

ARC Centre for Complex Systems

annual report 2004

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 a 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 will develop strong engineering infrastructure for the modelling and analysis of network-based systems, including high-performance computing and visualisation facilities, to enable the science to be applied to real-world problems. The result will be methods and tools that can be 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

What do genes have in common with aircraft and farmers irrigating their fields?

The answer is that, when they interact in network with others of their type, the resulting system can have very interesting, and often unexpected properties:

- Biologists have discovered that certain sets of genes work together in networks to regulate cell growth, determining for example what kinds of 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.
- Air traffic control is a complex task, requiring highly skilled, alert controllers. But the system comes close to overload at times. 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 resulting chaos and missed connections. The network is not as robust as travellers would wish.
- Farmers' use of water and fertiliser can have severe effects on conditions downstream if different farmer's usage patterns 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 system-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 evolution of economic systems – which are described in more detail later in the Annual Report.

The ACCS started operation officially in April 2004 with the signing of the inter-institutional agreement between the organisations involved. During 2004 the Centre built up its research staff numbers, hiring the best available researchers to staff its research programs, and developing the research infrastructure on which its programs will be based.

Key joint staff appointments have strengthened our domain expertise in the three core application areas and enabled us to collaborate with other organisations working in these areas. Such appointments enable projects to draw on a wide range of expertise and provide access to case studies on which to hone the Centre's research and validate its results. And perhaps most importantly, they give the ACCS a direct link with (some of) the intended end users of its methods and tools.

For example, Dr Jim Hanan, an expert on modelling of gene regulation of plant growth, holds joint appointments with the Centre of Excellence for Integrated Legume Research and the ARC Centre for Bioinformatics. The collaboration means that the ACCS's theoretical approaches to studying gene regulation of growth can be tested on actual plant genomes in our collaborators' experimental laboratories. Conversely, Jim's models give plant researchers fundamental insights into the plant species and mutations, and help them formulate new hypotheses to test in their labs.

A second noteworthy example is the Air Traffic Control (ATC) Workload project, which is a collaboration with Airservices Australia (the national provider of Australia's air traffic services) and UQ's Key Centre for Human Factors and Applied Cognitive Psychology, funded with the aid of an ARC Linkage grant from mid 2004. The ATC Workload project is using an operator-behaviour modelling technique that was developed by ACCS researchers to model how air traffic controllers perform their tasks and predict the effect of different traffic patterns on controllers' workload. Feedback from the project is enabling us to improve the modelling technique and extend the range of analysis that it possible. It also helps familiarise our researchers with the ATC domain and gives access to data for populating our "free flight" studies.

The projects undertaken in 2004 are outlined, with some of their achievements, in the body of the report. As will be evident, much progress was made in 2004, and strong foundations have been laid for delivering the methods, tools and theory for solving complex systems problems. A series of workshops and seminars were held throughout the year to learn about each other's techniques.

The Centre is well on track to expand Australia's capability in the Complex and Intelligent Systems priority area. By bringing together what were largely separate small groups or individuals working in different areas of complex systems science and engineering, the Centre is providing a focus for complex systems research and enabling collaboration across disciplines and across universities. Witness to this are the number of new collaborations across disciplines where collaborations did not exist before. For example, a 3D visualisation technique that was originally developed for plant growth is being applied to air-traffic control and to cell-level development of biological organisms. In another project, a notation that was originally developed for computer-system requirements specifications is being applied to gene regulation models. And grid technology developed at Monash University has made it feasible to apply new forms of statistical analysis to models developed at UQ, significantly enhancing the insights that arise from the models.

As will be evident from the research project reports below, the Centre is undertaking case studies with great potential for economic, social and environmental benefit for Australia. Our three core application areas (genetic regulation of growth in living organisms, air traffic control, and evolution of economic systems) are directly motivated by these concerns. For example, in the economic systems program, one of our main projects is concerned with sedimentation flowing from rivers into the Great Barrier Reef marine ecosystem, and another with water usage in the Murray Darling Basin – both very topical issues.

The Centre's Advisory Board met late in 2004, chaired by Dr John Finnigan, Director of CSIRO's Complex Systems Science Initiative. As well as senior university management, the Advisory Board includes key representatives of the Centre's target end-user organisations, including Boeing, Airservices Australia, CSIRO and the Defence Science and Technology Organisation (DSTO). We are grateful for their involvement and look forward to strengthening our links with their organisations.

In closing, I would like to thank everyone who helped in putting this Annual Report together, but especially Leanne Brandis, John Hawkins and Virginia Garton of the ACCS and Christine Clarke and Renee Rogers of Studio 55. As you'll see when reading this report, the ARC Centre for Complex Systems has got off to a great start, and we look forward to building on this strong base in 2005.

Peter Lindsay
Director, ACCS
March 2005

Recognition of Centre Personnel

Professor John Quiggin, School of Economics and School of Political Science and International Studies, has been named 2004 Australian Citation Laureate for economics. The award puts Professor Quiggin in the top 0.1 percent of his field globally.

The Australian Agricultural and Resource Economics Society has elected Professor John Quiggin a Distinguished Fellow. His work in agricultural and resource economics focuses on risk management and environmental issues. The award honours continuing general contributions to the profession.

Penelope Sanderson was elected Fellow of the Academy of Social Sciences. In addition, she was awarded the US-based Human Factors and Ergonomics Society Distinguished International Colleague Award for 2004.

Professor John Foster was elected Vice President of the International Joseph Schumpeter Society in June 2004. This is the premier evolutionary economics association and Professor Foster is the first Australian to be elected to this position.

Professor John Foster was also appointed to the ARC College of Experts (Social, Behavioural and Economics Panel) in December 2004. He is the first economist based in Queensland to be appointed to an ARC panel.

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		
Dr Hussein Abbass	Information Technology & Electrical Engineering	University NSW (ADFA)
Prof David Abramson	School of Computer Science & Software Engineering	Monash University
Dr Peter Adams	Mathematics	The University of Queensland
Prof Kevin Burrage	Mathematics	The University of Queensland
Prof Geoff Dromey	Information and 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		
Virginia Garton	Centre Manager	
Leanne Brandis	Education Officer	
John Hawkins	Webmaster	
Collaborators		
Mr 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	Distributed Systems Technology Centre	Monash University
Dr Michael Gagen	Institute for Molecular Bioscience	The University of Queensland

Collaborators	School/Unit	Institution
Dr Marcus Gallagher	Information Technology & Electrical Engineering	The University of Queensland
Mr Rob Grant	Air Traffic Control	Airservices Australia
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	Institute for Molecular Bioscience/Information Technology & Electrical Engineering	The University of Queensland
Dr Jim Hanan	Advanced Computational Modelling Centre	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
Professor Melvin Hinich	Department of Government	The University of Texas, Austin, USA
Dr Peter Kwantes	Simulation & Modelling (SMART)	Defence Research & Development, Canada
Dr Andrew Neal	Key Centre for Human Factors & Applied Cognitive Psychology	The University of Queensland
Dr David Newth	Environmental & Information Sciences	Charles Sturt University
Dr Jason Potts	School of Economics	The University of Queensland
Dr Danny Powell	School of Information and Communication Technology	Griffith University
Prof Mark Ragan	ARC Centre for Bioinformatics	The University of Queensland
Dr Peter Robinson	Information Technology & Electrical Engineering	The University of Queensland
Prof Anne Street	Mathematics	The University of Queensland
Professor Chengzheng Sun	Information & Communication Technology	Griffith University
A/Prof Janet Wiles	Information Technology & Electrical Engineering	The University of Queensland
Research Staff		
Mr Clement Chu	ACCS	Monash University
Mr Simon Connelly	ACCS	The University of Queensland
Mr Nic Geard	ACCS	The University of Queensland
Mr Ken Gray	ACCS	The University of Queensland
Mr Alex Tee Neng Heng	ACCS	Monash University
Dr Barbara Maenhaut	ACCS	The University of Queensland
Mr Stuart McDonald	ACCS	The University of Queensland
Ms Kate Morrison	ACCS	The University of Queensland
Mr James Patterson	ACCS	The University of Queensland
Dr Colin Ramsay	ACCS	The University of Queensland
Mr Tim Rudge	ACCS	The University of Queensland
Mr Cameron Smith	ACCS	Griffith University
Mr Junhua Wang	ACCS	The University of Queensland
Mr James Watson	ACCS	The University of Queensland
Mr Lian Wen	ACCS	Griffith University
Mr Kai Willadsen	ACCS	The University of Queensland
Dr Phillip Wild	ACCS	The University of Queensland
Dr Kirsten Winter	ACCS	The University of Queensland
Ms Nisansala Yatapanage	ACCS	Griffith University
Visiting Researchers		
Mr Martijn Mooij		San Jose State University, California, USA

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 yearly to review the Centre's research and research plans.

