ARC Centre for Complex Systems

annual report 2005

ARC CENTRE FOR
COMPLEX SYSTEMS

Contents

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 is headquartered at the University of Queensland in Brisbane, with nodes at Griffith University in Brisbane, Monash University in Melbourne, and the Australian Defence Force Academy in Canberra. The Centre brings together leading researchers from a range of disciplines including systems and software engineering, visualisation, human factors, 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 will be established over the life of the program in order to apply the Centre's research.

Director's Report

Modelling and simulation are key techniques for understanding complex systems. But there is a class of systems which are presenting tough challenges to researchers, because the properties of the whole system seem to be much greater than the sum of the parts of the system. I'm referring to distributed network-based systems which exhibit emergent phenomena: that is, their components essentially act autonomously, yet somehow achieve coordinated effects.

Biologists, economists and systems engineers have been independently tackling very similar problems for some time. Without specifically realising it, they have all been trying to answer the question: what is it about how agents behave – and how they interact in networks – that enables systems to function as a whole, without using a centralised control mechanism. In biology, genes evidently operate in this way to control the growth of networks of cells. In economics, trading markets function in this way, to efficiently distribute products and services. And electricity grids also work in this way, to balance load across the electricity network.

But all of these systems can also go seriously wrong. Cancer has a genetic basis which allows cells to sometimes divide uncontrollably. Markets have bubbles, in which prices far exceed the real value of the commodity being traded. And whole regions can be blacked out as a result of relatively small failures cascading through the electricity network, as has been seen dramatically in many different parts of the world in recent years. Our understanding of such systems is still in its infancy.

Many branches of science and engineering have reached the limits of what can be done with standard modelling and simulation techniques in solving such problems, and are recognising the need for fundamentally new approaches, methods and tools. The ARC Centre for Complex Systems (ACCS) was established to bring together a multi-disciplinary team to tackle exactly this issue.

The ACCS's core research program is concerned with distributed control in network-based systems. We're working with biologists to try to understand how genes control the growth of networks of cells. We're working with economists to understand how markets function (or in some cases, don't function), to efficiently distribute products and services. We're working with human factors experts to understand and predict the implications of proposed changes to air traffic control, giving airlines more say in the decisions that are made. We're also undertaking fundamental research in dependability of computer-based systems and in methods and tools for the analysis of 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. As will be evident from the research project reports below, and the diversity of disciplines represented among the researchers, there is broad interest in the work we are doing. In 2005 we collaborated with the Centre of Excellence in Integrative Legume Research, the ARC Centre for Bioinformatics, the Queensland Brain Institute, and Airservices Australia, amongst others. Centre staff and associated academics are jointly supervising PhD projects with the Institute of Molecular Bioscience, the Defence Science and Technology Organisation, CSIRO and other research organisations. We're developing the methods and tools that people will use to understand, design and manage the complex systems of the future.

As with any fundamental research, it is hard to predict exactly where it might lead. But it is clear that by creating a focus for applied complex systems research in Australia, the ACCS is keeping Australia at the forefront of this exciting new area. As a recent Centre visitor observed, we have one of the largest concentrations of complex systems researchers in the world, and our research is cutting edge. The potential for economic, social and environmental benefit to Australia is enormous, through innovations in bioengineering and health, agriculture, air traffic management, and government economic policy.

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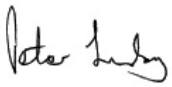
2005 was a year of continued success and cross-fertilisation for the ACCS. We exceeded almost every Key Performance Indicator, and are well-placed to continue strong work into the future. There were 38 active projects, involving about 70 researchers. Centre research outcomes have been exceptional, with at least 40 papers accepted in refereed journals, Centre participants making presentations at over 30 national and international conferences, and almost 60 research students associated with the Centre. The Centre held an inaugural Winter School in July which attracted over 40 participants, and received extremely positive feedback.

A very successful patterns workshop was held jointly with the Complex Open Systems (COSNet) research network.

Postdoctoral research fellows were appointed in the Air Traffic Control and Genetic Regulatory Networks areas. A Tools Coordinator was appointed and is working actively with the different project teams to foster good software engineering practice. A weekly seminar series has operated since April, with regular participation by staff and students from the UQ, Griffith and ADFA nodes, the last via videoconference link.

Having brought together a world-class group of researchers and established the infrastructure and mechanisms to enable them to interact in a cross-disciplinary manner, the Centre's focus in 2006 will be on demonstrating quality and achieving uptake of the Centre's research. Please contact me if you would like to discuss possibilities for collaboration.

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



Peter Lindsay
Director, ACCS
March 2006

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. A storm over Dallas, Texas, for example, can result in flights being grounded thousands of miles away in New York, with all the resulting chaos and missed connections. The traffic network is not as robust as travellers would wish.
- 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 ARC Centre for Complex Systems (ACCS) 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 three core application areas - genetic regulatory networks, free-flight air traffic control, and evolutionary economic systems - which are described in more detail later in this Report.

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.

	School/Unit	Institution
Director		
Prof Peter Lindsay	Information Technology & Electrical Engineering	The University of Queensland
Deputy Director		
Prof Ian Hayes	Information Technology & Electrical Engineering	The University of Queensland
Chief Investigators		
Assoc 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 John Foster	Economics	The University of Queensland
Prof David Green	Computer Science & Software Engineering	Monash University
Prof Simon Kaplan	Information Technology	Queensland University of Technology
Prof Geoff McLachlan	Mathematics	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
Partner Investigators		
Prof Kalyanmoy Deb	Mechanical Engineering	Indian Institute of Technology, Dehli, India
Mr Rick Neilson	Chief Engineer	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
Ms Leanne Brandis	Education Officer	The University of Queensland
Mr Leighton Brough	Tools Coordinator	The University of Queensland
Mr John Hawkins	Webmaster	The University of Queensland
Ms Kate Williamson	Acting Centre Manager	The University of Queensland
Ms Peta Bignell	Administrative Support	Griffith University
Ms Diana Dragisic	Administrative Support	The University of Queensland
Mr Chris Greenacre	Administrative Support	Griffith University
Mr Carlo Hamalainen	Administrative Support	The University of Queensland
Collaborators		
Dr Michael Barlow	Information Technology & Electrical Engineering	UNSW@ADFA
Dr Rodney Beard	Economics	The University of Queensland
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	The University of Queensland
Dr Margot Brereton	Information Technology & Electrical Engineering	The University of Queensland
Dr Darryn Bryant	Mathematics	The University of Queensland
Dr David Carrington	Information Technology & Electrical Engineering	The University of Queensland
Dr David Chen	Information & Communication Technology	Griffith University
Dr David Cornforth	Environmental & Information Sciences	Charles Sturt University
Dr Zhao Yang Dong	Information Technology & Electrical Engineering	The University of Queensland
Mr Colin Enticott	Computer Science & Software Engineering	Monash University
Dr Daryl Essam	Information Technology & Electrical Engineering	UNSW@ADFA
Dr Marcus Gallagher	Information Technology & Electrical Engineering	The University of Queensland
Mr Slavisa Garic	Computer Science & Software Engineering	Monash University
Prof Peter Gresshof	ARC Centre of Excellence for Integrative Legume Research	The University of Queensland
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
Ms Karen Harris	Mathematics	The University of Queensland
Dr Jim Haseloff	Department of Plant Sciences	University of Cambridge, UK
Dr George Havas	Information Technology & Electrical Engineering	The University of Queensland
Prof Melvin Hinich	Department of Government	The University of Texas at Austin, USA
Ms Sue Keey	Future Direction Group	Airservices Australia
Dr Peter Kwantes	Simulation & Modelling (SMART)	Defence Research & Development, Canada
Dr Stuart McDonald	Economics	The University of Queensland
Dr Rizah Memisevic	Information Technology & Electrical Engineering	The University of Queensland

	School/Unit	Institution
Collaborators		
Dr Keith Mitchelson	Research & Technology	Australian Genome Research Facility
Dr Andrew Neal	Key Centre for Human Factors & Applied Cognitive Psychology	The University of Queensland
Dr David Newth	Environmental & Information Sciences	CSIRO Centre for Complex Systems Science
Prof Stefano Nolfi	Institute of Cognitive Sciences & Technologies	National Research Council (CNR), Italy
Mr Tom Peachey	Computer Science & Software Engineering	Monash University
Dr Jason Potts	Economics	The University of Queensland
Prof Mark Ragan	ARC Centre for Bioinformatics	The University of Queensland
Dr Peter Robinson	Information Technology & Electrical Engineering	The University of Queensland
Dr Ruhul Sarker	Information Technology & Electrical Engineering	UNSW@ADFA
Dr John Steen	UQ Business School	The University of Queensland
Prof Anne Street	Centre for Discrete Mathematics & Computing	The University of Queensland
Prof Chengzheng Sun	Information & Communication Technology	Griffith University
Dr Jeff Tan	Computer Science & Software Engineering	Monash University
Assoc Prof Kay Chen Tan	Electrical & Computer Engineering	National University of Singapore
Prof Janet Wiles	Information Technology & Electrical Engineering	The University of Queensland
Dr Yubin Yang	Information Technology & Electrical Engineering	UNSW@ADFA
Prof Xin Yao	Centre of Excellence for Research in Computational Intelligence & Applications	The University of Birmingham, UK
Research Staff		
Ms Tania Bransden	ACCS	Monash University
Mr Archie Chapman	ACCS	The University of Queensland
Ms Rachel Chitoni	ACCS	The University of Queensland
Mr Clement Chu	ACCS	Monash University
Mr Dale Clutterbuck	ACCS	The University of Queensland
Dr Robert Colvin	ACCS	The University of Queensland
Mr Simon Connelly	ACCS	The University of Queensland
Ms Jingru Dai	ACCS	The University of Queensland
Mr Nic Geard	ACCS	The University of Queensland
Dr Ken Gray	ACCS	The University of Queensland
Dr Jim Hanan	ACCS	The University of Queensland
Mr John Hawkins	ACCS	The University of Queensland
Mr Benson Heng	ACCS	The University of Queensland
Mr Charles Hudson	ACCS	The University of Queensland
Dr Ariel Liebman	ACCS	The University of Queensland
Dr Barbara Maenhaut	ACCS	The University of Queensland
Mr Robert McLeay	ACCS	The University of Queensland
Mr Martijn Mooij	ACCS	The University of Queensland
Ms Kate Morrison	ACCS	The University of Queensland
Mr Alex Tee Neng Heng	ACCS	Monash University
Mr James Patterson	ACCS	The University of Queensland
Dr Danny Powell	ACCS	Griffith University
Mr Fan Qi	ACCS	UNSW@ADFA
Dr Colin Ramsay	ACCS	The University of Queensland
Mr Tim Rudge	ACCS	The University of Queensland
Mr Cameron Smith	ACCS	Griffith University
Ms Kim Taylor	ACCS	Griffith University
Mr Liam Wagner	ACCS	The University of Queensland
Mr Junhua Wang	ACCS	The University of Queensland
Dr Kui Wang	ACCS	The University of Queensland
Mr James Watson	ACCS	The University of Queensland
Mr Lian Wen	ACCS	Griffith University
Dr Jacqueline Wicks	ACCS	The University of Queensland
Dr Phillip Wild	ACCS	The University of Queensland
Mr Kai Willadsen	ACCS	The University of Queensland
Dr Kirsten Winter	ACCS	The University of Queensland
Ms Tania Xiao	ACCS	The University of Queensland
Mr Wang Jian Xiong	ACCS	The University of Queensland
Ms Nisansala Yatapanage	ACCS	Griffith University
Dr Emine Şule Yazıcı	ACCS	The University of Queensland
Mr Aaron Yeung	ACCS	The University of Queensland
Mr Saad Zafar	ACCS	Griffith University

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.

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 2005:

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
Research Leader, Integrated Capabilities Branch, Defence Systems Analysis Division, DSTO, Canberra, ACT

Professor John Eccleston
Acting Executive Dean, Faculty of Engineering, Physical Sciences and Architecture, The University of Queensland, St Lucia, Qld

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 Rick Neilson
Chief Engineer, Boeing Australia, Brisbane, Qld

Mr Keith Orkney
Director R&D, Airservices Australia, Canberra, ACT

Professor David Siddle
Deputy Vice Chancellor – Research, The University of Queensland, St Lucia, Qld

Advisory Board members at the meeting on 14 November.
Front row left to right: Paul Bailes, John Finnigan, Keith Orkney, Peter Lindsay
Back row left to right: Richard Davis, John Eccleston, Rick Neilson, John Foster

Recognition of Centre Personnel

Dr Jennifer Hallinan was presented with the award for the Best Overall Paper at the IEEE Symposium on Computational Intelligence in Bioinformatics and Computational Biology in San Diego, USA, in November. Jennifer moved from The University of Queensland to the University of Newcastle on Tyne, UK in late 2005.

Centre Collaborator Dr Rodney Beard was the recipient of the prestigious 2005 PhD prize of the Australian Agricultural and Resource Economics Society, for his thesis: 'Ito stochastic control theory, stochastic differential games and the economic theory of mobile pastoralism'.

ACCS PhD student Xinlin Li was joint winner of the conference award for the Best Paper presented at the 24th European Annual Conference on Human Decision Making and Manual Control (EAM2005) in Athens, Greece, in October 2005.

Chief Investigator Peter Adams and GRN Program Leader Janet Wiles received promotions to Professors, and Chief Investigator Hussein Abbass was promoted to Associate Professor.

Professor Janet Wiles won an Award for Excellence in Research Higher Degree Supervision, one of the UQ Excellence in Teaching and Learning Awards.

Janet Wiles

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 ACCS 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.

Computer modelling and simulation of complex systems are important for testing the validity of existing theories and developing new theories. 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. It will also facilitate application of the theories to real-world systems, and develop principles for managing (planning and controlling) complex systems.

The Centre's core ARC-funded program is based around three application areas:

- genetic regulatory networks,
- evolutionary economic systems, and
- free-flight air traffic control.

These programs are supported by projects concerned with improved methods and tools for analysing and developing complex systems.

Genetic Regulatory Networks

Program Leader: Janet Wiles

The ACCS is tackling fundamental questions about growth and form in cellular biology. Traditional reaction-diffusion models take a top-down view that examines the control of growth patterns by biochemical gradients. These models need to be integrated with models that capture local organisations and interactions. We are studying how ontogeny based on realistic phenotypic descriptions such as L-systems can be derived from genetic regulatory models. We are seeking deeper understanding of the network structuring and control mechanisms that underlie genetic regulation in cell-level development of organisms. The vision is to be able to take insights arising from how DNA regulates the growth of organisms, extract general principles, and then transfer them to other domains, such as air traffic control and economics.

Modelling regulatory networks at cell, tissue and organism level

Project Leader: Jim Hanan
Researchers: Kevin Burrage, Robert McLeay, Janet Wiles

Computer-aided models of biological regulatory networks provide a framework for: systematic investigation of hypothesised network structures; management of data on large numbers of system components and interactions; and simulation studies aimed at revealing emergent properties and consequences of hypothesised networks. This project focuses on agent-based generative modelling systems for simulation of regulatory networks within a developing spatial structure. Analysis of the resulting complex system models will lead to further development of software methodologies and serve as background for investigation of mechanisms for managing and controlling complex systems.

In 2005, at the cellular level, in a joint project with the ARC Centre in Bioinformatics, Robert McLeay developed hierarchical Petri Net models of macrophage regulatory and signalling networks. At the intracellular level, Denis Bauer built a Petri Net model of the GRN controlling differentiation in vulval tissues of C. elegans. An invited presentation was given at the *International Botanical Congress* on the model of genetic control of branching in pea being developed in collaboration with L. Dun and C. Beveridge. During Prof Prusinkiewicz' visit, prototype models were refined for studying genetic control of carbon allocation in plants with Alla Seleznyova, New Zealand HortResearch. (Included 2005/06 summer project)

Recent outputs

Hanan, J., Thornby, D., Adkins, S., 'Modelling cotton plant development with L-systems: a template model for incorporating physiology.', *Proceedings of ModSim 05,* 2005, 1243–1250.

Renton, M., Hanan, J., Burrage, K., 'Using the canonical modelling approach to simplify the simulation of function in functional-structural plant models', *New Phytologist*, vol. 166, no. 3, June 2005, 845–857.

Renton, M., Kaitaniemi, P., Hanan, J., 'Functional-structural plant modelling using a combination of architectural analysis, L-systems, and a canonical model of function.', *Ecological Modelling*, vol. 184, no. 2–4, June 2005, 277–298.

Watanabe, T., Hanan, J., Hasegawa, T., Nakagawa, H., Takahashi, W., Room, P., 'Rice morphogenesis and plant architecture: Measurement, specification and the reconstruction of structural development by 3D architectural modelling', *Annals of Botany*, vol. 95, 2005, 1131–1143.

