quality of publications	28	See Publications, page 46	At least eight in the top 10% of journals & conferences in relevant areas
Invitations to address and participate in international conferences	11	See Keynote & Invited Addresses, page 36	5-6
Invitations to visit leading international laboratories	12	See Visits to International Institutions, page 40	3
Number and nature of commentaries about the Centre's achievements	5	See ACCS in the Media, page 11	3

P2. Research training and professional education			
Description	2007 Actual	Details	2007 Target
Number of postgraduates recruited - with Centre financial support - affiliated with the Centre	4 (26 total to date) 11 (45 total to date)	See Research Students, page 32	14 over the life of the Centre
Number of postgraduate completions	6 (15 total to date)	See Research Students, page 32	14 over the life of the Centre
Number of honours students	13 (28 total to date)	See Research Students, Honours, page 35	30 over the life of the Centre
Number of professional courses/workshops	10	See Workshops, page 41	1
Participation in professional courses	6	See Professional Courses, page 41	2
Number and level of undergraduate and high school courses in the complex systems area	primary contributor: 4 other contributor: 5	See Undergraduate & Postgraduate Courses, page 44	Primary contributors to 2-3 undergraduate courses per annum, and contributions (eg guest lectures) to other courses; contribution to high school awareness events

P3. International, national and regional links and networks			
Description	2007 Actual	Details	2007 Target
Number of international visitors	20 (of these, 5 had significant Centre financial support)	See Visitors to the Centre, page 38	4
Number of national and international workshops	9	See Workshops, page 41	2
Number of visits to overseas laboratories	43	See Visits to International Institutions, page 40	5
Examples of relevant Social Science & Humanities research supported by the Centre	4 publications	See Evolutionary Economic Systems publications, pages 15-17	1 publication

P4. End-user links
See the Director's Report, page 2, and Technology Transfer and Commercialisation Activities, page 43, for details of end-user links

P5. Organisational support
See the Financial Statement, page 52 for details of organisational support

P6. Governance
See the Management section, page 6 for details of governance of the Centre

P7. National benefit
See the Director's Report, page 2 for details of national benefit

Financial Statement

Statement of operating income and expenditure for the year ended 31 December 2007.

INCOME	
ARC Centre grant	979,476
Collaborating institutions' cash contribution	325,000
NHMRC	34,250
Industry cash contribution	70,006
Other funds	79,920
Funds carried forward from 2006	393,977
TOTAL INCOME	1,882,629

EXPENDITURE	
Maintenance	78,165
Travel	90,088
Equipment	6,059
Salaries	1,268,180
Scholarships	102,792
TOTAL EXPENDITURE	1,545,283

Funds carried forward to 2008	337,346
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Activity Plan for 2008

ARC Centre funding will terminate at the end of 2008. The Centre's main activities in 2008 will focus on completing our core research programs, maximising the outcomes, and facilitating an orderly transition to post-Centre funding.

More specifically, the following new initiatives are planned:

- ❖ Initiate new projects with industry partners in three core programs (Electricity networks and energy markets, Dependable computer-based systems, and Air traffic control) with a view to ensuring take up of the Centre's research outcomes.
- ❖ Provide research project leadership training for Centre personnel.
- ❖ Participate in the ARC Research Outcomes Forum at Parliament House in June.
- ❖ Assist staff in finding employment after cessation of Centre funding.
- ❖ Transition research higher degree students to appropriate schools in host universities.

Ongoing activities include:

- ❖ Foster cross-disciplinary research across the Centre by undertaking joint projects.
- ❖ Work with end-user organisations to develop collaborative projects, to trial and evaluate the Centre's research.
- ❖ Identify opportunities for the transfer of ACCS methods and tools to industry.
- ❖ Invite key international researchers to visit the Centre for discussions with Centre participants.



Australian Government
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The ARC Centre for Complex
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