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. Current membership is:

Dr John Finnigan (Chair)
Director, Centre for Complex Systems Science, CSIRO, Canberra, ACT.

Professor Paul Bailes
Head of School, School of ITEE, 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 Foster
Head of School, School of Economics, The University of Queensland, St Lucia, Qld

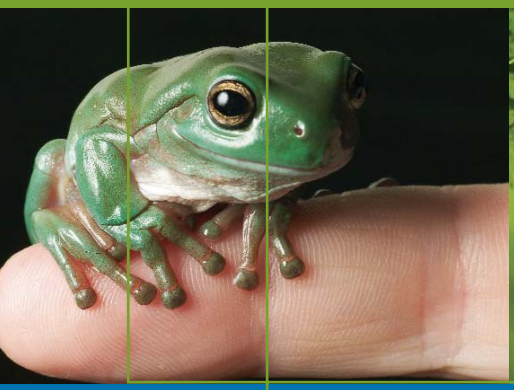
Professor Mick Keniger
Executive Dean, Faculty of Engineering, Physical Sciences and Architecture, The University of Queensland, St Lucia, Qld

Mr Rick Neilson
Chief Engineer, Boeing Australia, Brisbane, Qld

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

The first Advisory Board meeting was held on 14 December 2004. At this meeting, the Board reviewed the Centre's strategic and operational plans.

Front row left to right: Peter Lindsay, John Finnigan, Rick Neilson
Back row left to right: Keith Orkney, Richard Davis, Mick Keniger, Paul Bailes and David Siddle



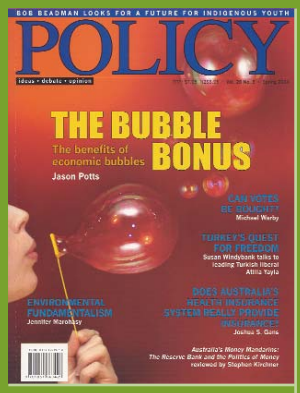
Liberty Bubbles

Policy "publishes articles by some of articles authored by some of today's foremost thinkers on public policy and big ideas. Due to the quality of writing and the diversity of topics, Policy is considered a 'must read' by leading politicians, businessmen and academics...Policy is the quarterly magazine of The Centre for Independent Studies, Australasia's leading independent public policy research institute or 'think-tank'" (www.cis.org.au/policy/about.htm)

The Spring 2004 issue of Policy featured ACCS Collaborator Jason Potts and his Real Bubbles theory as the cover story.

Jason's research was subsequently picked up by Alan Wood, Economics Editor of The Australian: Equity blowouts can attract capital to new technologies.

(The Weekend Australian 11.09.2004, p44)



Research Program

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 will explore 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, drawing inspiration from nature. The focus will be on how complex system behaviours arise from (relatively) simple agent behaviours and connections between agents. 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 will be 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
- Free flight Air Traffic Control

Genetic Regulatory Networks

Program Leader: Janet Wiles
Acting Program Leader for 2004: Jim Hanan

Research in this program tackles 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 (the development of an individual organism from embryo to adult) 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.

Insights from modelling RNA networks

Project Leader: Janet Wiles
Researchers: Kevin Burrage, Jennifer Hallinan, John Mattick

One of the most exciting new ideas for understanding the regulation of gene expression involves the contribution of intronic and other non-protein coding RNAs to regulatory networks within cells. This novel role for intronic RNA is currently making headlines within the molecular biology community but has not yet been modelled computationally. The network of genetic regulatory interactions forms a complex system which is amenable to computational analysis. This project aims to extend current models to incorporate intronic RNA feedback control, complementing parallel studies in vivo, and computationally testing ideas essential to the theoretical understanding of the basis of life.

In 2004, the research team developed a number of mechanisms for fast decomposition of problems. The outcomes of this research were a paper published in LNCS, AI 2004 conference and two other papers under review.

Recent outputs:

Geard, N., Wiles, J., "A gene network model for developing cell lineages", to appear in Alife Journal, 2005.

Hallinan, J., Wiles, J., "Asynchronous dynamics of an artificial genetic regulatory network", Artificial Life IX: Proceedings of the Ninth International Conference on the Simulation and Synthesis of Living Systems, 2004, 399-403.

Hallinan, J., Wiles, J., "Evolving genetic regulatory networks using an artificial genome", Proc. Second Asia-Pacific Bioinformatics Conference (APBC2004), 2004; Conferences in Research and Practice in Information Technology, Vol. 29, 291-296.

Watson, J., Geard, N., Wiles, J., "Toward more biological mutation operators in gene regulation studies", Biosystems, Vol. 76, No. 1-3, 2004, 239-248.

Modelling regulatory networks at cell, tissue and organism level

Project Leader: Jim Hanan
Researchers: Kevin Burrage, Janet Wiles, Tim Rudge

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

Investigations have been undertaken at the three different scales of biological systems in 2004. Extension of the cell layer modelling system, CellModeller, allows improved solution of dynamical systems. A new algorithm for polar cell behaviour has been implemented to further collaborative work with Jim Haselhoff, University of Cambridge, UK. An L-system-based prototyping system capturing intra- and inter-cellular signalling has been developed. This incorporates an interface to the Qu-Prolog logic programming language, which will form the basis for further exploration of Belief-Desire-Intention agent-based systems for modelling genetic regulatory networks. In collaboration with Peter Greshoff of the ARC Centre of Excellence for Integrative Legume Research, a prototype model of autoregulation of nodulation in legumes incorporating root-shoot signalling at whole-plant scale has been developed.

Recent outputs:

Bian, R., Hanan, J., Chiba, N., "Statistical data directed evolution of L-system models for botanical trees", Proceedings of the 4th International Workshop on Functional-Structural Plant Models, 2004, 253-256.

Godin, C., Hanan, J., Kurth, K., Lacointe, A., Takenaka, A., Prusinkiewicz, P., DeJong, T., Beveridge, C., Andrieu, B., Proceedings of the 4th International Workshop on Functional Structural Plant Models, UMR AMAP, 2004.

Renton, M., Hanan, J., "A canonical toolkit for modelling plant function", Proceedings of the 4th International Workshop on Functional-Structural Plant Models, 2004, 226-230.

Renton, M., Hanan, J., Burrage, K., "Using the canonical modelling approach to simplify the simulation of function in functional-structural plant models", to appear in New Phytologist, 2005.

Renton, M., Kaitaniemi, P., Hanan, J., "Functional-structural plant modelling using a combination of architectural analysis, L-systems, and a canonical model of function", to appear in Ecological Modelling, 2005.

Thornby, D., Hanan, J., "A modelling exploration of branch extension, defoliation responses, and carbohydrate physiology in cotton", Proceedings of the 4th International Workshop on Functional-Structural Plant Models, 2004, 319-322.