On the training of mixture of experts with multilevel gating and expert networks

Project Leader: Geoff McLachlan
Researchers: Kui Wang

This project proposes to study the methodology in incorporating multilevel data hierarchies within networks modelling. The proposed research aims at generalizing Mixtures of Expert (ME) networks by allowing both the gating and expert networks to incorporate the multilevel data hierarchy via the generalised linear mixed-effects model. That is, we assume that each unit contributes (scalar) random effects within the gating and expert networks through the corresponding linear predictors. We also aim at developing the fast learning of the proposed generalised ME network via the EM algorithm. The extension of the methodology to Gaussian mixtures and multi-layered perceptron neural networks for tackling problems with hierarchically structured data will also be studied. Although neural networks and mixtures of experts can be applied to problems in network-based systems in general, the aim here is to apply them to problems in genetic regulatory networks, such as the analysis of time-course gene expression data.

The project started in mid April 2005. We have extended mixture-of-experts networks to incorporate multilevel data hierarchies via the generalised linear mixed-effects model. Research papers have been produced to disseminate the research findings to a wide audience in highly-regarded international journals and conferences in relevant scientific fields.

Recent outputs

Ng, S., McLachlan, G., 'Mixture model-based statistical pattern recognition of clustered or longitudinal data', *Proceedings of WDIC 2005, APRS Workshop on Digital Image Computing*, 2005, 139–144.

Ng, S., McLachlan, G., 'Normalized Gaussian networks with mixed feature data', *Lecture Notes in Artificial Intelligence*, vol. 3809, 2005, 879–882.

Genetic modularity

Project Leader: David Green
Researchers: Tania Bransden, David Cornforth, Alex Heng, David Newth, Suzanne Sadedin

The genome is highly modular in structure, both at a molecular level, where groups of genes function together, and on a macro scale, where speciation and geography lead to genetic differentiation. This project uses simulation models to investigate the processes, such as feedback and natural selection, that are involved in the emergence of genetic modularity.

In 2005 we implemented Weasel World, a model that allows experimentation with the factors that lead to the combination of modules, or building blocks, to form hierarchical structures. With this model, we quantified the effects on genetic module formation of variable length genotype, variable genotype to phenotype mapping, pseudo-spatial environment, and memetic evolution. We showed that information shared between organisms allows them to combine and build larger modules. These results have implications for the understanding of the formation of hierarchical structures in evolution. Another 2005 achievement is that we used a spatially explicit model of population genetics in a landscape to investigate the effects of genetic trade-offs (where organisms must split resources between different features) on the response of monoecious diploid populations to environmental gradients. One trade-off related the plasticity of an individual to its overall fitness, where individuals that can tolerate a wide range of environmental values are less fit than individuals with a narrow tolerance range. The second trade-off assumed that individuals that can live at in extreme environments are placed under stress and therefore reach maturity later in their life cycle. In both cases the resulting population distributions produced clear genetic differentiation, showing that simple trade-off mechanisms are one route towards genetic isolation and, ultimately, speciation.

Recent outputs

Cornforth, D., Green, D., Awburn, J., 'The formation of hierarchical structures in a pseudo-spatial co-evolutionary artificial life environment', in *Recent Advances in Artificial Life, Advances in Natural Computation-Vol. 3*, World Scientific Publishers, 2005, 55–68.

Green, D., Sadedin, S., 'Interactions matter - Complexity in landscapes and ecosystems', *Ecological Complexity*, vol. 2, no. 2, 2005, 117–130.

Modelling and mapping genes for complex phenotypes in humans

Project Leader: Jacqueline Wicks
Researchers: Ananthila Anandacoomarasamy, David Duffy, Katrina Scurrah, Susan Wilson

The genotype-phenotype correspondence in humans is difficult to uncover for a number of reasons. For complex phenotypes, there may be hundreds of genes that influence the phenotype, as well as environmental, and the more recently discovered epigenetic influences on phenotypes. This project aims to develop mathematical, statistical and computational approaches to mapping genes that influence phenotypes of interest in humans, and to apply the methods in gene mapping projects currently underway in Australia. The emphasis is on flexible modelling that captures the important influences of complex disease genetics, and allows for multi-gene, environmental, and epigenetic interactions.

In 2005, several significant papers were finalised and published in high quality journals during the year. Two papers presented results from gene mapping studies, for the complex disease endometriosis, that Dr Wicks was involved in. These were conducted at the Queensland Institute of Medical Research and headed by Dr Susan Treloar. Another paper was published which described new conceptual approaches to gene mapping. In April

Dr Wicks was an Invited Discussant at the prestigious International Statistical Institute, and presented a paper on some theoretical results in gene mapping. Several collaborations on future gene mapping projects in Australia were also initiated.

Recent outputs

Treloar, S., Wicks, J., Nyholt, D., Montgomery, G., Bahlo, M., Smith, V., Dawson, G., Mackay, I., Weeks, D., Bennett, S., Carey, A., Ewen-White, K., Duffy, D., O'Connor, D., Barlow, D., Martin, N., Kennedy, S., 'Genomewide linkage study in 1 176 affected sister pair families identifies a significant susceptibility locus for endometriosis on chromosome 10q26', *American Journal of Human Genetics*, vol. 77, no. 3, 2005, 365–376.

Treloar, S., Zhao, Z., Armitage, T., Duffy, D., Wicks, J., Martin, N., 'Association between polymorphisms in the progesterone receptor gene and endometriosis', *Molecular Human Reproduction*, vol. 11, no. 9, September 2005, 641–647.

Wicks, J., 'Genetic modelling assumptions for gene mapping and the triangle constraints', *Bulletin of the International Statistical Institute*, 2005.

Wicks, J., Treloar, S., Martin, N., Duffy, D., 'New concepts for distinguishing the hidden patterns of linkage disequilibrium which underlie association between genotypes and complex phenotypes', *Twin Research and Human Genetics*, vol. 8, no. 2, April 2005, 95–100.

Patterns in complex systems models

Project Leader: Janet Wiles
Researchers: David Carrington, Jim Hanan, James Watson, Mark Wakabayashi

The aim of this project was to find and document experience in complex systems modelling using a patterns methodology taken from software engineering. The project had three main goals: identify an initial collection of inter-related GRN patterns with potential for application in all of the Centre's domains, documented in a form comprehensible to all complex systems researchers; establish a framework for a patterns library which allows complex systems researchers to contribute and ratify solutions; and raise awareness in the complex system's community of the value of patterns in advancing the field.

In 2005, an online presence for the project was developed (http://www.itee.uq.edu.au/~patterns/), which includes a submission mechanism for new pattern proposals. A patterns template and classification scheme suitable for complex systems modelling was adapted from software engineering. Software demonstrating the patterns approach was implemented and made available online. Two workshops were held to foster interest in the complex systems community and to develop new patterns through cross-disciplinary collaboration. The first was held on 6–7 June and resulted in successful collaborations between ACCS, UQ's School of Information Technology & Electrical Engineering, the ARC Centre in Bioinformatics and CSIRO researchers. The second was held 5 December as a special session of the *Second Australian Conference on Artificial Life* (ACAL'05). Six complex systems modelling patterns were developed, four in collaboration with attendees of the first workshop. A paper describing patterns in complex systems modelling was presented at the *IDEAL* conference in Brisbane, and published in the *Lecture Notes in Computer Science* series. A paper discussing the computational modelling process, and developed in collaboration with ITEE and Institute of Molecular Bioscience researchers, was presented in June at *GECCO* in Washington. Two further papers resulting from discussions at the first workshop were presented at *The Second Australian Conference on Artificial Life in Sydney*, and published in the *Advances in Natural Computation series*.

This project led to a summer project in collaboration with the Queensland Brain Institute. The ACCS patterns project provided the infrastructure for collating patterns in complex systems modelling. The summer project involved the development of patterns used within ACCS research, in particular for representing information using tree diagrams. The software patterns developed in the project were used in a software tool to model neurosphere growth. The neurosphere modelling tool enables researchers to specify rules for how each cell divides, and then view how it grows from a single cell to several thousand cells. (Included 2005/06 summer project).

Recent outputs

Geard, N., Willadsen, K., Wiles, J., 'Perturbation analysis: A complex systems pattern', *Recent Advances in Artificial Life*, 2005; *Advances in Natural Computation-Vol. 3*, 69–83.

Watson, J., Hawkins, J., Bradley, D., Dassanayake, D., Wiles, J., Hanan, J., 'Towards a network pattern language for complex systems', *Recent Advances in Artificial Life*, 2005; *Advances in Natural Computation-Vol. 3*, 309–317.

Wiles, J., Watson, J., 'Patterns in complex systems modelling', *Proceedings of Sixth International Conference on Intelligent Data Engineering and Automated Learning (IDEAL'05)*; *Lecture Notes in Computer Science*, vol. 3578, 532–539.

Kernel methods for biological sequence analysis

Project Leader: Mikael Boden
Researchers: Lynne Davis, Johnson Shih

This project developed a flexible software library for kernel methods as applied to data-driven biological sequence analysis. Several example kernels selected from the literature were tested. Benchmarking targeted bioinformatics modelling problems such as organellar protein import and protein subnuclear localisation.(2005/06 summer project)

An integrated approach to multicellular development

Project Leader: Janet Wiles
Researchers: Nic Geard, Jim Hanan, Jim Haseloff, Peter Lindsay, Tim Rudge

In this project, we are concerned with the processes in plants and animals that coordinate the formation of shape. How does a single egg or seed cell develop into the shapes that make up an embryo or adult organism? How does it do this so reliably, even in a noisy environment? The key is the interaction of the signals that are passed between cells and the DNA processing (or genetic regulation) that occurs within each cell. We are using complex systems models to study the nature of these interactions and how they control shape formation in a robust way. This analysis will allow us to generalise principles from biological shape formation to apply to the understanding and design of systems in the engineering domain.

Recent outputs

Rudge, T., Geard, N., 'Evolving gene regulatory networks for cellular morphogenesis', *Advances in Natural Computation - Vol. 3 Recent Advances in Artificial Life*, 2005, 231–252.

Rudge, T., Haseloff, J., 'A computational model of cellular morphogenesis in plants', *Advances in Natural Computation - Vol. 3 Recent Advances in Artificial Life*, 2005, 78–87.

General GRN publications

Bauer, D.C., Boden, M., Their, R., Yuan, Z., 'Predicting structural disruption of proteins caused by crossover', *Proceedings of the IEEE Symposium on Computational Intelligence in Bioinformatics and Computational Biology*, November 2005, 514–520.

Boden, M., Hawkins, J., 'Improved access to sequential motifs: A note on the architectural bias of recurrent networks', *IEEE Transactions on Neural Networks*, vol. 16, no. 2, 2005, 491–494.

Geard, N., Wiles, J., 'A gene network model for developing cell lineages', *Artificial Life*, vol. 11, no. 1–2, 2005, 249–68.

Hallinan, J., Jackway, P., 'Network motifs, feedback loops and the dynamics of genetic regulatory networks', *Proceedings of the IEEE Symposium on Computational Intelligence in Bioinformatics and Computational Biology*, 2005.

Hawkins, J., Boden, M., 'The applicability of recurrent neural networks for biological sequence analysis', *IEEE/ACM Transactions on Computational Biology and Bioinformatics*, vol. 2, no. 3, 2005, 243–253.

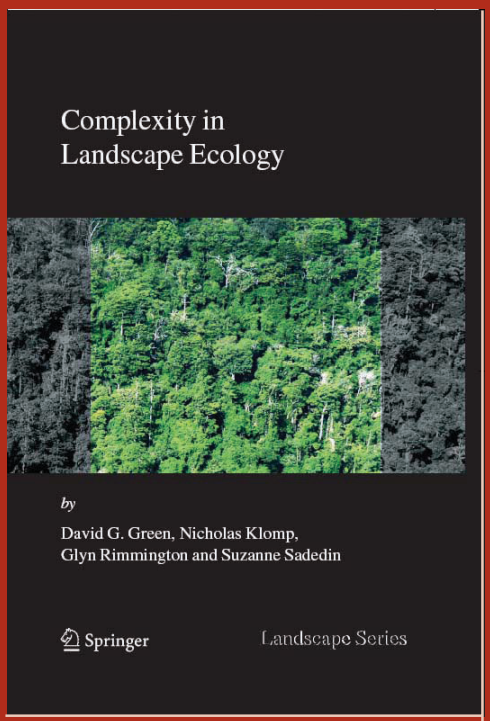
Hawkins, J., Boden, M., 'Predicting peroxisomal proteins', *Proceedings of the IEEE Symposium on Computational Intelligence in Bioinformatics and Computational Biology*, November 2005, 469–474.

Complexity in Landscape Ecology

'Interactions matter. To understand the distributions of plants and animals in a landscape you need to understand how they interact with each other, and with their environment.'

Centre Chief Investigator David Green explores these interactions in a forthcoming book he has co-authored. Written for an audience that includes the general reader, *Complexity in Landscape Ecology* provides a new perspective on traditional ecology. The authors present an overview of recent research on complexity and artificial life and the many new insights this research reveals about patterns and processes in landscapes and ecosystems.

Complexity in Landscape Ecology by Green, D.G., Klomp, N., Rimmington, G. and Sadedin, S., (Springer; ISBN: 1-4020-4285-X) will be published in 2006. Further details are at www.csse.monash.edu.au/~dgreen/books/kluwer/



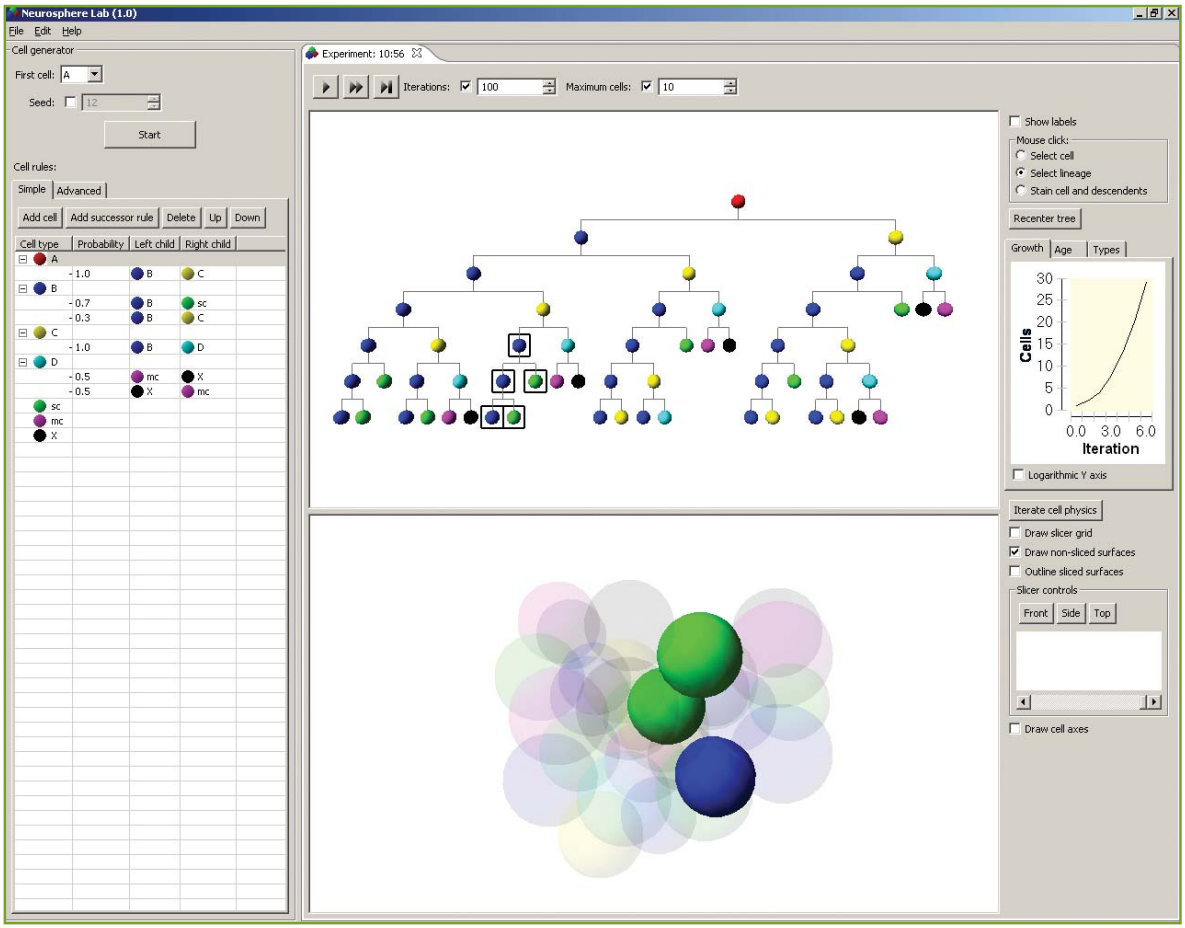
Maetschke, S., Towsey, M., Boden, M., 'BLOMAP: An encoding of amino acids which improves signal peptide cleavage prediction', *Proceedings of the 3rd Asia-Pacific Bioinformatics Conference*, 2005, 141-150.