Modularity in genetic networks

Project Leaders: David Green
Researchers: David Cornforth, David Newth

Biomolecular studies point increasingly to the importance of modularity in the organisation of the genome. Processes such as the maintenance of metabolism are controlled by suites of genes that act as distinct, self-contained units or modules. This project uses simulation models to investigate the role of processes such as feedback, natural selection and genetic translocation in the formation of gene clusters and modules.

In his 1986 book, The Blind Watchmaker", Richard Dawkins used the example of a child trying to type a line from Shakespeare to illustrate evolution. In "Weasel World...", Cornforth and Green extended this idea to open-ended evolution within an artificial universe. The results achieved in 2004 highlight the role of genetic modularity in allowing the emergence of ever more complex forms. In other work this year, David Green's book The Serendipity Machine included an overview of recent genomic research and a simulation study by Whigham and Green investigated the role of genetic tradeoffs in the differentiation of genotypes.

Recent outputs:

Cornforth, D., Green, D., Awburn, J., "Weasel world: A simple artificial environment for investigating open-ended evolution", Proceedings of the 8th Asia Pacific Symposium on Intelligent and Evolutionary Systems, 2004, 40-49.

Whigham, P., Green, D., "A spatially-explicit model of genetic tradeoff", Proceedings of the 7th Asia-Pacific Complex Systems Conference, 2004, 91-100.

eScience and complex systems: Developing intuitive Web interfaces to complex simulation algorithms

Project Leaders: Kevin Burrage
Researchers: Janet Wiles, Roger Sidje, Rachit Srivastava, Stephen Jeffrey, Tianhai Tian

The project is investigating Web technologies that can be used to construct graphical interfaces to complex simulation algorithms. Web standards such as MathML are used to create user-friendly interfaces to grid-computing resources. Simple and intuitive interfaces allow users to run simulations without requiring an expert knowledge of the underlying algorithm. World Wide Web interfaces have been developed for two parallel simulation algorithms: evolutionary rewiring and chemical kinetic simulation in genetic regulation.

In 2004 a prototype interface was constructed and demonstrated using a parallel algorithm for chemical kinetic simulation in genetic regulation. The interface is written in PHP and JavaScript, and is coupled to a MySQL database for storing simulation data, results and parameters. Users access the facility via a login screen and may then proceed to define and execute new simulations or view the results of previous simulations. A suite of administrative tools are provided so that users can actively manage their portfolio of simulations, and users with administrative rights can create, modify and delete user accounts.

Modelling GRNs: From complex systems to systems biology

Project Leaders: Jennifer Hallinan, Janet Wiles
Researcher: Nic Geard

This project consisted of the production of an extensive literature review on modelling genetic regulatory networks, with an emphasis on methodologies from complex systems science. The project produced a technical report, which is available in both PDF and web format, as well as accompanying seminar materials, all of which are available from: ww.itee.uq.edu.au/~nic/_accs-grn/

The completion of this project in 2004 resulted in: (a) the production of a comprehensive review of the literature on the modelling of gene regulatory networks, which was published as a technical report (b) the production of accompanying seminar / tutorial material; (c) the presentation of a seminar to the ACCS community, and; (d) the presentation of a seminar / tutorial as a guest lecture for the 4th year Cognitive Computing course.

Increasing confidence in complex system simulation software

Project Leader: Janet Wiles
Researchers: Jim Hanan, James Watson

This project seeks to investigate software engineering techniques that can be incorporated into the development and use of regulatory models in biology. Through an online survey and interviews with members of the biological modelling community, key characteristics of regulatory model development will be identified, and techniques that can address the unique needs of such modellers will be recommended.

In 2004, data gathered from the regulatory modelling community through an online survey and focused interviews led to the identification of four key characteristics of the simulations used within this community. These were small team sizes, transient systems, rapidly evolving specifications and non-linear behaviour. Software engineering techniques that cater for these characteristics were identified. These techniques fall into three categories of recommendations: the maintenance of static components, tracking of component interactions, and visualisation techniques that aid understanding of emergent interactions.

Recent outputs:

Watson, J., Abbass, H., Lokan, C., Lindsay, P., "Software engineering for artificial life, complex systems, and agent-based distillation", Proceedings of the 7th Asia-Pacific Complex Systems Conference, 2004, 649-661.

Modelling globular cell colony growth

Project Leader: Kevin Burrage
Researcher: David Woolford

This work is motivated by the desire to model the growth pattern of stem cell neural spheres, which start as a single cell and grow to a sphere containing around 16 000 cells. The proposed system models globular cell colony growth in a 3D environment using OpenGL. The end result of the project was a program, executable on Linux based systems, that facilitates user interaction and animates cell colony growth starting with a solitary cell. (Summer Project 2003/04)

Virtual drug discovery

Project Leader: Peter Adams
Researcher: Stephen Long

Modern methods in drug discovery are characterised by a large number of candidate drug molecules, often stored in silico. Traditional methods of screening such molecules are inefficient, so computational approaches need to be developed, to enable high-throughput screening. In this project we continued investigation into a method for rapidly identifying structures on the surface of candidate molecules which may indicate a higher probability of identifying lead molecules. (Summer Project 2003/04)

Case studies in dynamics of complex systems

Project Leader: Janet Wiles
Researcher: Shev Macnamara

This project consisted of a tutorial review of the common mathematical techniques underlying the complex systems analyses of current network-based models of RNA. (Summer Project 2003/04)

A visual framework for online biological sequence analysis

Project Leader: Mikael Boden
Researcher: Mark Wakabayashi

The currently most successful algorithms for biological sequence analysis employ intricate dynamics and offer powerful prediction tools. In this project we strive to tap on this power by making our own algorithms available over the internet where their full benefit can be evaluated. Outcomes - consisting of a visual interface and tools - are realised by using our protein subcellular localisation predictor, the Protein Prowler http://pprowler.imb.uq.edu.au.

In 2004, the Java servlet/JSP framework was investigated and used to build visualisation tools and sequence data support tools. These tools are currently being integrated into the Protein Prowler. The project has, besides providing the research assistant and the group with experience in utilising JSP/Servlet technology for sequence analysis also allowed the research assistant to generate new data sets to be used in further development of new prediction modules. A research paper has been submitted for publication. (Summer Project 2004/05)

Recent outputs:

Boden, M., Hawkins, J., "Prediction of subcellular localisation using sequence-biased recurrent networks", to appear in Bioinformatics, 2005.

Radial basis function neural networks with recursive bias field correction

Project Leader: Geoff McLachlan
Researcher: Jianxiong Wang

In many important application areas such as control, pattern recognition, and signal processing, nonlinear adaptive systems such as radial basis function (RBF) networks are needed to approximate underlying nonlinear mappings through learning from examples. In this project, we consider the extension of RBF networks to model signal inhomogeneities due to acquisition equipments. Such low frequency artifacts (bias field) could be spatial or temporal correlated. By adopting a Markov random field (MRF) model and a recursive bias field correction scheme, the bias field and the true signal intensities can be estimated simultaneously. (Summer Project 2004/05)

General GRN Publications

Hanan, J., Loch, B., McAleer, T., "Processing laser scanner data to extract structural information", Proceedings of the 4th International Workshop on Functional-Structural Plant Models, 2004, 6-8.

Hanan, J., Wang, Y., "Floradig: A configurable program for capturing plant architecture", Proceedings of the 4th International Workshop on Functional-Structural Plant Models, 2004, 407-411.

McLachlan, G., Chang, S., Mar, J., Ambroise, C., "On the simultaneous use of clinical and microarray expression data in the cluster analysis of tissue samples", Proceedings of the second conference on Asia-Pacific bioinformatics, 2004; ACM International Conference Proceeding Series, Vol. 29, 167-171.

Wiles, J., Tonkes, B., "Hyperspace geography: visualizing fitness landscapes beyond 4D", to appear in Alife Journal, 2005.

Wiles, J., Watson, J., Tonkes, B., Deacon, T., "Transient phenomena in learning and evolution: genetic assimilation and genetic redistribution", to appear in Alife Journal, 2005.

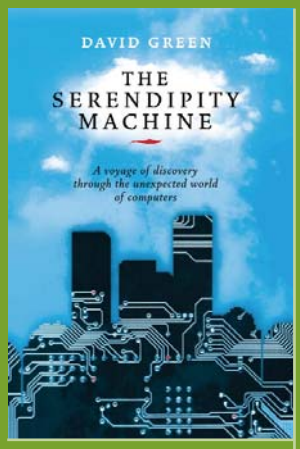
The Serendipity Machine

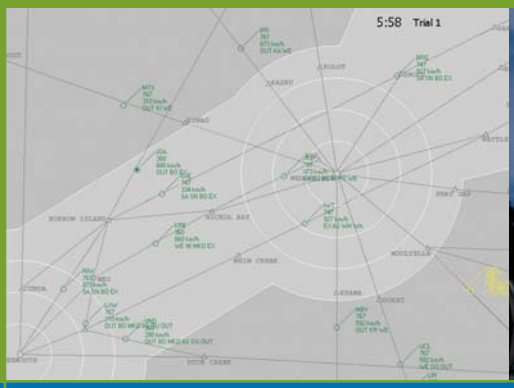
A Voyage of Discovery through the Unexpected World of Computers

David Green

David Green's recently published book, The Serendipity Machine "helps us make sense of recent developments in information technology. It explains how innovations such as data mining and evolutionary computing deal with the complexity by exploiting serendipity." (www.allen-unwin.com.au)

The Book Review (www.memorabletv.com/bookreviews) claims that "what makes the book worthwhile for the average reader is the fact that Green doesn't weigh us down with technical details but lets us get to the meat of the subject." David Green's book serves to simplify the complexity of systems for the general public.





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, whereby 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

ATC workload

Project Leader: Andrew Neal
Researchers: Peter Lindsay, Penelope Sanderson, Graham Halford, Mike Humphreys, Martijn Mooij, Scott Bolland

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 & 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 2004, we undertook intensive air traffic control training to familiarise all members of the project team with the domain, carried out a systematic review of the technical literature to identify the factors previously found to predict workload, and carried out interviews with controllers, using the critical decision method. We also commenced an analysis of air traffic incidents in preparation for the development of the simulation tool. The scope of the study has been expanded due to the increased commitment from our industry partner.

Safety assessment of ATC human-computer interaction

Project Leader: Peter Lindsay
Researchers: Andrew Neal, Junhua Wang, Simon Connelly

This project is developing a new approach to human reliability assessment and evaluation of Human-Computer Interaction (HCI) design options, by application to ATC. 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. The latter are conducting experiments in which human subjects attempt to manage ATC scenarios presented to them on a computer screen. 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 ATC operators and the second is to use this model their behaviour more realistically in the simulations. The work is also a collaboration with Peter Kwantes from Defence Research and Development Canada.

During 2004 collaborators from the Key Centre for Human Factors and Applied Cognitive Psychology conducted a large number of ATC experiments. These experiments explored the effects of aircraft geometry (speed, angle, order), time pressure, and work-load in order to gain a greater understanding of how humans respond when faced with different ATC scenarios. Important factors have been identified and analysis of this large data resource is continuing into 2005.

Sensitivity analysis of ATC operator performance models

Project Leader: Peter Lindsay
Researchers: David Abramson, Andrew Neal, Colin Enticott, Junhua Wang, Simon Connelly

The SafeHCI project developed an approach to Human Reliability Assessment based on modelling of the cognitive processes involved in the operator's task. This project is investigating the application of Nimrod middleware to SafeHCI-like models in order to run thousands of different scenarios in a distributed fashion over the Grid, and to perform statistical analysis on the results, to identify emergent effects. The approach will enable us to identify how sensitive the models are to changes in parameters, such as traffic patterns.

In 2004 we used the Nimrod middleware to evaluate thousands of ATC scenarios. Through repeated experiments, it was discovered that the original SafeHCI approach - of comprehensively exploring a model's state space - was prohibitively slow and yielded incomplete results. Performance improved immensely when we converted it to use a Monte Carlo approach instead, run with a large number of iterations. A set of scenarios was developed in order to evaluate the model systematically, to encompass various traffic patterns, workload levels, and geometry of aircraft interactions. Each of these scenarios was evaluated against various models of interaction, representing different possible designs for a given interface. The settings for these models were also altered systematically to test sensitivity of the results against how the tools behaved. The result was a proof of concept that the approach can be used to investigate the impact of Human Computer Interface design changes on operator performance.

Recent outputs:

Abramson, D., Dongarra, J., Meek, E., Roe, P., Shi, Z., "Simplified grid computing through spreadsheets and NetSolve", Proceedings of the 7th International Conference on High-Performance Computing and Grid in the Asia-Pacific Region, 2004.

Beasley, J., Krishnamoorthy, M., Sharaiha, Y., Abramson, D., "Displacement problem and dynamically scheduling aircraft landings", The Journal of the Operational Research Society, Vol. 55, 2004, 54-64.

Lewis, A., Abramson, D., Peachey, T., "RSCS: A parallel simplex algorithm for the Nimrod/O optimization toolset", Third International Symposium on Parallel and Distributed Computing/Third International Workshop on Algorithms, Models and Tools for Parallel Computing on Heterogeneous Networks (ISPDC/HeteroPar'04), 2004, 71-78.

Agent-based ATC simulation and visualization

Project Leader: Peter Robinson
Researchers: Peter Lindsay, Colin Ramsay, Dale Clutterbuck, Katherine Duczmal, Martijn Mooij, Robert McLeay, Tim Rudge

The aim of this project is to develop a framework for agent-based simulations and visualizations of ATC systems. The logic programming language Qu-Prolog, with built-in support for threads and high-level communication, will be used to implement the required ATC agents. The intention is to take a proposal for a free-flight ATC 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 2004 we produced an initial implementation of a C-level library for supporting simulations, and two prototype visualizations to aid in testing our agent models. Several simple models for controller behaviour were developed as a proof of concept and to check the adequacy of the C-level support library. We also started work on automatic scenario extraction and generation software. The C-level library is used to keep track of aircraft as time evolves and to respond to requests for information such as where aircraft are, how close a pair of aircraft will get, and time to minimum separation. The library also provides an interface to Qu-Prolog, in which we can write intelligent agents. These agents (such as controller agents) can ask for aircraft information from the library to aid in decision making. Katie Duczmal (a summer RA) has developed a more sophisticated controller agent that models conflict detection, conflict resolution and monitoring. Robert McLeay and Dale Clutterbuck (summer RAs) have been porting Qu-Prolog from Unix to Windows in order to make our modelling techniques more accessible to other researchers. (Included Summer Projects 2004/05)

Conceptual framework for FFATC

Project Leader: Peter Lindsay
Researchers: Martijn Mooij

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 2004, a baseline conceptual framework for the modelling and evaluation of operational concepts was developed. This framework is based on the Boeing 2020 ATM Concept and captures the agent environment interaction at a number of levels of aggregation, using a hierarchical control structure. The Agent-based ATC simulation and visualization project is currently working on implementing this framework.

Operator performance modelling in Microsaint

Project Leader: Peter Lindsay
Researcher(s): Sean Ness

This summer student project explored the use of the Microsaint simulation tool for modelling operator behaviours. In particular, it developed guidelines for translating from SafeHCI-like models into Microsaint. (Summer Project 2003/04)

Recent outputs:

Ness, S., "Feasibility study on implementing the SafeHCI model in Microsaint", ACCS Technical Report, 2004.

Evolutionary Economic Systems

Program Leader: John Foster

In the Evolutionary Economic Systems program, we apply complex systems and network theory to 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, will be 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 'history friendly' in complex adaptive system settings.