Myers, B., Dix, T., Coppel, R., Green, D., 'Database integration and querying in the bioinformatics domain', *Proceedings of the 7th Asia-Pacific Complex Systems Conference*, 2005, 14–20.

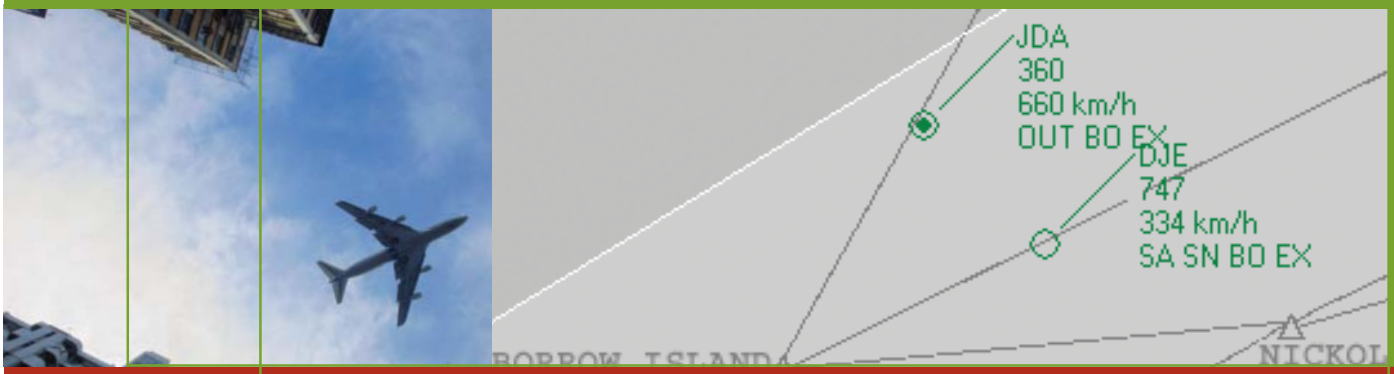
Suksawatchon, J., Lursinsap, C., Boden, M., 'Heuristic algorithm for computing reversal distance with multigene families via binary integer programming', *Proceedings of the IEEE Symposium on Computational Intelligence in Bioinformatics and Computational Biology*, November 2005, 187–193.

Wiles, J., Tonkes, B., 'Hyperspace geography: Visualising fitness landscapes beyond 4D', *Artificial Life, Special Issue on Visualisation,* vol. 12, no. 2, 2006.

Wiles, J., Watson, J., Tonkes, B., Deacon, T., 'Transient phenomena in learning and evolution: genetic assimilation and genetic redistribution', *Artificial Life*, vol. 11, no. 1–2, 2005, 177–188.



The Neurosphere Lab (above) is an interactive tool that enables researchers at the Queensland Brain Institute to model the growth of cells in a simulated culture. The model is specified in a set of rules about how cells divide and differentiate (shown in the left panel). These rules are then applied to a single cell (top panel shown in red) which results in a lineage tree of cells. The cells form a sphere (shown in the bottom panel). The tool enables interactive exploration of the cells, highlighting components of lineages, and a variety of analysis techniques can be applied (right panel). See also 'Patterns in complex systems models', page 10.



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. Free flight involves a fundamental shift from centralised control mechanisms, such as en-route air traffic control, to localised control, where pilots take over primary responsibility for maintaining separation between aircraft. Major issues arise with respect to assuring safety and providing aviation services. 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 the interplay between centralised control mechanisms, such as airport approach sequencing, and local control. This work builds on the group's existing work in human factors and human-computer interaction in air traffic control.

Conceptual framework for free-flight air traffic control

Project Leader: Peter Lindsay
Researcher: Binu John, Ariel Liebman, Martijn Mooij, Colin Ramsay, Morgan Smith

The aim of this project is to enable different free-flight operational concepts to be modelled and explored. It will develop a hierarchical framework to capture the complex, dynamic and interdependent nature of control in the National Airspace System (NAS). A suitable framework needs to encompass a wide variety of agents, from pilots, controllers and flow managers through to airports and airline operations centres. We plan to adapt existing conceptual frameworks such as the Boeing 2020 ATM Concept, and extend them for Australian operations.

In 2005 the project underwent conceptual re-alignment and development. In the first instance, the project is now aligned with the ASTRA (Australian Strategic Air Traffic Management Group) 2003 strategic plan. This involves the integration into the free-flight air traffic control concept, of several intermediate steps that go some way towards distributed control. These intermediate operation concepts are user-preferred routes and user-preferred trajectories. The former concept allows airlines/aircraft to choose the 3-D path taken by the aircraft while the latter also allows the choice of the times at which the aircraft arrive at any point along that path. Each of these could have a potentially major impact on emergent system properties. The most significant of those is collision risk, but others include operator workload and delays. In order to support the analysis of the various free-flight air traffic control concepts prototype simulations tools have been developed (see project: 'Development of a robust ATC simulation codebase'). A preliminary concept has been developed for the comparison of the performance of the centralised air traffic control operational concept to the free-flight air traffic control one. Air traffic control operator agents have been implemented as well as simple pilot agents obeying limited controller instructions. Both the operator agents and the pilot agents are capable of following rudimentary conflict detection and resolution strategies. (Included two 2005/06 summer projects)

Air traffic control workload

Project Leaders: Andrew Neal
Researchers: Scott Bolland, Graham Halford, Charles Hudson, Mike Humphreys, Ariel Liebman, Peter Lindsay, Martijn Mooij, Penelope Sanderson, Tania Xiao, Aaron Yeung

The aim of the project is to develop a model for predicting workload for air traffic controllers. The model will simulate

how controllers perform key cognitive components of their job (e.g. conflict detection and resolution) under different levels of workload. The goal is to develop a simulation tool that can be used for the purpose of risk analysis and scenario planning. The project is funded jointly by an ARC Linkage grant and Airservices Australia. The project is administered through UQ's Key Centre for Human Factors and Applied Cognitive Psychology.

In 2005, the project focused on three key areas: experiments which provided air traffic control operator behaviour information; the development of an operator model; and the development of software tools for the simulation of aircraft trajectories, emulation of air traffic control operator behaviour, and the computation of workload metrics. The experiments performed cover both 'part-task' studies, which focused on specific components of the air traffic control operator's problem solving activities, such as conflict detection conflict resolution, and high fidelity simulations where aircraft trajectories and controller actions were recorded using realistic training simulations. The information gathered during the experimental studies was used, and continues to be used, to develop and calibrate the operator model. Elements of the operator model have been developed and implemented. This includes conflict detection under aircraft uncertainty conditions, and conflict resolution through flight level changes. The tools developed include a prototype for the replay of recorded aircraft trajectory data and the calculation of some workload measures. This prototype was demonstrated to Airservices Australia personnel involved in the project. Furthermore, this tool served as the basis for the development of the ACCS air traffic control simulation toolkit (ATC-ST). The tool was then redeveloped to support general simulation using flight-plans and a complete workload calculation module added.

Recent outputs

Neal, A., Sanderson, P., Lindsay, P., Loft, S., Mooij, M., Boland, S., Fothergill, S., Liebman, A., 'ATC workload modelling project: Year 1 progress report', *Key Centre for Human Factors Technical Report*, Prepared for Airservices Australia, June 2005.

Agent-based ATC simulation and visualisation

Project Leader: Peter Robinson
Researchers: Katherine Duczmal

The aim of this project is to develop a framework for agent-based simulations and visualisations of air traffic control systems. The logic programming language Qu-Prolog, with built-in support for threads and high-level communication, will be used to implement the required air traffic control agents. The intention is to take a proposal for a free-flight air traffic control system, model the behaviours of the various players of this system, and run simulations to determine how the system will perform e.g. to determine how likely near misses are.

In 2005 we further extended the Qu-Prolog model of a controller and, based on the addition of floating point arithmetic to Qu-Prolog, simplified the various calculations used by the controller agent. We also added the ability to dump information to a file and to run the same scenario multiple times. In combination this allows us to carry out statistical analyses of the behaviour of the controller agent. The results of this project were presented at the ACCS winter school.

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

Project Leader: Hussein Abbass
Researchers: Sameer Alam, Michael Barlow, Peter Lindsay

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 (ACO) is an optimisation technique inspired by the behaviour of real ants. In this project, we are developing safe conflict detection and resolution (CDR) 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.

We first investigated a neuro-controller for CDR, which raised a number of safety challenges (Alam et al 2005a). We then designed an efficient and safe ant-colony based algorithm for CDR that is able to adapt to changes in the surrounding environment. Preliminary experiments of this algorithm can be found in Alam et al 2005b. The current version of the method meets safety standards and constraints for a safe and reliable conflict detection and resolution algorithm. Outcomes will also include recommendations of safety protocols for 'manoeuvre choices' in conflict situations.

Recent outputs

Alam, S., Abbass, H., Barlow, M., Lindsay, P., 'Mapping lessons from ants to free flight: An ant-based weather avoidance algorithm in free flight airspace', *The International Society for Optical Engineering (SPIE), Microelectronics, MEMS, and Nanotechnology Symposium*, 2005, 9.

Alam, S., McPartland, M., Barlow, M., Lindsay, P., Abbass, H., 'Neural evolution for collision detection and resolution in a 2D free flight environment', *Recent Advances in Artificial Life*, vol. 3, World Scientific Publishers, 2005, 13–28.

Safety assessment of ATC human-computer interaction

Project Leaders: Andrew Neal, Jacqueline Wicks
Researchers: Rachel Chitoni, Simon Connelly, Jingru Dai, Peter Lindsay, Colin Ramsay, Junhua Wang

This project is developing a new approach to human reliability assessment and evaluation of human-computer interaction design options, by application to air traffic control. The approach is based on modelling the activities (cognitive processes and interactions) involved in en-route control as stochastic processes. The effect of a proposed design intervention can then be investigated by hypothesising its effect on individual activities and conducting simulations to gauge performance over a range of scenarios. The project is a close collaboration between computer scientists from the School of IT and Electrical Engineering and psychologists from the Key Centre for Human Factors and Applied Cognitive Psychology. We are conducting experiments in which human subjects make judgements about, and attempt to manage, air traffic control scenarios presented to them on a computer display. These experiments are being conducted with two related goals in mind: the first is to gain a greater understanding of the decision making processes of air traffic control operators; and the second is to model their behaviour more realistically in the simulations. The work is also a collaboration with Peter Kwantes from Defence Research and Development, Canada.

The majority of the psychology experiments for this project were completed during 2005. The first working version of the Operator Choice Model to simulate air traffic controller behaviour was successfully developed. It employs data from the psychological experiments that were designed for this purpose. The results were presented at the *International Congress on Modelling and Simulation*. This novel approach to modelling an agent, where the agent is required to address a variety of challenging problems within a complex system, was well received. A theoretical paper describing the use of the Operator Choice Model for analysing human error in interactive systems was presented to the *International Conference on Software Engineering and Formal Methods*.

Recent outputs

Cerone, A., Connelly, S., Lindsay, P., 'Formal analysis of human-computer interaction using model-checking', *3rd IEEE International Conference on Software Engineering and Formal Methods (SEFM 05)*, September 2005.

Wicks, J., Connelly, S., Lindsay, P., Neal, A., Wang, J., Chitoni, R., 'Simulation of air traffic controllers' behaviour using the operator choice model', *International Congress on Modelling and Simulation*, December 2005, 3023–3029.

Development of robust ATC simulation code base

Project Leader: Ariel Liebman
Researchers: Bangjun Chen, Colin Ramsay

This project aims to produce a robust codebase for a toolkit which can be used to simulate the motion of aircraft in a 3-D airspace. The toolkit consists of a core 3-D + Time simulator and interface modules which enable the use of standard flight plan data and airspace specifications. The airspace specification uses standard air traffic management approach (e.g. nautical miles (NM) for distance). Aircraft motion is represented to the user graphically with position and altitude being displayed in NM and 100's of feet. The toolkit will also contain support for Agents (air traffic control controllers, pilots and so on).

This project commenced in July 2005. The ATC Simulation Toolkit (ATC-ST) grew out of aircraft trajectory replay and simulation software written by Scott Bolland of the Key Centre for Human Factors for the ATC Workload project. The original codebase was completely re-written to make it useable as a simulation library with a well-defined API. This toolkit now supports simulation of aircraft trajectories in both replay mode and from initial flight-plans. The latter is of key importance for supporting the free-flight air traffic control research. The trajectory simulation component also supports advanced aircraft characteristics simulation, and the impacts that wind velocity has on aircraft trajectories. Additional functionality includes support for intelligent agents and inter-agent communication. (Included 2005/06 summer project)

General ATC publications

Chang, R., Lindsay, P., 'A simulator for exploring autonomous control of multiple UAVs at non-radar controlled airstrips', 2005 *Intelligent Sensors, Sensor Networks & Information Processing Conference*, December 2005, 391–396.

Evolutionary Economic Systems

Program Leader: John Foster

We are applying complex systems and network theory in economics to understand how change occurs. Thus, 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. Also visualisation techniques, rarely used in economics, are being applied in 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 advances, care has been taken to work within 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.

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. This project seeks to develop econometric techniques capable of identifying underlying emergent complexity in time series data. This will involve applying a battery of nonlinear tests to both confirm the existence and identification of nonlinear interactions. This will principally be 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 2005, we completed program testing and validation of the bispectrum and trispectrum based tests. Preliminary attempts have been undertaken at applying the trispectrum tests to high frequency finance data. The trispectrum tests allow direct assessment of nonlinear serial dependence associated with excessive kurtosis, and, as such, are a very powerful testing procedure when applied to high frequency finance data. The actual properties of all the test statistics have been examined using simulation methods to assess their actual (empirical) properties against their expected theoretical properties. These tests have allowed us to examine how large the sample sizes need to be to get actual rejection rates which match the theoretically expected rejection rates for the various test statistics. We have also begun using simulation methods to apply the tests to a wide assortment of nonlinear models to examine the relative power of the various test statistics. This information will be used to identify specific nonlinear structures associated with artificial data generated from various nonlinear models as well as confirming the structure contained in simulations of empirically estimated non-linear models. An article entitled 'Structural change in macroeconomic time series: A complex systems perspective' was accepted for publication in the *Journal of Macroeconomics*.

Recent outputs

Hinich, M., Foster, J., Wild, P., 'Structural change in macroeconomic time series: a complex systems perspective', *Journal of Macroeconomics,* vol. 28, no. 1, 2006, 136-150.

Complex behaviour in financial markets

Project Leader: Jason Potts
Researchers: Mark Bowden, John Foster, Stuart McDonald, Kate Morrison

This project studies financial markets using complexity based tools. There are two sub-projects currently completed: real bubbles theory, which looks at the connection between stock market bubbles and evolutionary economic growth; and a network based simulation model of decentralised trading over four asset classes. We are also working on models of fourth-order complexity in financial markets, which involves modelling expectation formation and interaction.

The modelling of interactive expectations is going well, with two key papers by Bowden (and McDonald) written and accepted to international conferences (including the prestigious *Computational Finance* conference in June 2006). Potts and Morrison have had a paper accepted for publication in The *Journal of Economic Behaviour and Organization* on how our complexity approach connects to computational theory of the evolution of market algorithms. Potts and Morrison completed interviews with 16 evolutionary economic and complexity theorists in the USA and Europe and have a book contract to Edward Elgar to deliver in 2006 (Title: *Conversations with evolutionary economists*).

Eutrophication of the Great Barrier Reef marine ecosystem

Project Leader: Rodney Beard
Researchers: Leighton Brough, John Foster, Stuart McDonald, Walter Reinhardt

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 2005 we submitted our paper 'Time consistent fair water sharing agreements' to the *Annals of International Society for Dynamic Games*, it was accepted for publication and is expected to appear in August 2006. The paper is concerned with the consistency of water trading contracts over time taking into account the direction in which water flows along a river. It is envisioned that the results can be applied to the problem of trading pollution permits when pollution, such as fertilisers, herbicides or sediments, flows downriver. In addition, we were able to complete a multi-agent simulation model using the simulation package DIAS. This extended earlier modelling using optimal control theory to a multi-agent setting with the application being the impact of fertiliser run-off on fishing activity in the Great Barrier Reef region. In addition, we collaborated with the computational game theory project and together developed a new approach to developing multi-agent simulation models using haystack games as a theoretical framework. This was applied to the development of a simulation model for fisheries fleet dynamics. (Included 2005/06 summer project)

Water usage modelling for the Murray-Darling Basin

Project Leader: John Quiggin
Researchers: Archie Chapman, James Patterson

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.