Nonlinear Econometric Modelling: A Complex Systems Perspective

Project Leaders: John Foster
Researchers: Melvin J 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.

The second year of this project, 2004, involved continued writing and commencement of testing and validation of FORTRAN code to: (a) activate various nonlinear and time reversible test statistics including trispectrum code; and (b) activate code which will allow the simulation of complex nonlinear artificial data series in a controlled setting. This involved performing a large number of replications so that the actual performance of test statistics under the controlled environment can be objectively assessed and compared with their expected theoretical properties. This was one important step used in the testing and validation of the FORTRAN code that we have developed. The other approach we used to validate our programs was to see if the code could reproduce known results. We have constructed and undertaken significant testing using a bridge program that incorporates all test statistics within the one general program. This step was judged to be crucial so that the results from running the program can be strictly controlled

Recent outputs:

Hinich, M., Foster, J., Wild, P., "Structural change in macroeconomic time series: a complex systems perspective", to appear in Journal of Macroeconomics, 2005.

Complex behaviour in financial markets

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

This projects studies financial markets using complexity based tools. There are two sub-projects currently completed: (1) real bubbles theory, which looks at the connection between stock market bubbles and evolutionary economic growth, and (2) 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.

In 2004, Kate Morrison built Java-based models of financial market interaction, Jason Potts' 'Real Bubbles theory' hypothesis was published and Mark Bowden completed an extensive review of models of financial market interaction and made due progress in developing models.

Recent outputs:

Potts, J., "Liberty bubbles", Policy, Vol. 20, No. 3, 2004, 15-21.

Eutrophication of the Great Barrier Reef marine ecosystem

Project Leader: Rodney Beard
Researchers: John Foster, Stuart McDonald

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

In 2004 we explored hydrological models from a complex systems perspective. We then developed a means of integrating cooperative game theoretic models of cost-sharing/benefit-sharing with hydrological models of fractal river networks. We then constructed a prototype model for a linear river network which computed the evolution of value (benefit/cost-share) through time and along the length of the river network. This allows us to determine how to share the costs of sedimentation and pollutants flowing into the Great Barrier Reef Lagoon in a fair way. The work was written up and presented at the World Conference on Natural Resource Modelling in Melbourne, the International Society for Dynamic Games Meeting in Tucson, Arizona and the 49th Conference of the Australian Agricultural and Resource Economics Society in Coffs Harbour.

Recent outputs:

Beard, R., McDonald, S., "Dynamic recontracting of water rights", 11th International Symposium on Dynamic Games and Applications, December 2004.

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.

Summer Research Assistants assisted in the construction and checking of these models, and in initial applications. (Included Summer Project 2004/05)

Recent outputs:

Chambers, R., Quiggin, J., "Technological and financial approaches to risk management in agriculture: an integrated approach", Australian Journal of Agricultural and Resource Economics, Vol. 48, No. 2, 2004, 199-233.

Freebaim, J., Quiggin, J., "Water rights for variable supplies", Working Paper, No. 2M04, Risk & Sustainable Management Group, University of Queensland, June 2004.

Patterson, J., "A model of river flood insurance using stochastic co-operative game theory", Technical Report, 2004.

Quiggin, J., "Conjectures, refutations and discoveries: incorporating new knowledge in models of belief and choice under uncertainty", 22nd Australian Economic Theory Workshop, 2004.

Quiggin, J., "Discounting and policy options for sustainable management of the Murray-Darling River System", Working Paper, No. 1M04, Risk & Sustainable Management Group, University of Queensland, February 2004.

Quiggin, J., Chambers, R., "Drought policy: a graphical analysis", Australian Journal of Agricultural and Resource Economics, Vol. 48, No. 2, 2004, 225-51.

Quiggin, J., Tan, P., "Sustainable management of the Great Artesian Basin: an analysis based on environmental economics and law", Working Paper, No. 3M04, Risk & Sustainable Management Group, University of Queensland, 2004.

Simulation studies of social networks

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

Links between people form networks by which ideas, opinions and attitudes can disseminate throughout societies. This project uses simulation models of social

networks to investigate questions such as the formation of social groups, the role of peer influence in marketing, and the effects of economic and resource issues on social behaviour.

The Virtual Laboratory (http://www.complexity.org.au/vlab/) includes several demonstrations of social networks arising from our recent research, including consensus and cohesion, and the impact of media on social opinion.

Power system transmission network service pricing using probabilistic analysis techniques

Project Leader: Zhao Dong
Researcher: Benson Gene Heng Li

The power transmission system is an essential part of the overall power grid. Despite the deregulation of the power industry over the past decades, the transmission network remains regulated because of its critical role in system security and reliability. However, with the generation side deregulated into a competitive market, there is increasing pressure to improve the efficiency of the transmission network services. Proper transmission pricing in a market situation is the key element in improving the efficiency and reliability of the transmission network services. Traditionally, transmission pricing methods depend on the power flow and system losses due to power transfer throughout the network. These techniques do not consider the social and economic impact. This project explores the social and economic impacts as well as the power flow information in the transmission network using probabilistic methods to form a framework of transmission pricing which can enhance the efficiency and reliability of the transmission network services.

State-of-the-art transmission pricing methods have been studied which include Contract Based Method, Distance Based MW-Mile Method, and Monetary Flow Method. A new probability-based transmission pricing method was developed and tested on bench mark electricity market power grids including an IEEE 30 bus system. Compared with other transmission pricing methods in practice, the new method provides a comprehensive approach for setting the prices for transmission services in an electricity market. (Summer Project 2004/05)

General EES Publications

Dopfer, K., Foster, J., Potts, J., "Micro-meso-macro", Journal of Evolutionary Economics, Vol. 14, No. 3, 2004, 263-280.

Foster, J., "From simplistic to complex systems in economics", to appear in Cambridge Journal of Economics, Vol. 29, 2005.

Foster, J., "Why is economics not a complex systems science?", ACCS Technical Report, 2004.

Foster, J., Holzl, W., Applied Evolutionary Economics and Complex Systems, Edward Elgar, 2004.

Foster, J., Metcalfe, J., Evolution and Economic Complexity, Edward Elgar, 2004.

Metcalfe, J., Foster, J., Ramlogan, R., "Adaptive economic growth", Cambridge Journal of Economics, Vol. 29, 2005.

Quiggin, J., "The incompleteness hypothesis and the precautionary principle", 48th Annual Conference of the Australian Agricultural and Resources Economics Society, 2004.

Quiggin, J., Grant, S., "Conjectures, refutations and discoveries: incorporating new knowledge in models of belief and decision under uncertainty", 11th International Conference on the Foundations and Applications of Utility, Risk and Decision Theory (FUR XI-Paris), 2004.

Infrastructure/General

In addition to the three core research programs described above, the ACCS includes a number of projects that were rolled into the Centre when it began operation in 2004, concerning analysis and design of complex computer-based and network-based systems. A number of cross-program projects were undertaken in 2004 to develop infrastructure for the Centre's research programs.

Building Dependability into Complex Computer-Based Systems

Project Leaders: Geoff Dromey, Ian Hayes, Peter Lindsay

Researchers: David Carrington, Lars Grunske, Danny Powell, Cameron Smith, Lian Wen, Kirsten Winter, Nisansala Yatapanage, Saad Zafar, Xuelin Zheng

The initial focus of this project is on identifying functional and dependability requirements at both system and component levels. The project aims at better, integrated approaches for modelling requirements, developing architecture and design that meets those requirements, and providing their assurance. The approaches need to cope with the scale, change and unpredictability associated with large systems.

The project is investigating the use of the Behavior Tree Notation for modelling large sets of functional requirements that are typical for complex engineered systems. The goal is improved requirements analysis and traceability, which are commonly regarded as key areas for improving system dependability. To provide an unambiguous semantics of the Behavior Tree Notation we proposed formalisations using CSP, and a strongest postcondition semantics. The CSP formalisation of a Behavior Tree reflects its component structure modelling interacting processes, whereas the strongest postcondition semantics allows reasoning about properties of system states. Thus, the two formalisations focus on different issues and provide different possibilities for support with analysis tools. Both semantics provide the basis for tool support to validate that the system meets its intended requirements.

As a modelling notation for requirements and system design, Behavior Trees are targeting the same issues as the UML notation. Our aim is to compare the facilities of both notations.

A set of tools is being developed to support the approach. These include tools to help the user specify the system (editors) as well as tools to check properties of the integrated set of requirements. Problem independent checks can be performed directly on the Behavior Tree using simple tree walking algorithms to extract information that can be checked for consistency and completeness. Behavior Trees can be translated to existing formalisms in order to make use of tools for analysing those formalisms. We are investigating translation to CSP to use the FDR analysis tool. As well as checking properties of the system, we can also check if a refinement relation holds between the specification and implementation of a system.

In addition, we have investigated translation of Behavior Trees to the SAL notation to use its model checking tools. We are investigating the explicit modelling of both the normal behaviour of components as well as likely faulty behaviour, in order to perform analysis of the system response to component faults.

Substantial progress was made on tool development and theory in 2004. Precondition analysis and safety checks were incorporated into the Behavior Tree (BT) editor. The editor was also improved to support a more information-rich BT structure, which allowed generation of CSP models, and a translator from Behavior Trees to CSP was implemented. This enabled the use of the FDR model checking tool to analyse the translated model for a set of functional requirements. With CSP we can check if a refinement relation holds between the specification and implementation of a system. Behavior Tree notation was extended to support mixed branches involving concurrent events on different components.

A component testing software package was developed which creates component interface diagrams from Behavior Trees and uses them to test component implementations writtten in either Java or .NET languages. We explored the use of BTs for Failure Modes and Effects Analysis, by systematically replacing functional requirements by faulty variants; a translation to Action Systems was then developed, so that a model checker could be used to identify which faults could lead to hazards. The Failure Analysis Software package, BTFail, was completed and merged it into the Behavior Tree Editor.

Behavior Trees have been used to model an autonomous shuttle system. In addition, they have been used to model Branching Regulatory Network in peas; this work was done in collaboration with Dr J. Hanan and Dr. C. Beveridge from Centre for Plant Architecture Informatics.

Recent outputs:

Dromey, R.G., "Using Behaviour Trees to model the autonomous shuttle system", 3rd International Workshop on Scenarios and State Machines: Models, Algorithms, and Tools (SCESM04) ICSE Workshop W5S, Edinburgh, 2004.

Hamoy, C., Hemer, D., Lindsay, P., "HazLog: tool support for hazard management", Proc 9th Australian Workshop on Safety Critical Systems and Software, 2004.

Hemer, D., Lindsay, P., "Template-based construction of verified software", to appear in IEE Proc Software, Vol. 152, No. 1, Feb 2005, 2-14.

Smith, C., Winter, K., Hayes, I.J., Dromey, R.G., Lindsay, P., Carrington, D., "An environment for building a system out of its requirements", Proceedings of the 19th IEEE International Conference on Automated Software Engineering, 2004, 398-399.

Winter, K., "Formalising behaviour trees with CSP", Integrated Formal Methods, April 2004; LNCS, Vol. 2999, 148-167.

Change management: Formalizing the impact of requirements change on design

Project Leader: Geoff Dromey
Researcher: Lian Wen

This project involves using Behavior Trees to model requirements change. This requires methods to visualise the changes to Behavior Tree models when those models are edited. Existing algorithms for transformation of Behavior Tree models need to be enhanced to propagate change information and support version control.

In 2004, the mapping from requirements change to design change were formalised. This allows changes in requirements to be automatically reflected in the architecture, the component interfaces, and the component designs.

Recent outputs:

Wen, L., Dromey, R.G., "From requirements change to design change: A formal path", SEFM 2004, IEEE International Conference on Software Engineering and Formal Methods, 2004, 104-113.

Collaborative software engineering based on Behavior Trees

Project Leader: Chengzheng Sun
Researchers: Geoff Dromey, David Chen, Kevin Lin

A Real-time Collaborative Genetic Software Engineering system (CoGSE) allows a group of users to view and edit the same Behavior-Tree representation at the same time from different sites. To develop CoGSE, we have been investigating constraint maintenance in collaborative systems. Constraint maintenance is an important issue in single-user CAD and CASE tools. In collaborative systems, constraint maintenance becomes even more complicated due to the generation and execution of various combinations of concurrent and dependent operations. In CoGSE, constraint maintenance is required to maintain Behavior-Tree structure and to resolve conflicts.

Tasks include multi-user editing of Behavior Trees, visualization methods and collaborative computing methods

In 2004, a strategy was developed for maintaining constraints. It involves duplicating components to maintain tree-structure representation in a collaborative setting. A prototype collaborative Behavior Tree editor has been implemented.

Recent outputs:

Lin, K., Chen, D., Chengzheng S., Dromey, R.G., "Tree structure maintenance in a collaborative genetic software engineering system", Proceedings of the Sixth International Workshop on Collaborative Editing Systems, 2004.

Model translation with MDA and XMI

Project Leaders: Kirsten Winter, Lars Grunske
Researchers: Bangjun Chen

The Behavior Trees notation enables system and software requirements to be modelled graphically. This project aims to build a rule-based translator that transforms Behavior Trees into UML and/or CSP. All three notations (Behavior Trees, UML and CSP) can be represented in XMI. In 2004 an XMI meta-model was developed for Behavior Trees and an export function was implemented for the BTE tool. (Summer Project 2004/05).

Multi-objective optimisation

Project Leader: Hussein Abbass
Researchers: David Green, Lam Bui

When solving many real life problems, one is usually faced with two or more objectives that are in conflict; where a compromise is needed 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 2004, the research team developed two approaches for handling multi-objective optimisation problems. The first approach, published in PPSN 2004, is an interactive method for solving multi-objective optimisation through a reciprocal set of actions between the decision maker and the computer. The second approach, under review, is looking at fast algorithms for handling noise multi-objective optimisation problems.

Recent outputs:

Abbass, H., Green, D., "Performance analysis of evolutionary multi-objective optimization methods in noisy environments", Proceedings of the 8th Asia Pacific Symposium on Intelligent and Evolutionary Systems, 2004, 29-39.

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

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

Complex systems require new and innovative modes of interaction so that computer technologies better support human work practice. This project has focussed 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. The dental surgery represents in many respects 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 interfaces 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 (i) understand how they work (ii) understand the potential of the technologies (iii) experiment with the technologies, engage in a dialogue about how to support their practice in quick surgery studies.

During 2004 Margot Brereton presented this work in a Panel at CHI, the premiere international Human Computer Interaction conference in Vienna. The group also presented several papers at the Participatory design conference in Toronto, which is the leading international forum on Participatory Design. We have conducted ethnographic studies and participatory design explorations with technology probes in dental surgeries. RFID tags, digital pens, speech and gestural devices have been configured for dental practitioner use and tested in participatory discussions. We will bring our evaluations and theoretical framework to a conclusion in 2005.

Recent outputs:

Campbell, B., Brereton, M., "Designing to maintain human agency in context-aware systems", Proceedings of the Participatory Design Conference, 2004, 97-100.

Campbell, B., Brereton, M., "Maintaining human agency in the design of context-aware systems: Design games in a dental surgery", OzCHI 2004, 2004.

Cederman-Haysom, T., Brereton, M., "Bridging technical and HCI research: Creating usable ubiquitous computing", OzCHI 2004, 2004.

Cederman-Haysom, T., Brereton, M., "Designing usable ubiquitous computing", Proceedings of the Participatory Design Conference, 2004, 101-104.

Donovan, J., Brereton, M., "Meaning in movement", Proceedings of the Participatory Design Conference, 2004, 163-166.