The main focus has been on the design of water rights in the presence of uncertainty. The aim has been to use concepts of state-contingent production to model alternative systems of property rights, and to relate the theoretical and modelling treatment of uncertainty to the policy goals set out in the National Water Initiative. Several articles on water policy have been completed (including joint work with Professor John Freebairn) and several have been accepted for publication in the *Australian Journal of Agricultural and Resource Economics*.

Recent outputs

Adamson, D., Mallawaarachchi, T., Quiggin, J, 'Modelling basin level allocation of water in the Murray-Darling Basin in a world of uncertainty', *49th Annual Conference of the Australian Agricultural and Resource Economics Society*, Coffs Harbour, February 2005.

Quiggin, J., 'Policy and modelling issues for sustainable management of the Murray-Darling Basin', Presentation to the Productivity Commission, Melbourne, 17 March 2005.

Quiggin, J., 'Risk and water management in the Murray-Darling Basin,' *Murray-Darling Program Working Papers WPM05-4*, Risk and Sustainable Management Group, University of Queensland, Brisbane, 2005.

Simulation studies of social networks

Project Leader: David Green
Researchers: Tania Bransden, David Cornforth, Suzanne Sadedin, Don Schauder, Rob Stocker

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 2005, the Virtual Laboratory (www.complexity.org.au/vlab/) was expanded, adding more demonstrations (e.g. cascading failures, spread of epidemics, law and order), and text explanations. In a study this year, we used simulations of social networks to show that both prescription and peer pressure are needed to achieve cooperation and social order in large societies. Our results show that in the absence of law enforcement in social networks, peer pressure acts either to maintain law-abiding behaviour, or to flip the entire society into law-breaking (e.g. speeding on the roads). However, if a social network is well-connected, then even a small incidence of punishment suffices to ensure conformity. In general law breaking increases as social interactions decrease.

Recent outputs

Bransden, T., Green, D., 'Getting along with your neighbours – emergent cooperation in networks of adaptive agents', *Intelligent and Evolutionary Systems*, November 2005.

Cornforth, D., Green, D., Newth, D., 'Ordered asynchronous processes in multi-agent systems', *Physica D*, vol. 204, May 2005, 70–82.

Computational game theory

Project Leader: Stuart McDonald
Researchers: Rodney Beard, John Foster, John Hawkins, Narender Rana, Liam Wagner

This project will examine 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 will be 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 will be on using these algorithms to increase the likelihood of game theory being used as a modelling tool for large, complicated multi-agent systems.

The project is split into two sub-projects. In 2005, the first sub-project focused on applying directed search and machine learning algorithms to the problem of finding Nash equilibria in non-cooperative games. Research from this sub-project focusing on the computational complexity is being written into a monograph that is currently being reviewed by Edward Elgar Publishing. Two papers based on this research have been accepted for publication with the *IEEE Transactions on Evolutionary Computation* and the *Journal of Network Security*. The second sub-project focused on modelling spatial interactions between agents and is nearing completion. The main objective of this research has been to develop a haystack model that can be used as paradigm for modelling network formation and agent self-organisation. This model is being used to simulate fishery fleet dynamics. The results of these simulations will be reported at the *Australian Agricultural and Resource Economics Conference* in Sydney during February 2006. We are currently investigating the application of these tools to the auctioning of airport landing slots.

Complexities of homelessness

Project Leader: John Quiggin
Researcher: Rhea Coleman

Since the mid-1970s, homelessness has grown to become an issue affecting, according to the ABS, roughly 100,000 people in Australia. Government policy to address this issue has focused primarily on the individual and their 'deficits'. The increasing trend towards homeless families, women and young people - a shift from the traditional stereotypical 'core' population of older, homeless men with substance abuse issues - suggests that individual 'deficits' are not the only factors affecting vulnerability to homelessness and, in turn, that a broader policy focus needs to be adopted to address this social pathology. This project is looking at the complex interaction between macroeconomic conditions, including housing market conditions, and individual characteristics, which create vulnerability to homelessness, by examining varying rates of homelessness across Australia. Understanding the broader forces at work upon homeless individuals will aid the better formulation of policy, at both a federal and state level, accounting for the factors which have been largely ignored to date.

General EES publications

Foster, J., 'From simplistic to complex systems in economics', *Cambridge Journal of Economics*, vol. 29, 2005, 873–892.

Foster, J., 'The self-organisation perspective on economic processes: a unifying paradigm?', *The Evolutionary Foundations of Economics*, Edited by Dopfer, K., 2005.

Quiggin, J., 'Risk, discounting and the public sector', in *Discount rates in Australian agriculture*, Edited by, Pannell, D. & Schilizzi, S., Edward Elgar, in press.

Steen, J.T., Liesch, P.W., Czinkota, M., Knight, G., 'International terrorism, uncertainty and the firm', *Academy of Management 2005 Conference Best Paper Proceedings*, August 2005.

Image by D.R. Fowler, N. Fuller, J. Hanan, and A. Snider, University of Regina, Canada 1990

Infrastructure/General

In addition to the three research programs described above, the ACCS includes a number of projects addressing key problems for complex systems. The original Infrastructure/General research program has evolved from an initial set of rolled in ARC Discovery Grant projects to a set of research sub-programs that support and complement the main research program. The main themes in the program are: modelling and analysis of computer-based systems; complex systems theory and applications; and new analysis techniques for complex systems. As this work matures greater cooperation and synergy is continuing to develop between the main program and the infrastructure/general program.

Modelling and Analysis of Computer-Based Systems

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.

Building dependability into complex computer-based systems

Project Leader: Geoff Dromey
Researchers: David Carrington, Robert Colvin, Lars Grunske, Ian Hayes, Peter Lindsay, John Seagrott, Cameron Smith, Kirsten Winter, Lian Wen, Nisansala Yatapanage, Saad Zafar, Xuelin Zheng

Large-scale, complex, software-intensive systems can be made more dependable by constructing comprehensive formal graphical models of their behaviour. These models need to clearly show how individual functional requirements interact with one another. They also need to show how safety, security, reliability and other types of dependability requirements are manifested as supporting behaviour that coherently integrates with the functional requirements. Ultimately all the functional and dependability requirements must integrate to preserve the overall behavioural integrity of a system. Adopting the underlying constructive development strategy of building a system out of its requirements, offers a promising approach for dealing with large-scale systems, building in dependability and assuring dependability while at the same time coping with change, requirements defects and the complexity of such systems. The Behavior Tree notation and supporting design and analysis methodology enables the investigation of constructive development and the creation of integrated views of requirements. Using this approach the project explored practical ways of engineering in and systematically assuring the dependability of large-scale and complex systems. (Included 2005/06 summer project)

Recent outputs

Dromey, R.G., 'Genetic design: Amplifying our ability to deal with requirements complexity', *Lecture Notes in Computer Science*, vol. 3466, 2005, 95–108.

Dromey, R.G., Powell, D., 'Early requirements defects detection', *TickIT Journal*, no. 4Q05, 2005, 3–13.

Grunske, L., Geiger, L., Zündorf, A., VanEetvelde, N., VanGorp, P., Varró, D., 'Using graph transformation for practical model driven software engineering', *Model-Driven Software Development - Volume II of Research and Practice in Software Engineering*, Springer Verlag, 2005, 91–119.

Grunske, L., Kaiser, B., 'An automated dependability analysis method for COTS-Based systems', *ICCBSS*

2005, February 2005; *Lecture Notes in Computer Science*, vol. 3412, 178–90

Grunske, L., Lindsay, P., Yatapanage, N., Winter, K., 'An automated failure mode and effect analysis based on high-level design specification with Behavior Trees', *5th International Conference on Integrated Formal Methods (IFM 2005)*, 2005; *Lecture Notes in Computer Science*, vol. 3771, 129–149.

Fitzgerald, J., Hayes, I.J., Tarlecki, A., FM 2005: Formal Methods - Proceedings 13th International Symposium of Formal Methods Europe, Newcastle, UK, July 2005, *Lecture Notes in Computer Science*, vol. 3582, Springer Verlag, July 2005.

Hemer, D., Lindsay, P., 'Template-based construction of verified software', *IEE Proc Software*, vol. 152, no. 1, February 2005, 2–14.

Lermer, K., Fidge, C.J., Hayes, I.J., 'A Theory for Execution Time Derivation in Real-time Programs', *Theoretical Computer Science,* vol. 346, no. 1, November 2005, 3–27.

Zafar, S., Dromey, R.G., 'Integrating safety and security requirements into design of an embedded system', *Proceedings of the Asia-Pacific Software Engineering Conference*, 2005, 629–636.

Zafar, S., Dromey, R.G., 'Managing complexity in modelling embedded systems', *Proceedings of Systems Engineering/Test and Evaluation Conference (SETE 05)*, 2005.

Model-based development of safety-critical systems

Project Leader: Peter Lindsay
Researcher: Lars Grunske

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 by the Boeing Postdoctoral Research Fellowship Award to the University of Queensland.

In 2005 research focused on failure propagation for component-based software engineering.

Recent outputs

Grunske, L., 'Using a graph transformation system to improve the quality characteristics of UML-RT specifications', *Advances in Software Engineering with UML and XML-Based Software Evolution*, Idea Group Inc, 2005, 19–45.

Grunske, L., Kaiser, B., 'Automatic generation of analyzable failure propagation models from component-level failure annotations', *5th International Conference on Quality Software (QSIC)*, 2005, 117–123

Grunske, L., Kaiser, B., Papadopoulos, Y., 'Model-driven safety evaluation with state-event-based component failure annotations', *Component-Based Software Engineering: 8th International Symposium, CBSE 2005*, February 2005; *Lecture Notes in Computer Science*, vol. 3412, 33–45.

Grunske, L., Kaiser, B., Reussner, R., 'Specification and evaluation of safety properties in a component-based software engineering process', *Embedded System Development with Components*, *Lecture Notes in Computer Science*, vol. 3778, Springer Verlag, 2005, 249 –274.

Maydl, W., Grunske, L., 'Behavioural types for embedded software - a survey', *Embedded System Development with Components*, *Lecture Notes in Computer Science*, vol. 3778, Springer Verlag, 2005, 82–106.

Papadopoulos, Y., Grante, C., Grunske, L., Kaiser, B., 'Continuous assessment of evolving designs and reuse of analyses in a model-based technique for semi-automatic Fault Tree and FMEA analysis of complex systems', *CD Proceedings IFAC WC 05, 16th World Congress, International Federation of Automatic Control*, 2005.

Validation and rapid prototyping for Behavior Trees

Project Leaders: Geoff Dromey, Ian Hayes
Researcher: Robert Colvin

Simulation and animation are techniques for quickly obtaining a dynamic, visual view of a system from a high-level specification. This may be useful for receiving feedback from a client early in the software life-cycle (validation), or for demonstrating the behaviour of a model which is difficult to observe statically (in particular, emergent behaviour). This project will develop simulation and animation tools for the Behavior Tree framework.

A simulation and model-checking tool began development in 2005. The tool is being developed in Mercury, a declarative programming language similar to Prolog. The high-level nature of Mercury meant that there was a straightforward translation of the semantics of the Behavior Tree process algebra into an executable format. Mercury's backtracking facility also allows the tool to act as a simulator (able to give a particular run of a system), as well as exhaustively produce all possible runs of a system.

Change management: Formalising the impact of requirements change on design

Project Leader: Geoff Dromey
Researcher: 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 2005, there have been two significant achievements with this project – one theoretical and one practical. The theoretical result shows how it is possible, by applying an appropriate sequence of transformations, to change from one architecture to some target architecture without changing the behaviour or impacting the set of functional requirements that a system satisfies. This very general and significant result has been written up in an international conference paper on architecture normalisation. The other significant development has been the completion of a tool to support the change component-based designs. This tool implements the theoretical results obtained and published in 2004.

Recent outputs

Wen, L., Dromey, R.G., 'Architecture normalisation for component-based systems', *Proceedings of the 2nd International Workshop on Formal Aspects of Component Software FACS '05*, 2005, 247–261.

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 will develop 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 2005, a flexible process algebra was designed that can be used to express the majority of Behavior Tree concepts. An operational semantics was defined for this language, and a straightforward translation from the high-level Behavior Tree notation into the process algebra was developed. The generality of the process algebra fed back into the development of the Behavior Tree notation, resulting in the addition of elegant and powerful specification constructs for the framework as a whole. In 2005 we also developed a metamodel for the core notation of Behavior Trees along similar lines to the UML metamodel.

Recent outputs

Dromey, R.G., 'System composition: Constructive support for the analysis and design of large systems', *Proceedings of the Systems Engineering/Test and Evaluation Conference (SETE 05)*, 2005.

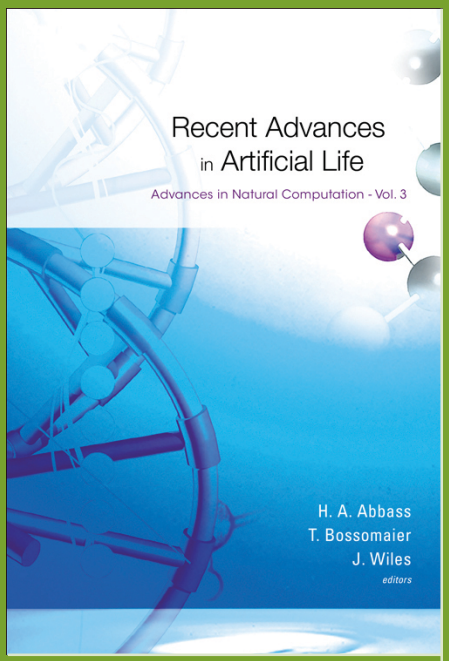
Recent Advances in Artificial Life

'Artificial life is now a recognised discipline of research with many important applications and software tools. However, many theoretical issues remain unresolved. This book brings together a cross-section of key developments in artificial life, which in turn gives us new insight into the theory of complex systems. '

Centre Chief Investigator, Hussein Abbass, and Centre Program Leader, Janet Wiles are co-editors of *Recent Advances in Artificial Life* which draws upon presentations at the Second Australian Conference on Artificial Life in Sydney in December. Eight of the chapters are written by ACCS personnel.

Underpinning the central concept of the book - genetics and evolution in an artificial life environment, 'are key theoretical developments surrounding network complexity, the development of pattern languages for complex networks and a deeper understanding of the edge of chaos where complex systems live. Practical applications include optimisation, gene regulatory networks, modelling the spread of disease and the evolution of ageing. '

Recent Advances in Artificial Life, *Advances in Natural Computation - Vol 3,* 2005, edited by H. A. Abbass, T. Bossomaier & J. Wiles (World Scientific; ISBN 981-256-615-5). Further details are at http://www.worldscibooks.com/lifesci/5992.html.



Gonzalez-Perez, C., Henderson-Sellers, B., Dromey, R.G., 'A metamodel for the Behavior Trees modelling technique', *Proceedings of the 3rd International Conference on Information Technology and Applications (ICITA)*, 2005.

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.

In 2005, we investigated the new features of collaborative systems with constraints, such as the difference between conflicts and constraint violations, the interferences among constraints in collaborative systems, etc. In particular, we have proposed a masking strategy that is able to maintain both constraints and system consistency in the face of concurrent operations. The strategy is independent of the execution orders of concurrent operations and able to retain the effects of all operations in resolving constraint violation. The proposed strategy can be adopted to enforce tree structure constraint in CoGSE, and maintain constraints in many kinds of collaborative systems as well. Moreover, we have proposed an approach to reconstruct computation flows to maintain dataflow constraints when concurrent user operations modify the constrained variables in collaborative systems.

Recent outputs

Lin, K., Chen, D., Dromey, R.G., Sun, C., 'Maintaining multi-way dataflow constraints in collaborative systems', *The First International Conference on Collaborative Computing: Networking, Applications and Worksharing (CollaborateCom 2005)*, 2005.

Lin, K., Chen, D., Sun, C., Dromey, R.G., 'A constraint maintenance strategy and applications in real-time collaborative environments', *The Second International Conference on Cooperative Design, Visualization and Engineering (CDVE2005)*, 2005.

Lin, K., Chen, D., Sun, C., Dromey, R.G., 'Maintaining constraints in collaborative graphic systems: the CoGSE approach', *9th European Conference on Computer-Supported Cooperative Work (ECSCW05)*, 2005.

AutoGuard: An interactive development environment for relative debugging of programs

Project Leader: David Abramson
Researchers: Clement Chu, Donny Kurniawan, Aaron Searle

Software systems are among the most complex systems developed by humans. This project is developing methods and tools to help software engineers debug their programs. Relative debugging involves comparing one program with another, to determine where they will diverge when being executed.