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. We will 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.

Building a System Out of its Requirements

Robert Glass writes the Practical Programmer column for the Communications of the Association for Computing Machinery (CACM), one of the most widely read and respected journals in the area of information technology.

Glass's column in the November 2004 issue of CACM featured the work of ACCS Chief Investigator Geoff Dromey. Under the title "Is this a revolutionary idea, or not?" he outlined Dromey's Behavior Tree method for software design.

Glass describes the innovation as being that, using Dromey's approach, a software system can be built "out of its requirements" rather than just "satisfying its requirements". The result is that "complexity can be handled piecewise ... rather than as one big global cognitively daunting task". This in turn means defects in requirements can be discovered earlier, and that new requirements can be more easily integrated into existing designs.

In his column Glass is open minded about the significance and scalability of the approach, but thinks it might truly represent a revolutionary new approach to software design. At the ACCS we're convinced the approach has considerable merit, and are investing significantly in further development of the method and tools to support it. In fact, we think its usefulness extends beyond design of software systems, to modelling and analysis of complex systems more generally.

During the year 2004, Havas presented six invited lectures at overseas conferences and universities. Jointly with Professor M.R. Vaughan-Lee of Oxford University, Havas resolved a long-standing problem about Engel groups, by proving that 4-Engel groups are locally nilpotent. A paper on this topic has been accepted to appear in the International Journal of Algebra and Computation. Three other papers on computational group theory appeared in 2004 in refereed journals.

Recent outputs:

Baumslag, G., Cleary, S., Havas, G., "Experimenting with infinite groups", Experimental Mathematics, Vol. 13, 2004, 495-502.

Campbell, C.M., Havas, G., Ramsay, C., Robertson, E.F., "Nice efficient presentations for all small simple groups and their covers", LMS Journal of Computation and Mathematics, Vol. 7, 2004, 266-283.

Havas, G., Vaughan-Lee, M.R., "4-Engel groups are locally nilpotent" ,to appear in International Journal of Algebra and Computation, 2005.

Emerging applications of advanced computational methods and discrete mathematics

Project Leader: Peter Adams
Researchers: Barbara Maenhaut, Darryn Bryant

Combinatorial designs play 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. Of particular interest is the development of sophisticated computational techniques to aid the construction of combinatorial designs, but broader applications are also under investigation. For example, we have been developing appropriate methodologies to enhance high-throughput screening methods for computational drug discovery. Future developments in combinatorial computing techniques may have broader applications including understanding network-based systems in biology, engineering and economics.

There were 9 journal articles published on the work of this project during 2004. These results predominantly represent developments in knowledge and understanding of combinatorial structures. In addition, we have published work on combinatorial representations and evolutionary algorithms used in computational drug discovery.

Recent outputs:

Adams, P., Bryant, D., Maenhaut, B., "Common multiples of complete graphs and a 4-cycle", Discrete Mathematics, Vol. 275, 2004, 289-297.

Adams, P., Bryant, D., Maenhaut, B., "Cube factorisations of complete graphs", Journal of Combinatorial Designs, Vol. 12, 2004, 381-388.

Adams, P., Bryant, D., Long, S., Smythe, M., Tran, T., "Virtual drug discovery using graph theory", Bulletin Institute Combinatorics and Applications, Vol. 40, 2004, 100-106.

Adams, P., Eggleton, R., MacDougall, J., "Structure of graph posets for orders 4 to 8", Congressus Numerantium, Vol. 166, 2004, 63-81.

Adams, P., Eggleton, R., MacDougall, J., "Degree sequences and poset structure of order 9 graphs", Congressus Numerantium, Vol. 166, 2004, 83-95.

Bryant, D., Maenhaut, B., "Decompositions of complete graphs into triangles and Hamilton cycles", Journal of Combinatorial Designs, Vol. 12, 2004, 221-232.

Bryant, D., Maenhaut, B., Quinn, K., Webb, B., "Existence and embeddings of partial Steiner triple systems of order ten with cubic leaves", Discrete Mathematics, Vol. 284, 2004, 83-95.

Gamble, G., Maenhaut, B., Seberrey, J., Street, A., "Further results on strongbox secured secret sharing", Utilitas Mathematica, Vol. 66, 2004, 187-215.

Maenhaut, B., Wanless, I., "Atomic latin squares of order 11", Journal of Combinatorial Designs, Vol. 12, 2004, 12-34.

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

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

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.

This year, Ken Gray, Colin Ramsay and Anne Penfold Street (together with Karen Harris) have been carrying out a more detailed study of the technique for allocating marking so as to support dynamic assignments of resources, and are studying further the properties of such allocations.

Recent outputs:

Gray, K., Street, A., Harris, K., Ramsay, C., "Existence of complementary pairs of proportionally balanced designs", to appear in Utilitas Mathematica, 2005.

Evolutionary computation using high performance computing facilities at UQ

Project Leader: Janet Wiles
Researcher: Scott Bolland

The aim of this project was to audit the high-performance computing resources available to ACCS members (including supercomputers and network clusters) and to create an online document detailing how to access them and run large-scale simulations in the area of evolutionary computation. The resulting resources can be found at www.itee.uq.edu.au/~complexity

Intro to graph and network theory for complex systems researchers

Project Leader: Janet Wiles
Researcher: Kai Willadsen

This project involves the collation and presentation of ways in which network and graph-theoretic techniques can and have been applied in various areas of complex systems research. The primary focus of this project is to make relevant graph-theoretic approaches easily accessible to complex systems researchers, and to facilitate cross-fertilisation of ideas on the use of graph-theoretic techniques between complex systems disciplines. In order to meet the above goals, this project will produce tutorial material aimed at providing a basic introduction to the applications of graph theory to complex systems research, and reference materials to facilitate further exploration of the subject matter.

In 2004, this project produced a self-guided tutorial, a tutorial presentation and a set of web- accessible reference material. The tutorial and accompanying presentation provide an introduction to the general area of graph theory in complex systems. The reference materials provide more formal definitions of common terms and measurements, as well as providing information about their usage. This material is available from: www.itee.uq.edu.au/~gtheory/

Network security

Project Leaders: Janet Wiles
Researchers: Zhao Dong, Jonathon Hadwen

The aims of this project were to explore the use of complex systems analysis techniques to detect patterns in network traffic. A feasibility study was completed and research training provided (Summer Project 2003/04 funded by AusCERT www.auscert.org.au)

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 2004, we were able to establish a very efficient methodology for decomposing a special type of black-box optimization problems. We then identified a special class of optimization problems in a changing environment, where changes are structural changes. In this class, we extended the methodology to track optima in a changing environment. The proposed method for changing environment can handle types of changes that previous methods in the literature cannot.

AutoGuard: An interactive development environment for relative debugging of programs

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

The aim of this project was to explore three significant research opportunities in relative debugging, a technique David Abramson had pioneered in 1993. First, we wanted to enhance our command line version of our relative debugger, called Guard, so it could be embedded into interactive development environments (IDEs). Second, we wanted to build an interactive browser that could present the data-flow of a program graphically, and in particular show the define and use points for variables. This would then allow a user to create the assertions required in relative debugging more easily. Third, we suggested that it would be possible to completely automate the process of assertion generation and program execution under certain circumstances. Under these conditions, it would be possible to present two programs to the system, and for the divergence between the execution of the two programs then to be deduced automatically.

During 2004, we have produced a relative debugger embedded in three difference IDE's, namely the Microsoft Visual Studio .NET environment, IBM's Eclipse and SUN's One Studio. We constructed a dataflow browser called DUCT, that allows a user to traverse the USE-DEFINE chains of any given variable. This function is performed on demand, and it builds a control flow graph of the program using static analysis techniques. This graph can then be used to locate the most likely definitions of variables given the static analysis. We have developed a number of new techniques that demonstrate significant progress towards our third aim. To do this DUCT has been modified so that it produces the entire DEFINE-USE tree for all variables, and these are used to generate assertions for all data structures. This provides the necessary infrastructure to automatically compare programs that are written in different languages. These assertions are then loaded into Guard using a special API that allows an external program to control the debugger. The system has been tested on a number of small programs and the results show that it is possible to automatically generate assertions under certain circumstances.