In 2005, PhD student Aaron Searle continued to develop techniques for automatically comparing the execution of two executing programs. Using sophisticated analysis techniques he was able to generate assertions automatically and these are used by the debugger to test the internal state of the programs, which enables divergence between the execution of the two programs to be deduced automatically. He is currently completing his PhD thesis on this topic.

Also in 2005, we added parallel support for our initial IBM Eclipse based relative debugger, EclipseGuard. This now allows a user to compare the state of two parallel programs whilst controlling the work from within a powerful integrated development environment. Finally, we have started a new thread to extend the work to support development and debugging of software systems for the Grid. This latter effort is being undertaken by PhD student Donny Kurniawan and will define a WSRF compliant architecture for debugging software. The project also underpins a collaboration with the Los Alamos National Laboratories (LANL) concerning the development of a parallel debugger plug in for Eclipse, and together with colleagues at LANL, we have made progress towards this goal.

Complex Systems Theory and Applications

This set of projects is concerned with the application of theory to solve issues in the design and operation of complex socio-technical systems.

Adaptive network-centric multi-agent architecture for land combat

Project Leader: Hussein Abbass
Researchers: Ruhul Sarker, Ang Yang

Land combat is a complex adaptive system. The aim of this project is to develop a multi-agent system for land combat to help understand the dynamics of this complex system and potentially map lessons learnt in the defence domain to other projects such as those related to game theory in economics. ACCS provided partial funding for this project in the form of financial assistance for training the student, with the main source of funding coming from UNSW.

In 2005, a multi-agent system called WISDOM, the warfare intelligent system for dynamic optimisation of missions, has been developed. The system is based on a new multi-agent architecture that we developed. The architecture is network-centric, where it combines network theory, dynamic systems, data mining, and distributed AI in a single architecture that is scalable and efficient. A number of papers have been published on this topic in high impact journals, conferences, and book chapters.

Recent outputs

Yang, A., Abbass, H., Barlow, M., Sarker, R., Curtis, N., 'Evolving capability requirements in WISDOM-II', *Recent Advances in Artificial Life*, vol. 3, World Scientific Publishers, 2005.

Yang, A., Abbass, H., Sarker, R., 'Evolving agents for network centric warfare', *Proceedings of the 2nd Workshop on Military and Security Applications of Evolutionary Computation (MSAEC 2)*, 2005; *Second Workshop on Military and Security Applications of Evolutionary Computation, Washington D.C.*

Yang, A., Abbass, H., Sarker, R., 'Risk assessment of capability requirements using WISDOM-II', *The International Society for Optical Engineering (SPIE), Microelectronics, MEMS, and Nanotechnology Symposium*, 2005.

Yang, A., Abbass, H., Sarker, R., 'WISDOM-II: A network centric model for warfare', *Knowledge-Based Intelligent Information and Engineering Systems*, 9 2005; *Lecture Notes in Computer Science*, vol. 3683, 813.

Adaptive network mining for security and safety

Project Leader: Hussein Abbass
Researchers: Michael Barlow, Daryl Essam, Yubin Yang

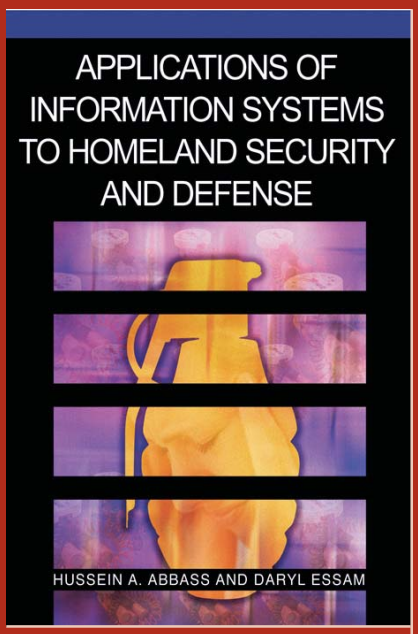
Network mining is a novel and new concept in data mining. Traditionally, data mining stood shorthanded when faced with a small dataset. Moreover, there have been many assumptions which were necessary to build the theory of data mining techniques, but unfortunately these assumptions were impractical. Take for example, the assumption of independency, where the values a field in a database table can take are independent of each other and also that the records are independent. Consider two fields in a database table: the name of employees and their telephone numbers. Let us assume two employees, John and Mark. Traditionally, these two values are considered entirely independent of each others. However, if both employees have the same telephone number, this assumption deems quickly to be invalid. It also implies that the two database records are somehow dependent. As such, assuming independency of data records and values within fields makes theoretical proofs easier, but certainly increases the demand for more data and traditional data mining techniques will certainly overlook and miss many interesting patterns. In this project, we are developing a software infrastructure for network mining that can potentially be used for security and safety applications such as analysing flight accidents.

Applying Complex Systems Science to Homeland Security

'A range of threats in the areas of safety and security, from natural disasters to terrorism to conventional warfare, involve complex interactions that are beyond the scope and capabilities of traditional problem solving techniques.'

The emerging discipline of complex systems science is finding application to a diverse array of real-world problems. In their recent book, *Application of Information Systems to Homeland Security and Defense*, Centre Chief Investigator Hussein Abbass and Centre Collaborator Daryl Essam explore the application of complex system techniques to security and defence applications.

Application of Information Systems to Homeland Security and Defense by Abbass, H.A. and Essam, D. (IGP; ISBN: 1-59140-641-2), 2005. Further details are at www.idea-group.com/books/details.asp?id=5057.



We started this project in 2005 and produced a software named DeepRed. DeepRed is capable of finding deep linkages in a dataset. It uses link analysis to identify linkage information. It uses Bayesian inference to estimate the importance of links and nodes in a graph. It analyse the temporal evolution of a network through efficient methods that combine social network measures and time series analysis. We extended the funding from the ARC through an ADFA strategic grant which helped us to improve the system further and develop further theory. A paper was published on analysing terrorist networks in the SPIE complex systems conference.

Recent outputs

Abbass, H., Barlow, M., Essam, D., Yang, Y., 'Connecting the dots to disconnect them: A study into network evolution and dynamics for analyzing terrorist networks', *Complex Systems*, 2005.

Efficient marking schedules for the short-response paper of the Queensland Core Skills Test

Project Leader: Anne Street
Researchers: Ken Gray, Karen Harris, Colin Ramsay

Each year, approximately 35,000 Queensland students in the final year of high school, from all over the state, take a Core Skills Test, one paper of which is in short-response format. The schedule and resources are such that it is impossible to take samples of the students' scripts and to train the 650 markers well ahead of time, so that real data on how long each question will take to mark is available before the marking starts. Training markers is expensive, so we want to keep it to a minimum, as well as to produce an optimal match of markers to questions, and to ensure a common finishing time for all markers. A successful technique has been developed which supports dynamic assignments of resources, using a network to ensure that the loads are optimally balanced. This technique, due to Ken Gray, is also being developed for use in other problems, including some that arise in connection with testing.

In 2005, a more detailed study of the technique was carried out, with a constructive proof of the existence of complementary pairs of the relevant designs bringing this project to completion.

Recent outputs

Gray, K., Street, A., Harris, K., Ramsay, C., 'Existence of complementary pairs of proportionally balanced designs', *Utilitas Mathematica*, 2005, 43–64.

An empirically-derived experimentally-validated framework for interactions in information environments

Project Leader: Margot Brereton
Researchers: Brett Campbell, Tim Cederman-Haysom, Jared Donovan

Complex systems require new and innovative modes of interaction so that computer technologies better support human work practice. This project has focused on participatory design of multi-modal interfaces for the dental surgery. In dental surgeries, there is growing use of computer technology to store, display and update patient records, digital x-rays, preventative care information, multimedia simulations and patient billing. In many respects, the dental surgery represents a typical work environment - one that is complex, replete with physical tools, people and information recording devices. However the increased embedding of traditional computer use into dental practice is problematic. The traditional interface of mouse and keyboard interferes with the way that dentists do their work. It poses both problems with infection control, and with the detailed level of attention that must be devoted to driving the interface. This suggests taking an approach using newer interface technologies such as gesture and speech recognition and other ubiquitous computing technologies. However although such technologies appear technically feasible, the most pressing problem for researchers is making them work in real world contexts. With a view to designing better interfaces for dental surgeries, we have done a number of participatory design studies and introduced a number of technical probes into the dental surgery. The probes consist of common ubiquitous computing technologies such as digital pens, accelerometer based gestural devices, speech recognition and RFID tagging. The probes have been configured into technologies for use by dentists with a specific view to having them as configurable as possible so that dentists can understand how they work, understand the potential of the technologies, experiment with the technologies, and engage in a dialogue about how to support their practice in quick surgery studies.

In 2005, we completed a trial of our gestural and speech ubiquitous computing technologies with three New Zealand dentists who are lead users with a collaborating dental software company EXACT. We will present this work in the *Aarhus Critical Computing Conference* in August 2006. This work is now being analysed and written up as we develop our framework for designing interactions with ubiquitous computing.

Software architecture and scale-free networks

Project Leaders: Geoff Dromey
Researchers: 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.

In 2005, the major achievement has been the development of a suite of graphics-based tools for studying the architectural properties (including scale-free network studies) of the implementations of large-scale

software systems and packages. A tool-set has also been developed for studying the scale-free properties of sorting algorithms of differing relative efficiencies. An important observation has been that the closer an algorithm approaches the N log N limit the more likely it is to exhibit scale-free properties.

Emergence of communication in multi-agent systems

Project Leader: Hussein Abbass
Researchers: Michelle McPartland, Stefano Nolfi

Communication is at the heart of many systems. Understanding how communication may emerge between agents in an unknown environment can shed light on key fundamental scientific questions as well as providing solutions for real life systems such as free-flight air traffic control. Key fundamental questions include: what are the minimum setup and conditions for communication to emerge, when would communication be considered beneficial for agents, and what are the advantages of indirect versus direction communication?

In 2005, we created a competitive environment with two teams of agents undertaking an exploration task - the quickest team to explore the largest area won. One team used indirect communication, controlled by an artificial neural network evolved using a Pareto multi-objective approach. The second team used direct communication and a fixed strategy for exploration. We found that different communication strategies result in different exploration strategies. We established that communication is essential for certain type of cooperative behaviour to emerge. Results of this project were published in *GECCO 2005*.

Recent outputs

McPartland M., Nolfi, S., Abbass, H., 'Emergence of communication in competitive multi-agent systems: A Pareto multi-objective approach', *Proceedings of the Genetic and Evolutionary Computation Conference GECCO'05*, 2005, 51–58.

Agent-based virtual insects: Extension and testing

Project Leader: Jim Hanan, Peter Robinson
Researcher: Katherine Duczmal

A Qu-Prolog based application-specific language for modelling insect behaviour has been prototyped by Katherine Duczmal in her honours project. Three dimensional models of plants expressed using L-systems provide the environment for insect perceptions. This project extends the language to meet the needs of entomological end-users. (2005/06 summer project)

Recent outputs

Duczmal, K., 'Agent-based virtual insects', *Proceedings of the Third Australian Undergraduate Students' Computing Conference*, 2005, 1–8.

Analysis Techniques for Complex Systems

This set of projects is concerned with the development of new analysis techniques for complex systems.

Multi-objective optimisation

Project Leader: Hussein Abbass
Researchers: Lam Bui, Hoang Xuan Dao, David Green, Tri Hai Le

When solving many real life problems, one is usually faced with two or more objectives that are in conflict, and require 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 2005, the research team developed methods for optimisation problems in changing environments using multi-objective approaches. We also developed a fast method, using the concept of fitness inheritance, for optimisation problems with noise. All methods are published in *GECCO 05* and *CEC 2005*. (Included two 2005/06 summer projects)

Recent outputs

Bui, L., Abbass, H., Essam, D., 'Cooperative coevolution of genotype-phenotype mappings to solve epistatic optimization problems', *Recent Advances in Artificial Life*, World Scientific Publishers, 2005, 29–42.

Bui, L., Abbass, H., Essam, D., 'Fitness inheritance for noisy evolutionary multi-objective optimization', *Proceedings of the Genetic and Evolutionary Computation Conference GECCO'05*, 2005, 779–785.

Bui, L., Branke, J., Abbass, H., 'Diversity as a selection pressure in dynamic environments', *Proceedings of the Genetic and Evolutionary Computation Conference GECCO'05*, 2005, 1557–1558.

Bui, L., Branke, J., Abbass, H., 'Multiobjective optimization for dynamic environments', *Congress on Evolutionary Computation*, 2005.

Teo, J., Abbass, H., 'Multi-objectivity and complexity in embodied cognition', *IEEE Transactions on Evolutionary Computation*, vol. 9, no. 4, 2005, 337–360.

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 will be 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.

The research has lead to the development of computational tools which the participants have successfully applied in various areas, including open problems in graph decomposition, and various bioinformatics projects. There were four journal articles published during 2005, predominantly representing developments in knowledge and understanding of combinatorial structures. In addition, Adams gave an invited presentation at a Bioinformatics symposium in Malaysia.

Recent outputs

Bryant, D., Grannell, M., Griggs, T., 'Large sets of cycle systems on nine points', *Journal of Combinatorial Mathematics and Combinatorial Computing*, vol. 53, 2005, 95–102.

Bryant, D., Horsley, D., Maenhaut, B., 'Decompositions into 2-regular subgraphs and equitable partial cycle decompositions', *Journal of Combinatorial Theory*, vol. 93, 2005, 67–72.

Bryant, D., Leach, C., Rodger, C., 'Hamilton decompositions of complete bipartite graphs with a 3-factor leave', *Australasian Journal of Combinatorics*, vol. 31, 2005, 331–336.

Keith, J.M., Adams, P., Ragan, M.A., Bryant, D., 'Sampling phylogenetic tree space with the generalised Gibbs sampler', *Molecular Phylogenetics and Evolution*, vol. 34, 2005, 459–468.

Computational group theory

Project Leader: George Havas
Researcher: Colin Ramsay

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 2005, Havas presented four invited lectures at overseas conferences and universities. Jointly with Professor Charles Leedham-Green of the University of London, Professor Eamonn O'Brien of the University of Auckland and Professor Michael Slattery of Marquette University, Havas resolved a challenging problem about groups associated with geometries. A paper on this topic has been accepted to appear in the international journal Advances in Geometry. One paper on computational group theory appeared in 2005 in a refereed journal and six papers were accepted to appear in refereed journals or conference proceedings.

Recent outputs

Havas, G., Vaughan-Lee, M.R., '4-Engel groups are locally nilpotent', *International Journal of Algebra and Computation*, vol. 15, no. 4, 2005, 649–682.

Automatic problem decomposition

Project Leader: Hussein Abbass
Researchers: David Goldberg, Kumara Sastry

Solving many real life problems is a complex task. The number of elements and factors in each problem is enormous and the only way to solve these problems reliably, quickly and accurately is by decomposing them into smaller sub-problems. Unfortunately, when we are faced with a new problem, we do not usually know the correct decomposition. This project is about automatically decomposing a problem on the fly while solving it.

In 2005, the research team continued developing efficient algorithms for hard problems with a paper appearing in *GECCO 2005* and another submitted for review.

Recent outputs

Sastry, K., Abbass, H., Goldberg, D., Johnson, D., 'Sub-structural niching in estimation of distribution algorithms', *Proceedings of the Genetic and Evolutionary Computation Conference GECCO'05*, 2005, 671–678.

General Infrastructure Publications

Bolliger, J., Lischke, H., Green, D., 'Simulating the spatial and temporal dynamics of landscapes using generic and complex models', *Ecological Complexity*, Vol. 2, no. 2, 2005, 107-116.

Nguyen, M., Abbass, H., McKay, R., 'Stopping criteria for ensemble of evolutionary artificial neural networks', *Applied Soft Computing*, Vol. 6, No. 1, 2005, 100-107.

Banks, J., Pailthorpe, B., Rothnagel, R., Hankamer, B., 'Automatic particle picking algorithms for high resolution single particle analysis', *Proc. APRS Workshop on Digital Image Computing*, 2005, 127-131.

Hai, D., Abbass, H., Lokan, C., 'DXCS: an XCS system for distributed data mining', *Proceedings of the Genetic and Evolutionary Computation Conference GECCO'05*.

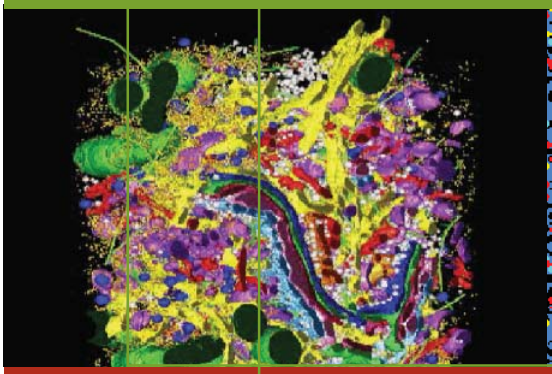
Hai, D., Abbass, H., Lokan, C., 'Be Real! XCS with Continuous-Valued Inputs', *The Eighth International Workshop on Learning Classifier Systems*, 2005.

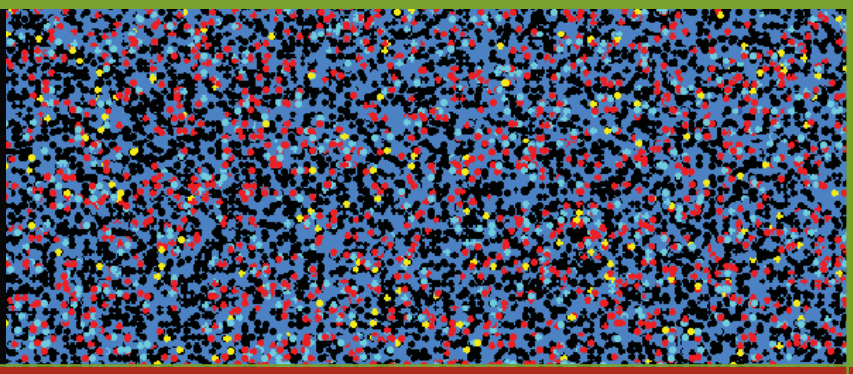
Recognition of Centre Research

Centre participant George Havas and a colleague have cracked an important problem in combinatorial group theory, by proving a deep property of a class of structures that are of keen interest to mathematicians:

> **Havas, G., Vaughan-Lee, M. R.,** '4-Engel groups are locally nilpotent', *International Journal of Algebra and Computation,* 15 (2005), no. 4, 649--682.

An article in Mathematical Reviews that will appear in April 2006 states: 'This impressive paper contains a splendid result and completes the solution to a longstanding open problem on Engel groups...' MR2160572 (2006d:20064).



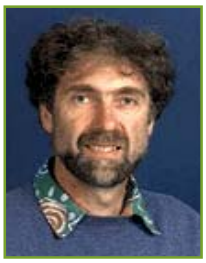


Federation Fellows

The Centre is fortunate to have two Federation Fellows, Professors Kevin Burrage and John Quiggin, as Chief Investigators. Kevin and John's recognised expertise is contributing to the Centre's research in the complex systems priority area.

John Quiggin is a Federation Fellow in Economics and Political Science at the University of Queensland. He is prominent both as a research economist and as a commentator on Australian economic policy, having published over 750 research articles, books and reports in a wide range of fields. His current research focuses on the sustainable management of the Murray-Darling Basin, considered as a complex system subject to fundamental uncertainty. The award of a Federation Fellowship has funded the establishment of the Risk and Sustainable Management Group, located in the School of Economics and the School of Political Science and International Studies and linked to the ACCS.

During 2005, the main focus of the group has been on the construction of a simulation model of the Murray-Darling sufficiently detailed to permit realistic representation of adaptations to uncertainty, and the way in which uncertainty regarding climate and yields interacts with policy decisions on the design of water rights. At a theoretical level, the Group is also attempting to formulate more robust and practically useful interpretations of the precautionary principle. The precautionary principle is commonly advocated as a guide to environmental policy, but there is no agreement on how the principle should (or should not) be applied in particular cases.



Kevin Burrage is a Federation Fellow and Professor of Computational Mathematics at the University of Queensland. He is Co-Director of the Advanced Computational Modelling Centre in Mathematics and has joint positions in Mathematics, Information Technology & Electrical Engineering and the Institute for Molecular Biosicence at the University of Queensland.

Kevin's current research aims to gain an understanding of the roles of stochasticity (more commonly known as noise) in cellular processes. The completion of the human genome marked the culmination of one hundred years of reductionist science in cell biology. Although further bioinformatics analysis will continue, the focus is shifting towards synthesis and understanding how the regulatory genetic components within a cell dynamically interact to form functional phenotypes. One of the most important questions that still remains unanswered is how genetic regulation takes place. Kevin's Federation Fellowship and his projects with the ACCS and ARC Centre for Bioinformatics are exploring the roles of stochasticity in genetic regulatory networks, and developing an integrated modelling, simulation and visualisation framework for understanding the wonderfully complex processes that take place within a cell. By developing models that account for noise, researchers will be in a better position to look at the role of different types of genes in the formation of cancerous tumours and the nature of cell-signalling in the formation of embryos and organ development.

James Watson & Scott Heckbert, Patterns Workshop

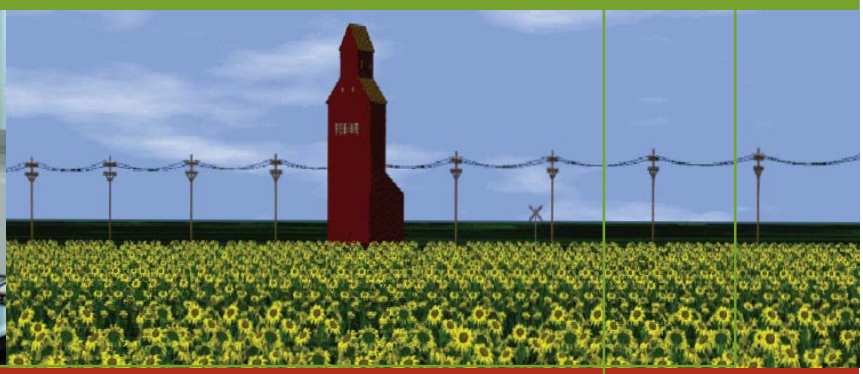


Image by D.R. Fowler, N. Fuller, J. Hanan, and A. Snider, University of Regina, Canada 1990

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 2005, a fifth round of PhD scholarships were advertised and three students were awarded joint scholarships to commence at UQ in 2005. Top-up funding was awarded to two IT&EE and two Economics students. One new PhD student is funded by the UNSW@ADFA node of the Centre. There are also four new PhD students affiliated with the ACCS.

To promote awareness of opportunities for postgraduate study with the Centre, the ACCS had a presence at Postgraduate Expos on 8 August at the St Lucia Campus, and 10 August and 30 November at Customs House in Brisbane.

In addition, the Centre sponsored a barbeque on 23 September for University of Queensland undergraduates from Information Technology & Electrical Engineering, Economics, Mathematics and Biology. Centre researchers spoke with the students with the aim of heightening their awareness of postgraduate study opportunities with the ACCS.

Degrees Awarded

Henk Stolk (UQ) - PhD
'Emergent models in hierarchical and distributed simulation of complex systems'
Advisors: Kevin Gates & Jim Hanan

John Mansfield (UQ) - PhD
'Investigating the proposal that socio-technical systems should be viewed as co-evolving systems and that their design may be informed by this view'
Advisor: Simon Kaplan

Timothy Smith (UQ) - Masters
'Evolving signalling systems in models of biological plants'
Advisors: Jim Hanan & Ian Hayes

PhD

Sameer Alam (UNSW@ADFA)
'A complex system approach to free-flight air traffic management'
Advisors: Hussein Abbass, Michael Barlow & Peter Lindsay

Shane Arnott (UQ)
'Use of modelling and simulation in support of strategic organisational decision making'
Advisors: Peter Lindsay & Richard Davis

Jennifer Badham (UNSW@ADFA)
'The effect of social network structure on the spread and control of epidemics'
Advisor: Hussein Abbass

Mark Bowden (UQ)
'Can the interaction of heterogeneous agents explain price fluctuations in financial markets?'
Advisors: Jason Potts, Stuart McDonald & John Foster

Lam Bui (UNSW@ADFA)
'Distributed multi-objective optimisation'
Advisors: Hussein Abbass, Daryl Essam, David Green & Kalyanmoy Deb

Tim Cederman-Haysom (UQ)
'Participatory design of ubiquitous computing'
Advisors: Margot Brereton & Peter Sutton

Brett Campbell (UQ)
'Designing to maintain human agency in context-aware systems'
Advisors: Margot Brereton & Ted McFadden

Kuang Yuan Steven Chen (UQ)
'A methodology for training teams of agents'
Advisors: Peter Lindsay & Hussein Abbass

Simon Connelly (UQ)
'Use of agent-based modelling to investigate shared situation awareness'
Advisors: Peter Lindsay & Marcus Gallagher

Jared Donovan (UQ)
'Participatory design of gestural interfaces in complex multi-modal work environments'
Advisors: Margot Brereton & Stephen Viller

Elizabeth Dun (UQ)
'Computational analysis of branching and flowering in pea'
Advisors: Christine Beveridge & Jim Hanan

Nic Geard (UQ)
'Modelling the roles of small RNAs in the gene regulation'
Advisor: Janet Wiles

John Hawkins (UQ)
'Machine learning architectures for biological sequence analysis'
Advisors: Mikael Boden & Janet Wiles

Geoffrey Jones (UQ)
'Institutions, information mediating competencies, service exporting sectors and economic growth in Vietnam and other developing countries'
Advisors: John Foster, Tom Mandeville & Jason Potts

Ashok Kanagarajah (UQ)
'Characteristics and improvement strategies for health-sector supply chains'
Advisors: Peter Lindsay, David Parker & Anne Miller

Tim Kastelle (UQ)
'Towards an evolutionary economic theory of firm internationalisation'
Advisors: Peter Liesch, John Steen & Jason Potts

Donny Kurniawan (Monash)
'Integrated software development environments for the Grid'
Advisor: David Abramson

Xilin Li (UQ)
'Visualisation and coordination with complex systems'
Advisors: Penelope Sanderson & Zhao Dong

Kevin Lin (Griffith)
'Collaborative editing of Behavior Trees'
Advisors: David Chen, Chengzhen Sun & Geoff Dromey

John Zhe Lu (UQ)
'Electricity market planning and management'
Advisors: Zhao Dong & Penelope Sanderson

Stefan Maetschke (UQ)
'Advanced machine learning approaches to sequence characterisation in bioinformatics'
Advisors: Marcus Gallagher, Geoff McLachlan & Mikael Boden

Michelle McPartland (UQ)
'Evolving non-player character behaviour in games'
Advisors: Peta Wyeth & Janet Wiles

Kate Morrison (UQ)
'The value of markets'
Advisors: Peter Earl & John Foster

Andrew Rae (UQ)
'A behaviour-based methodology for fault tree generation'
Advisor: Peter Lindsay

Alan Raine (UQ)
'On growth, property and energy transformation'
Advisors: John Foster, Jason Potts & Tom Mandeville

Ella Reeks (Rohen) (UQ)
'Agent coordination in emerging markets'
Advisors: Tom Mandeville, John Foster & Peter Earl

Blaize Rhodes (UQ)
'Presence, awareness and a process trellis'
Advisor: Simon Kaplan

Aaron Searle (QUT)
'Automatic relative debugging'
Advisors: John Gough & David Abramson

Lesley Seebeck (UQ)
'The co-evolution of information technologies and their host systems'
Advisor: Simon Kaplan

Philip Valencia (UQ)
'Can practical distributed robotic solutions be automatically generated for real world applications'
Advisors: Peter Lindsay & Peter Corke

James Watson (UQ)
'From phenes to genes and back again'
Advisor: Janet Wiles

Lian Wen (Griffith)
'Mapping requirements changes to design changes'
Advisor: Geoff Dromey

Kai Willadsen (UQ)
'Dynamics from structure in simulating genetic regulatory networks'
Advisor: Janet Wiles

Ang Yang (UNSW@ADFA)
'Network centric multi-agent systems for military analysis'
Advisor: Hussein Abbass

Yu-Hei Flora Yeh (UQ)
'Model selection in machine learning using computational statistics'
Advisors: Marcus Gallagher, Hussein Abbass & Janet Wiles

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

Masters

Remus Chang (UQ)
'A free-flight simulator for multiple autonomous unmanned air vehicles'
Advisor: Peter Lindsay

Andriy Kvyatkovskyy (UQ)
'Evolutionary computation in combinatorial graph theory'
Advisors: Peter Adams & Marcus Gallagher

Honours

Katherine Duczmal (UQ)
'Agent-based virtual insects'
Advisors: Peter Robinson & Jim Hanan

Philippa Hall (UQ)
'A community based dynamic bio-economic model of the impact of sugar cane production on eutrophication of the Great Barrier Reef lagoon'
Advisor: Rodney Beard

Andrew Kemp (UQ)
'The use of genetic algorithms in combinatorial graph theory'
Advisor: Peter Adams

Brian Pack (Griffith)
'A case study comparison of GSE and DoDAF'
Advisor: Geoff Dromey

John Seagrott (Griffith)
'A comparison of RUP and GSE software development approaches'
Advisor: Geoff Dromey

Summer Student Projects

To encourage students to pursue research careers, the Centre funded the following summer student projects at the Brisbane and Canberra nodes. The 2004/05 summer student projects were reported in the 2004 Annual Report.

2005/2006 Projects

Bangjun Jeff Chen (UQ)
'Implementation of a 3-D mid and high altitude wind model and its effect on aircraft velocities'
Supervisor: Ariel Liebman
(See page 15)

Rhea Coleman (UQ)
'Complexities of homelessness'
Supervisor: John Quiggin
(See page 18)

Hoang Xuan Dao (UNSW@ADFA)
'Multi-objective optimisation'
Supervisor: Hussein Abbass
(See page 25)

Lynne Davis (UQ)
'Data-driven modelling of the compartmentalisation of proteins'
Supervisor: Mikael Boden
(See page 10)

Katherine Duczmal (UQ)
'Agent-based virtual insects: Extension and testing'
Supervisor: Jim Hanan & Peter Robinson
(See page 25)

Binu George John (UQ)
'Implementations of intelligent agents for ATC operator simulation'
Supervisor: Ariel Liebman
(See page 13)

Tri Hai Le (UNSW@ADFA)
'Multi-objective optimisation'
Supervisor: Hussein Abbass
(See page 25)

Robert McLeay (UQ)
'Modelling cellular regulatory networks'
Supervisor: Jim Hanan
Co-funded by ARC Centre in Bioinformatics
(See page 8)

Narender Rana (UQ)
'Allocation of airport landing slots via combinatorial auction'
Supervisors: Stuart McDonald & Rodney Beard
(See page 18)

Walter Reinhardt (UQ)
'Validation of biological parameters of some models developed by the Eutrophication of Barrier Reef project'
Supervisor: Rodney Beard
(See page 17)

John Seagrott (Griffith)
'Implementation strategies for Behavior Tree design'
Supervisor: Geoff Dromey
(See page 19)

Johnson Shih (UQ)
'A plug-in kernel for support vector algorithms'
Supervisor: Mikael Boden
(See page10)

Morgan Smith (UQ)
'Development and implementation of collision risk models'
Supervisor: Ariel Liebman
(See page 13)

Mark Wakabayashi (UQ)
'Trees and other complex systems patterns'
Supervisor: Janet Wiles
(See page 10)

ACCS in the Media

It's life, but not as we know it

Centre research featured prominently in an article by Beverley Head that appeared in *The Age*, 29 November 2005, in the *Sydney Morning Herald* as the Cover Story for the *Next* section, and as the Top Feature for *Sydney Morning Herald's* electronic *Technology Daily* that day.

The article outlined research being undertaken by various centres and individuals throughout Australia and highlighted that Australian industry remains essentially unaware of the benefits and potential applications of the research.

The article is at www.theage.com.au/news/next/its-life-but-not-as-we-know-it/2005/11/28/1133026374254.html?page=fullpage#contentSwap2.

Modelling water usage for the Murray-Darling Basin

Chief Investigator John Quiggin's project developing water usage modelling for the Murray-Darling Basin generated considerable interest in 2005. John was interviewed on four occasions:

- with the *Quest* newspaper about 'Water in South-East Queensland', 12 October 2005;
- with *ABC Radio* (612 Brisbane Breakfast program) on 'Water trading', 24 October 2005;
- with *Radio Adelaide* (Breakfast program) on 'Energy and the economy', 31 October 2005; and
- with *ABC Radio* (Sydney) on 'Biodiversity trading', 3 November 2005.

I am blogger, hear me roar

In an article in *The Sydney Morning Herald*, 31 May 2005, Hugh J. Martin and Rob O'Neill consider weblogs and ways of measuring their quality and influence. Centre Chief Investigator John Quiggin's weblog is identified as one of Australia's four most influential. John is described as 'one of the elder statesmen of the Oz blogosphere' who is a 'a firm believer in the value of blogs as quality alternatives to the mainstream media'.

John Quiggins blog is at www.johnquiggin.com.
The article is at www.smh.com.au/news/Next/I-am-blogger-hear-me-roar/2005/05/30/1117305534356.html.

Alex Pudmenzky, Jim Hanan & Przemyslaw Prusinkiewicz

Rodney Beard, Ardeshir Ahmadi, Ferenc Szidarovsky, Ariel Liebman & Michael Gagen

Outreach, Links and Service to Community

Keynote and Invited Addresses at International Conferences

Hussein Abbass, Invited Speaker, 4th Homeland Security SET Summit, Canberra, July, 'Current and future challenges in connecting the dots.'

Hussein Abbass, Invited Paper, SPIE Complex Systems Conference, Brisbane, December, 'Connecting the dots to disconnect them: a study into network dynamics and evolution.'

Peter Adams, Invited Speaker, HELP Institute Bioinformatics Symposium, HELP Institute, Kuala Lumpur, Malaysia, July, 'Resolving DNA sequencing errors and ambiguities using a combination of techniques.'

Jim Hanan, Invited Speaker, 17th International Botanical Congress (XVII IBC), Vienna, Austria, July, 'Modelling genetic regulatory control of pea phenotype.'

George Havas, Invited Speaker, Groups St Andrews 2005; St Andrews, Scotland; July-August, '4-Engel groups are locally nilpotent.'

Ian Hayes, Invited Speaker, Workshop on Rigorous Engineering of Fault Tolerant Systems (REFT), Newcastle, UK, July, 'Using domain models to specify systems.'

Geoff McLachlan, Keynote Speaker, Sixth International Conference on Intelligent Data Engineering and Automated Learning IDEAL '05, Brisbane, July, 'Selection bias and other issues in applications of machine learning in bioinformatics.'

Anne Street, Invited Speaker, Sixteenth Australasian Workshop on Combinatorial Algorithms (AWOCA 2005), Ballarat, September, 'How much is enough? Economical specifications of combinatorial designs.'

Jacqueline Wicks, Invited Presentation, 55th Session of the International Statistical Institute, Sydney, April, 'Genetic modelling assumptions for gene mapping and the triangle constraints.'

Janet Wiles, Invited Speaker, CSIRO Network Theory Working Group II, Canberra, February.

Janet Wiles, Invited Speaker, University of New England, Armidale, August, ' Language and robots: Computational models of the evolution of language.'

Janet Wiles, Invited Speaker, NICTA Large Scale Analysis Workshop, Sydney, November.

Serving the Research Community

The ACCS sponsored the Best Paper award (awarded to James Gordon) and Best Student Paper award (Sho Nariai) at the IDEAL '05 conference held in Brisbane in July.

The ACCS co-sponsored two best paper awards at the SETE '05 Conference held in Brisbane in December. Anthony Dekker from DSTO was awarded the Best Paper in Systems Engineering, and Paul Bunnik & Michael Harris were awarded the Best Paper in Test & Evaluation.

Centre participants served on a considerable number of international conference program committees:

Hussein Abbass was the conference co-chair for the 2nd Australian Conference on Artificial Life (ACAL 05),

Peter Robinson & Silvana Zapacosta-Amboldi

Geoff Dromey, John McDermid & Peter Lindsay

Sydney; publicity chair for AI2005: 18th Australian Joint Conference on Artificial Intelligence, Sydney; and on the program committee for the European Conference on Artificial Life (ECAL 05), Kent, UK, the Genetic and Evolutionary Computation Conference (GECCO2005), Washington, D.C. USA (GA Track), the 8th European Conference on Genetic Programming (EuroGP2005), University of Lausanne, Switzerland, the 9th International Conference on Knowledge-Based Intelligent Information and Engineering Systems (KES2005), Melbourne, the 3rd International Conference on Evolutionary Multi-Criterion Optimisation (EMO 2005), Guanajuato, Mexico, and the 28th Australasian Computer Science Conference (ACSC2005), Newcastle, Australia.

Geoff Dromey was a member of the steering committee for the 3rd IEEE International Conference on Software Engineering and Formal Methods SEFM 2005.

Ian Hayes was programme committee chair for Formal Methods (FM 2005), Newcastle, UK; and a member of the following programme committees: International Conference of B and Z Users (ZB 2005) London, UK; IFIP Working Conference on Software Verification Tools and Trials (SVTT 2005), Zurich, Switzerland; Formal Methods (FM 2006) to be held in Hamilton, Canada; 4th Workshop on Quantitative Aspects of Programming Languages (QAPL 2006) Vienna, Austria; and the 8th International Conference on Mathematics of Program Construction (MPC 2006), Tallinn, Estonia. Ian is also a member of the editorial board of the BSC/Springer journal, *Formal Aspects of Computing*.

Peter Lindsay was conference committee co-chair for the Complex Systems Conference - part of SPIE International Symposium; chair of the Program Committee of the Australian Systems Engineering, Test & Evaluation Conference (SETE '05); and a member of the program committee for the International Conference on Engineering of Complex Computer-based Systems (ICECCS) 2005, the International Conference on Formal Engineering Methods (ICFEM) 2005, and the 2nd International Conference on Research in Air Transportation (ICRAT 2006). Peter was also on the editorial board of the *Science of Computer Programming* journal.

Bernard Pailthorpe was co-host of the APAC Conference and Exhibition on Advanced Computing, Grid Applications and eResearch (APAC'05), Gold Coast; the official Australian representative at the OECD e-Science Planning Workshop in Sydney; and on the program committee for the Grid Workshop at SC'05, Seattle, USA.

Janet Wiles was co-organiser of the Australian Conference on Artificial Life, Sydney. Janet has been invited to join the committee to judge the Australian Distinguished Doctoral Award in Computer Science.

Visitors to the Centre

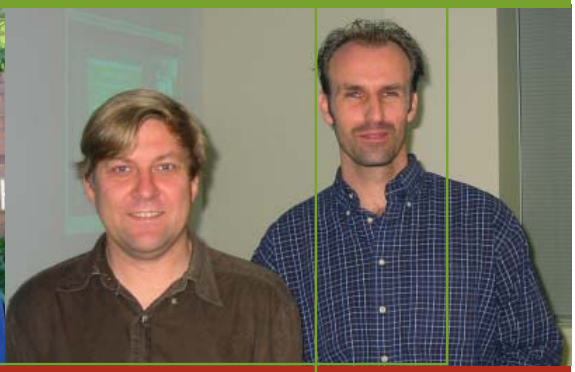
The Centre conducts an international visitor program and other networking activities that engage allied researchers who might not be formally associated with the Centre.

Prof Mark Bedau
Dept of Philosophy, Reed College, Oregon, USA
December

Prof Keith Clark
Dept of Computing, Imperial College, London, UK
March, July, October

Peter Lindsay & Eurocontrol Experimental Centre staff


Phil Hugenholtz


Rodney Beard & Peter Roebeling

Prof Roger Eggleton
Dept of Mathematics, Illinois State University, USA
June

Prof Robert Glass
Indiana University
September onwards

Prof David Goldberg
Dept of General Engineering, University of Illinois at Urbana-Champaign (UIUC), USA
December

Prof M J Grannell
Dept of Mathematics, Open University, Milton Keynes, UK
November - December

Prof Melvin Hinich
Dept of Government, University of Texas at Austin, USA,
August

Dr Phil Hugenholtz
Department of Energy, Joint Genome Institute, USA
July

Dr Tim Kovacs
Dept of Computer Science, Bristol University, UK
December

Prof C C Lindner
Dept of Mathematics, Auburn University, Alabama, USA
November - December

Prof Zhiming Liu
International Institute for Software Technology of the United Nations University, Macao, China
May

Prof Robert S. MacKay
Mathematics Institute, University of Warwick, UK
November

Prof John McDermid
Dept of Computer Science, University of York, UK
December

Prof Przemyslaw Prusinkiewicz
University of Calgary, Canada
September - December

Dr Leanne Rylands
School of Computing and Mathematics, University of Western Sydney
July

Dr Katrina Scurrah
Dept of Physiology and Centre for Genetic Epidemiology, University of Melbourne
November

Prof Ferenc Szidarovszky
Dept of Systems and Industrial Engineering, University of Arizona, Tucson, USA
March

Dr Andy Wuensche
Dept of Informatics, School of Science and Technology, University of Sussex, UK
December

Prof Xin Yao
School of Computer Science, University of Birmingham, UK
November

Dr Silvana Zapacosta-Amboldi
Dept of Computing, Imperial College, London, UK
July-August

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, four are of particular note because of the high standing of the laboratories visited in the complex systems field: Janet Wiles' visit to the Salk Institute, Peter Lindsay's visits to the Animal Cognition Lab and to the Eurocontrol Experimental Centre, and Ian Hayes' visit to the Interdisciplinary Research Collaboration in Dependability.

Lars Grunske spent a week each at Linköping University, Sweden, at Mälardalen University, Sweden, and at Fraunhofer Institute for Experimental Software Engineering (IESE) Kaiserslautern, Germany. He presented seminars on 'Component-based safety evaluation and safety interfaces', 'Putting safety into save CCM', on 'Online optimisation of integration test strategies' and 'Module testing of Behavior Trees'.

Jim Hanan visited HortResearch New Zealand at the Mt Albert Research Centre in Auckland and the Palmerston North Research Centre. Jim also visited the University of Minnesota, USA and the Jean-Pierre Bourgin Institute, at the Versailles Centre of the National Institute for Agronomical Research (INRA), Versailles, France.

George Havas undertook a research trip to Oxford University and the University of St Andrews, UK, Auckland University, NZ and the City University of New York, USA.

John Hawkins visited the Complex Systems group at the University of Mexico City and presented 'The role of machine learning in modelling the cell'.

Ian Hayes was Visiting Senior Research Fellow at the Interdisciplinary Research Collaboration in Dependability (DIRC), Newcastle, UK. He visited in July.

Peter Lindsay visited partner investigator Dr Guy Theraulaz at the Animal Cognition Lab at the University Paul Sabatier in Toulouse, France. He also visited the Innovative Research Lab, Eurocontrol Experimental Centre near Paris; the Global Optimisation Lab, Centre d'Etudes de la Navigation Aérienne (CENA) and Ecole National de l'Aviation Civile (ENAC), Tolouse, France; the new Complex Systems Modelling & Cognition Laboratory at the Ecole Pratique des Hautes Etudes (EPHE), Paris; and the High Integrity Systems group at the University of York, UK.

Bernard Pailthorpe visited Scripps Institute of Oceanography, SDSC – San Diego Supercomputer Centre & Calit2 - California Institute for Telecommunications and Information Technology, all in San Diego, USA, in relation to data Grids and SensorNets.

Anne Street visited Professor Curt Lindner and the Combinatorics Group at Auburn University, Alabama, USA.

Lian Wen visited Xi'an Institute of Space Radio Technology, Xi'an, China. He gave four seminars on 'The concepts of genetic software engineering', 'Software change impact analysis based on GSE', 'Software architecture normalisation' and 'Scale-free networks in software systems'.

Janet Wiles visited the Salk Institute for Biological Studies at the University of California, San Diego, USA.

Seminars

In April, a weekly ACCS seminar series was introduced. It has been well attended, including weekly participation of the Canberra node via videoconferencing. Neil Diamond presented his seminar (on 20 June) from Monash, with videoconference participation by Centre researchers from the Brisbane and Canberra nodes.

Details of past and future seminars in this series are available on the ACCS website. Anyone is welcome to join the ACCS emailing lists to receive regular announcements of seminars and other Centre activities. Simply email the Director with your request and your preferred email address.

Hussein Abbass and ACCS Canberra node participants joining in a weekly Centre seminar by videoconference

Seminars presented by Centre visitors in 2005 included:

17 February
Mark Neal – University of NSW
'Optimisation of a whole-farm model'

10 March
Ferenc Szidarovsky – University of Arizona, UK
'Cournot models: Dynamics, uncertainty and learning'

1 April
Keith Clark – Imperial College, UK
'BDI agents with telco-reactive plans'

21 April
Peter Roebeling – CSIRO, Townsville
'Efficiency in Great Barrier Reef water pollution control: A case study for the Douglas shire'

17 May
Zhiming Liu – UNU-IIST, China
'Real-time and fault-tolerance specification, verification, refinement and scheduling'

20 June
Neil Diamond – Monash University
'Experimental design for a statistical perspective'

30 June
Kit Po Wong – Hong Kong Polytechnic University, Hong Kong
'Enhanced evolutionary programming for optimal reactive power flow problem'

9 July
Phil Hugenholtz – DOE Joint Genome Institute, USA
'Comparative metagenomics'

23 August
Melvin Hinich – University of Texas at Austin, USA
'Estimating randomly modulated periodic processes generated from nonlinear mechanisms'

1 September
Silvana Zappacosta-Amboldi – Imperial College, UK
'Programming multi-agent systems in Qu-Prolog'

8 September
Przemyslaw Prusinkiewica – University of Calgary, Canada
'A multiscale model of Arabidopsis development: from molecules to plant architecture'

17 October
David Batten – CSIRO, Melbourne
'Agency and the evolution of diversity'

10 November
Ryan McAllister – CSIRO, Townsville
'Agistment networks: Complex systems science, rangelands and resource heterogeneity'

21 November
Paul Ormerod – Volterra Consulting, UK
'21st century economics'

30 Novemeber
Tim Kovacs – Bristol University, UK
'Strength or accuracy? Credit assignment in classifier systems'

1 December
John McDermid – University of York, UK
'Model-based software development for safety-critical systems'

16 December
Andy Wuensche – University of Sussex, UK
'DDlab and emergent complexity'

Professional Courses

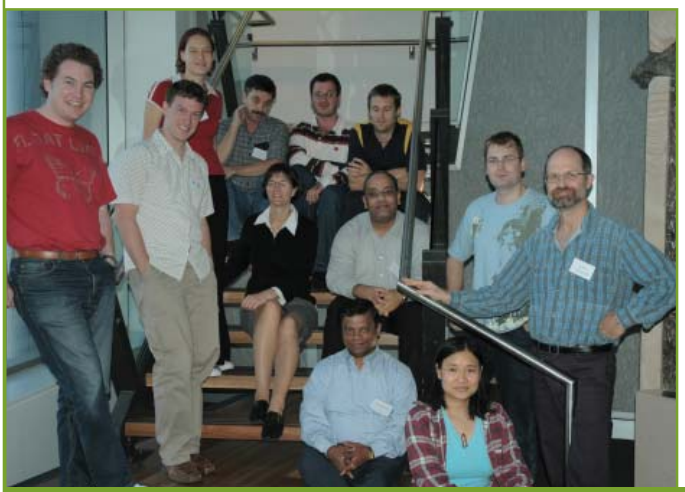
Centre participants benefited from participation in a range of professional courses:

NECSI Course
Ashok Kanagarajah, a Centre PhD student, attended a one-week intensive course on 'Complex Physical, Biological and Social Systems' in Sydney in December. The course, presented by Yaneer Bar-Yam, Director of the New England Complex Systems Institute provided a coherent program of study of complex systems concepts and methods.

Complex Systems Winter School
See details on page 38. A number of ACCS researchers and students participated in the Winter School, including Tania Bransden from Monash, and Kamran Shafi, Ang Yang, Sameer Alam and Lam Bui from UNSW@ADFA.

DIAS Workshop
A three-day training course in the DIAS agent-based modelling framework from Argonne National Laboratories, Illinois, USA was run at The University of Queensland on 17-19 August. It was attended by 10 ACCS staff from the UQ and UNSW@ADFA nodes.

Intellectual Property & Research Commercialisation
ACCS associates were trained in technology transfer and commercialisation. David Israel from UniQuest presented two courses: Intellectual Property for ACCS Participants and Research Commercialisation for ACCS Participants. Twenty staff (including eight from the Canberra node) participated in these workshops.



Participants in the Complex Systems Patterns Workshop I

Workshops

The Centre presented or co-presented a number of workshops to enhance education and training, collaboration, and excellence in research.

Complex Systems Winter School
See details on page 38.

Complex Systems Patterns Workshop I
A joint workshop on patterns for complex system modelling held with Complex Open Systems Network (COSNet) at the University of Queensland in July (see the Patterns in Complex Systems Models project on page 10).

Complex Systems Patterns Workshop II
The workshop was held as a special session of the Second Australian Conference on Artificial Life (ACAL) in Sydney, on December 5. Janet Wiles and James Watson were key presenters and organisers. The workshop attracted both national and international researchers (see the 'Patterns in complex systems models' project on page 10).

International Workshop on Evolutionary Macroeconomics
The Centre co-sponsored this workshop, titled 'Building Micro and Meso Foundations from Studies of Systems of Innovation, Self-Organisation, Competitive Processes, Knowledge Networks and Complex Adaptive Economic Systems.' Held at The University of Queensland on 14-17 July, it was attended by about 20 international participants. ACCS Chief Investigator, John Foster presented at this workshop.

Other Workshops

In addition, Peter Lindsay and Penelope Sanderson presented at the **Human Performance Modelling Workshop** in January, organised by the University of Queensland's Key Centre for Human Factors.

ACCS researcher Jim Hanan and ACCS visitor Premyslaw Prusinkiewicz presented at the **CILR Hypothesis-Driven Modelling Using L-Systems Workshop.** This workshop in November was hosted by the ARC Centre of Excellence for Integrative Legume Research. It attracted international plant scientists and students.

Janet Wiles was invited to present at the EII/NICTA Workshop on **Large-scale Network Analysis** in Sydney in November. Her presentation was titled 'Mapping biology onto computation: Network structure, dynamics and function?'

John Quiggin presented 'The precautionary principle and the theory of choice under uncertainty', to the Environmental Panel of a workshop on **World of Risk: New Approaches to Global Risk Society.** The workshop, hosted by the School of Political Science and International Studies, University of Queensland was held in Brisbane on 30 September.

John Quiggin presentation to a multidisciplinary workshop on **Policy Choices for Salinity Mitigation**, jointly hosted by the Bureau of Rural Sciences and the Centre for Applied Economic Research, School of Economics, University of New South Wales, Sydney, 2 December. John's presentation was on 'Modelling sustainable management of the Murray-Darling Basin.'

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.

Geoff Dromey presented a half day course at the Australian Software Engineering Process Group conference in Sydney in September on 'Modelling requirements for complex software intensive systems.'

Ariel Liebman presented a three-day workshop, Energy Risk Management, in June. The workshop was attended by 10 industry participants from companies including Energy Australia, Energex, ACTEW AGL, and First Gulf Bank, UAE.

Ariel Liebman was invited to speak at the 8th Annual Energy Risk and Trading Conference in Sydney in September. He also presented a Post Conference Masterclass 'Practical electricity risk management and analytics for a changing market'.

Peter Lindsay gave presentations on ACCS research at the Complex Adaptive Systems in Defence Workshop in Canberra in April; the CSIRO Complex Systems Science Workshop in Melbourne in August; and to Airservices Australia in Brisbane in December.

Peter Lindsay and **Penelope Sanderson** presented to a delegation from Boeing in July.

John Quiggin presented to the Productivity Commission in Melbourne in March on 'Policy and modelling issues for sustainable management of the Murray-Darling Basin.'

Janet Wiles spoke on Networks at the CSIRO Showcase to Government in February.

Industry Visitors

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

Dr David Batten, CSIRO Manufacturing & Infrastructure Technology
Mr Chuck Concannon, Boeing USA
Mr Philip Crosby, Boeing Australia
Ms Susan Dart, Defence Materiel Organisation
Mr Walter Dolman, Qantas
Mr Stuart Garrett, Department of Defence
Mr Paul E. Gartz, President, IEEE Aerospace and Electronic Systems Society, USA

ACCS Complex Systems Winter School

In July, the Centre hosted a Winter School aimed at giving participants an understanding of complex systems science and its application to real-life scenarios.

The Winter School was attended by over 40 honours, masters, post-graduate, early-program PhD, and high achieving 3rd year students, interested university personnel and an industry participant. The ACCS supported the attendance of 18 of the interstate students.

Participants were from a range of disciplines including biology, mathematics, economics and computer science. A number of ACCS staff and students benefited from participation in the Winter School.

The Winter School was a mix of lectures and hands-on challenges. ACCS staff and researchers presented the lectures and tutorials.

The first day provided an introduction to complex systems theory. Subsequent days focused on each of the three core program areas: genetic regulatory networks, evolutionary economic systems and free-flight air traffic control.

Phil Hugenholtz from the US Department of Energy's Joint Genome Institute in California gave a well-received keynote talk on ‘Comparative metagenomics’.

Participant feedback indicated that they found the Winter School to be a valuable introduction to complex systems and complex systems theory - indeed many participants wished it were longer!

Jennifer Hallinan presenting at the ACCS Complex Systems Winter School

Dr Peter Kwantes, SMART, Defence Research & Development, Canada
Dr Bill Lyons, Phantom Works, Boeing USA
Mr Greg McDonald, Airservices Australia
Ms Margaret Morse, Boeing USA
Mr Paul Omerod, Volterra Consulting, UK
Dr Roger Remington, NASA Ames Research Centre, USA
Dr Peter Roebeling, CSIRO Sustainable Systems
Mr Dennis Sommers, Queensland Transport
Mr Dean Webb, Boeing USA
Prof David Winkler, CSIRO Centre for Complexity in Drug Design
Dr Alla Seleznyova, New Zealand HortResearch

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 (see page 8, 'Modelling regulatory networks at cell, tissue and organism level'),
- Queensland Brain Institute (see page 10, 'Patterns in complex systems models')
- Airservices Australia (see page 13, 'Air traffic control workload'),
- Queensland Institute of Medical Research (see page 9, 'Modelling and mapping genes for complex phenotypes in humans'), and
- ARC Centre for Bioinformatics (see page 8, 'Modelling regulatory networks at cell, tissue and organism level', and page 10, 'Patterns in complex systems models').

Centre staff and associated academics jointly supervise PhD projects with the Defence Science and Technology Organisation, CSIRO and other research organisations.

A Postdoctoral Fellowship position was advertised and filled, to begin in 2006, funded jointly with the ARC Centre for Bioinformatics. A PhD scholarship in self-assembly in biomolecular engineering was advertised, to start in 2006, jointly funded with the Australian Institute for Nanotechnology and Bioengineering (AIBN) and CSIRO.

There is also industry interest in the Behavior Trees method whose development is being partly funded through the ACCS (see page 19). A patent application is under development, and a presentation was given to the SciVentures fund management company. An analysis trial has been conducted with Raytheon on initial requirements for the Coastwatch system, a ten-year billion-dollar program to manage the surveillance of Australia's coastline.

ACCS Complex Systems Winter School participants

Some of the analytical and modelling techniques developed by the Complexity in Economic Systems group are being trialled in forecasting platforms used by economics consultancies that specialise in the application of complex systems theory such as Volterra in the UK and Volterra Pacific in Brisbane. This brings us closer to understanding the kinds of problems that commercial entities are trying to solve and to facilitate the sharing of tools and techniques for doing so.

And finally, in December, Centre Collaborator Dr Keith Mitchelson visited the USA to meet with a potential research and commercial partner for technology which uses discrete mathematics and grid-based combinatorial computing to enable analysis of sequence data in various genomes. This technology has partially arisen from work on the Infrastructure project `Emerging applications of advanced computational methods and discrete mathematics'.

Public Awareness Programs

Through Public Awareness Programs and Industry Workshops, the Centre aims to raise awareness of complex systems in Australia, and its importance in innovation and international competitiveness.

The Centre maintains a website (www.accs.ed.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 presents simulations to help people understand how complex organisation and behaviour emerges in living systems. VLAB is a valuable tool for raising awareness of complex systems.

The following presentations aimed to increase public awareness of complex systems.

Peter Lindsay presented 'The engineering of complex systems' to The Institute of Engineers Australia seminar in Brisbane in July.

Peter Lindsay gave a presentation on air traffic control on 22 August. This was part of the 'Introduction to Complex Systems' course (details in the following section) but was open to the public.

Peter Lindsay & Lars Grunske presented the 'Development of safety critical systems' at The University of Queensland, 8-10 August (offered in conjunction with System Safety Engineering UQ ENGG7020 – details in the following section).

John Quiggin presented on 'Water pricing' to the Brisbane Institute's public seminar on 'Governing Water in South East Queensland', Customs House, Brisbane, 18 October

John Quiggin presented at an event jointly sponsored by the Ecological Society of Australia and ABC Science Outreach (recorded for broadcast for Radio National) at The University of Queensland, Brisbane, 29 November. John spoke on 'Biodiversity trading: environmental saviour or disaster? Can we make biodiversity trading work?'

ACCS personnel presented at the following conferences:

3rd Asia-Pacific Bioinformatics Conference
3rd Australian Undergraduate Students' Computing Conference
3rd International Conference on Information Technology and Applications (ICITA)
3rd IEEE International Conference on Software Engineering and Formal Methods (SEFM 05)
4th International Conference on COTS-Based Software Systems (ICCBSS 2005)
5th International Conference on Integrated Formal Methods (IFM 2005)

ACCS Extends its Collaboration to a Secure Australia

The Research Network for a Secure Australia (RNSA) was established in late 2004 to facilitate networking and communication among researchers with interest in the area of security. The network encourages multi-disciplinary collaborations and knowledge exchange among like-minded researchers. The research program is divided into three themes: Information Security, Physical Infrastructure Protection, and Surveillance and Intelligent Systems. The third program encompasses complex systems.

Three of ACCS Chief Investigators (Peter Lindsay, David Green, and Hussein Abbass) were among the 50 chief investigators who initiated the original network application. ACCS Chief Investigator Hussein Abbass is also the coordinator of the Surveillance and Intelligent Systems hub of the network. The cross-fertilisation of research programs in ACCS and RNSA have resulted in the new book Applications of Information Systems to Homeland Security and Defense.

ACCS as Part of the Complex Systems Network

COSNet - the ARC Complex Open Systems Research Network aims to link specialists in the physical, biological and social sciences who have adopted a complex systems approach. Many ACCS personnel are participants of COSNet. COSNet draws upon the expertise of the ACCS and related research centres and links it to the wider community.

ACCS and COSNet co-sponsored two workshops during the year, the Complex Systems Patterns Workshop I, Brisbane, June 6-7, 2005 and Workshop II, Sydney 5 Dec 05, in conjuction with the Second Australian Conference on Artificial Life (ACAL), Sydney, 5 - 8 Dec 2005. Strong links were formed between participants who attended and spoke in these forums, resulting in collaborations, joint papers and grant applications and a stronger sense of the community who work in this area.

5th International Conference on Quality Software (QSIC 2005)
7th International Power Conference (IPEC)
8th International Workshop on Learning Classifier Systems
8th European Conference on Artificial Life
9th European Conference on Computer-Supported Cooperative Work (ECSCW05)
16th World Congress, International Federation of Automatic Control (IFAC WC 05)
28th Australasian Computer Science Conference (ACSC2005)
55th Session of the International Statistical Institute
2005 Intelligent Sensors, Sensor Networks & Information Processing Conference
Academy of Management 2005 Conference
Advances in Artificial Intelligence (AI 2005)
APRS Workshop on Digital Image Computing (WDIC 2005)
Asia-Pacific Software Engineering Conference
Component-Based Software Engineering: 8th International Symposium (CBSE 2005)
Congress on Evolutionary Computation
Genetic and Evolutionary Computation Conference (GECCO'05)
ICWE 2005 Workshop on Web Information Systems Modelling
IEEE Symposium on Computational Intelligence in Bioinformatics and Computational Biology
Intelligent Data Engineering and Automated Learning (IDEAL 2005)
International Congress on Modelling and Simulation (MODSIM 2005)
International Society for Optical Engineering (SPIE), Microelectronics, MEMS, and Nanotechnology Symposium
Intelligent and Evolutionary Systems
Knowledge-Based Intelligent Information and Engineering Systems
Systems Engineering/Test and Evaluation Conference (SETE 05)

Undergraduate & Postgraduate Courses

The following course was developed and delivered by ACCS participants.

Introduction to Complex Systems
(UQ COMP4001/7001)
Coordinator: Jennifer Hallinan (with guest lectures from ACCS personnel Jim Hanan, Peter Lindsay and Janet Wiles).
Level: Undergraduate/Postgraduate

In addition, ACCS participants presented aspects of complex systems science and engineering in the following undergraduate and postgraduate courses:

Advanced Algorithms and Data Structures
(UQ COMP4500/COMP7500)
Coordinator: George Havas
Level: Undergraduate/Postgraduate

Algorithm Complexity
(PhD Spring School, ARC Research Network in Enterprise Information Infrastructure)
Presenter: George Havas
Level: Postgraduate

Applications of Scientific Computing
(UQ MATH4201)
Coordinator: Bernard Pailthorpe
Level: Undergraduate

Frontiers in Computational Science
(UQ MATH1070)
Coordinator: Bernard Pailthorpe
Level: Undergraduate

Functional Plant Biology
(UQ BOTN2002)
Presenter: Guest lectures by Jim Hanan on modelling of regulatory networks
Level: Undergraduate

Mathematical Biology
(UQ MATH3104)
Coordinator: Jim Hanan. Included material on modelling genetic regulatory networks
Level: Undergraduate

Programming multi-agent systems in Qu-Prolog
(Imperial College, London)
Coordinators: Keith Clark & Silvana Zappacosta-Amboldi
Level: Honours
The Qu-Prolog language, developed and maintained by Peter Robinson, is used as the programming language in this advanced agent programming course.

Scientific Computing: Advanced Techniques and Applications
(UQ MATH3201)
Coordinator: Bernard Pailthorpe
Level: Undergraduate

System Safety Engineering
(UQ ENGG7020)
Presenters: Peter Lindsay (Coordinator), Lars Grunske, Simon Connelly
Level: Postgraduate, also offered as a public course to industry
Included dependability analysis for complex engineered systems

Systems Engineering
(UQ ENGG4000/7000)
Coordinators: Peter Lindsay, Lars Grunske
Level: Undergraduate/Postgraduate

High School Awareness Events

Centre collaborator, Jason Potts, presented at the University of Queensland's Economics Schools Day in July. About 200 high school students attended Jason's presentation and received ACCS brochures providing an introduction to complex systems and complex systems science.

Publications

2005

Papers published in publications that the University of Queensland considers Tier 1, the top twenty percent in their field, are starred ❖.

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Performance Indicators Report

P1. Research findings			
Description	2005 Actual	Details	2005 Target
Quality of publications	14	See Publications, page 42.	At least five in the top 10% of journals & conferences in relevant areas
Invitations to address and participate in international conferences	12	See Keynote & Invited Addresses, page 32.	5-6
Invitations to visit leading international laboratories	4	See Visits to International Institutions, page 35.	3
Number and nature of commentaries about the Centre's achievements	5	See ACCS in the Media on page 31.	3

P2. Research training and professional education			
Description	2005 Actual	Details	2005 Target
Number of postgraduates recruited - with Centre financial support - affiliated with the Centre	 6 (20 total to date) 4 (22 total to date)	See Research Students, page 28	14 over the life of the Centre
Number of postgraduate completions	3 (3 total to date)	See Research Students, page 28	14 over the life of the Centre
Number of honours students	5 (11 total to date)	See Research Students, Honours, page 30	30 over the life of the Centre
Number of professional courses	1	Complex Systems Winter School, page 38	1
Participation in professional courses	4	See Professional Courses, page 36	2
Number and level of undergraduate and high school courses in the complex systems area	primary contributor: 1 other contributor: 10	See Undergraduate & Postgraduate courses, page 40	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	2005 Actual	Details	2005 Target
Number of international visitors	20 (8 of these had significant Centre financial support)	See Visitors to the Centre, page 33	4
Number of national and international workshops	4	See Workshops, page 37	2
Number of visits to overseas laboratories	10	See Visits to International Institutions, page 35	5
Examples of relevant Social Science & Humanities research supported by the Centre	10 publications	See Evolutionary Economic Systems Research pages 16-18.	1 publication

P4. End-user links
See the Director's Report, page 2, and Technology Transfer and Commercialisation Activities, page 38, for details of end-user links.

P5. Organisational support
See the Financial Statement, page 47 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 income and expenditure for the year ended 31 December 2005.

INCOME	
ARC centre grant	942 135
Host institutions funds	325 000
Funds carried forward from 2004	834 173
TOTAL INCOME	2 101 308

EXPENDITURE	
Salaries	1 027 520
Equipment	45 887
Travel	131 656
Maintenance/consumables	101 135
Scholarships	190 827
TOTAL EXPENDITURE	1 497 027

Funds carried forward to 2006	604 282

Activity Plan for 2006

Having brought together a world-class group of researchers and established the infrastructure and mechanisms to enable them to interact in a cross-disciplinary manner, the Centre's focus in 2006 will be on demonstrating quality and achieving uptake of the Centre's research.

More specifically, the following new initiatives are planned:

- Develop and deliver a ‘road show’ to raise awareness of the Centre's research outcomes and capabilities, targeting potential users in government, industry and academia.
- Continue to improve Centre researchers' skills in development and validation of models. In particular, train Centre staff and others in efficient exploitation of distributed computing power in modelling and simulation.
- Hold strategic planning workshops with potential end-user organisations to identify new application domains and problems where a complex systems approach is needed.
- Arrange to host an international conference in complex systems.

Ongoing activities include:

- Foster cross-disciplinary research across the Centre by undertaking projects to explore domain-independent notations and modelling techniques.
- 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
Australian Research Council

The ARC Centre for Complex Systems is a partnership of:

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Griffith UNIVERSITY Queensland, Australia

MONASH UNIVERSITY

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

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