General Infrastructure Publications

Abbass, H., "An inexpensive cognitive approach for bi-objective optimization using Bliss points and interaction", The 8th International Conference on Parallel Problem Solving from Nature (PPSN VIII), 2004; LNCS, Vol. 3242, 712-721.

Abbass, H., "Learning regularities and patterns using probabilistic finite state machines", Complexity International, 2005.

Ben-Tovim J.L., Ng, S., Monico, K., McLachlan, G., "Linking gene-expression experiments with survival-time data.", Statistical Modelling. Proceedings of the 19th International Workshop on Statistical Modelling, 2004, 71-75.

Bordes, N., Pailthorpe, B., "High resolution scalable displays: Manufacturing and use", Proceedings. Information Visualisation, 2004, 151-156.

Green, D., The Serendipity Machine, Allen and Unwin, 2004.

Green, D., McKay, B., Namatame, A., Proceedings of the 8th Asia Pacific Symposium on Intelligent and Evolutionary Systems, Monash University, 2004.

Grunske, L., Neumann, R., Process components for quality evaluation and quality improvement", in Second Workshop on Method Engineering for Object-Oriented and Component-Based Development, OOPSLA 2004, 51-62.

Martin, R., Bordes, N., Pailthorpe, B., "Semi-automatic feature delineation in medical images", Proceedings. Information Visualisation, 2004, 127-132.

Meyer, B., "On the convergence behaviour of ant colony search", Proceedings of the 7th Asia-Pacific Complex Systems Conference, 2004, 153-167.

McDonald, S., "The design and maintenance of secure communications networks", 48th Australian Mathematical Society Meeting, 2004.

McDonald, S., Wagner, L., "Uncovering message spoofing in secure networks", 2nd World Congress on Game Theory, 2004.

McLachlan, G., Do, K., Ambroise, C., Analyzing Microarray Gene Expression Data, Wiley, 2004.

McLachlan, G., Khan, M., "On a resampling approach for tests on the number of clusters with mixture model-based clustering of tissue samples", Journal of Multivariate Analysis, Vol. 90, 2004, 90-105.

McLachlan, G., Chang, S., "Mixture modelling for cluster analysis.", Statistical Methods in Medical Research, Vol. 13, 2004, 347-361.

McLachlan, G., Bean, R., "Contribution to the discussion of paper by J. Friedman and J. Meulman.", Journal of the Royal Statistical Society B, Vol. 66, 2004, 846.

Ng, S., McLachlan, G., "Speeding up the EM algorithm for mixture model-based segmentation of magnetic resonance images", Pattern Recognition, Vol. 37, 2004, 1573-1589.

Ng, S., McLachlan, G., "Applying the EM algorithm in training neural networks: misconceptions and a new algorithm for multiclass classification", IEEE Transactions on Neural Networks, Vol. 15, 2004, 738-749.

Ng, S., McLachlan, G., Yau, K., Lee, A., "A survival mixture model adjusting random hospital effects for analysing", Statistics in Medicine, Vol. 23, 2004, 2729-2744.

Ng, S., Krishnan, T., McLachlan, G., "The EM algorithm", Handbook of Computational Statistics, Vol. 1, Springer Verlag2004, 137-168.

Pailthorpe, B., Bordes, N., "Ultra-resolution display systems for computational science and engineering", 2004; Proceedings of SPIE, Vol. 5443.

Sastry, K., Abbass, H., Goldberg, D., "Sub-structural niching in non-stationary environments", AI 2004: Advances in Artificial Intelligence, December 2004; LNCS, Vol. 3339, 873-885.

Seebeck, L., Kaplan, S., "Understanding time in system design", Proceedings of the 8th World Conference on Systemics, Cybernetics and Informatics, 2004.

Wagner, L., McDonald, S., "Finding traitors in secure networks using Byzantine agreements", ACCS Technical Report, 2004.

Yang, A., Abbass, H., Sarker, R., "Landscape dynamics in multi-agent simulation combat systems", AI 2004: Advances in Artificial Intelligence, December 2004; LNCS, Vol. 3339, 39-50.

Participants in STEP 2004 Workshop

Boeing systems engineering teaching laboratory

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 2004 the Centre awarded PhD scholarships to 14 students for PhD study in areas related to the Centre's research program. In some cases scholarship funding was shared with the enrolling schools: ITEE, Economics or Psychology.

As 2004 is the first year research students have been associated with the Centre, the 'recruitments to the Centre' include some students beyond the first year of their degree.

PhD

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

Shahaan Ayyub (Griffith)
"Advanced scheduling services for the Grid"
Advisor: David Abramson

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

Lam Bui (UNSW)
"Distributed multi-objective optimization"
Advisors: Hussein Abbass, Daryl Essam, David Green & Kalanmoy Deb

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

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

Philip Chan (Monash)
"NetFiles: A novel approach to parallel programming
Advisor: David Abramson

Simon Connelly (UQ)
"Situation awareness & usability guidelines for complex engineered systems"
Advisors: Anthony MacDonald & Peter Lindsay

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

Elizabeth Dunn (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

Wojtek Goscinski (Griffith)
"Application deployment in Grid Systems"
Advisor: David Abramson

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

Tim Ho (Griffith)
"Grid program construction in the GriddLeS system"
Advisor: David Abramson

Donny Kurniawan (Griffith)
"Integrated software development environments for the Grid"
Advisor: David Abramson

Andriy Kvyatkovskyy (UQ)
"Learning and modelling techniques in metaheuristic global optimisation algorithms"
Advisors: Marcus Gallagher & Peter Adams

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

Kevin Lin (Griffith)
“Collaborative editing of behaviour trees”
Advisors: David Chen, Chengzhen Sun & Geoff Dromey

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

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

John Mansfield (UQ)
"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

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

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

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

Ella Rohen (UQ)
"Complexity and economic agency"
Advisors: Peter Earl, John Foster & Tom Mandeville

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

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

Nam Tran (Monash)
"Language independent contracts for component software:
Advisor: David Abramson

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

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

Timothy Smith (UQ)
"Evolving signalling systems in models of biological plants"
Advisors: Jim Hanan, Ian Hayes

Honours

Archie Chapman (UQ)
"Emergent conventions and equilibrium selection: Learning dynamics in repeated stag hunt games"
Advisor: Rodney Beard

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

Kate Morrison (UQ)
"A model of asset price dynamics under networked expectations"
Advisors: Peter Earl and Rodney Beard

James Patterson (UQ)
"A model of river flood insurance using stochastic co-operative game theory"
Advisor: Rodney Beard

Jeremy Russell (Monash)
"Improving robustness in distributed systems"
Advisor: David Green

Matthew Poulson (Monash)
"The psychology of technology adoption: how consumer strategies influence social trends"
Advisor: David Green

Summer Student Projects

To encourage students to pursue research careers, the Centre funded the following summer student projects at the University of Queensland node:

2003/2004 Projects

Jonathon Hadwen
"Security of networks"
Supervisors: Janet Wiles, Zhao Dong, Marcus Gallagher, Jennifer Hallinan & Auscert personnel.
(See page 21)

Stephen Long
"Virtual drug discovery"
Supervisors: Peter Adams
(See page 10)

Shev MacNamara
"Case studies characterizing the dynamics of complex systems"
Supervisors: Janet Wiles, Zhao Dong, Mikael Boden & Jennifer Hallinan
(See page 10)

Sean Ness
"Evaluation of Microsaint tool"
Supervisors: Peter Lindsay & Penelope Sanderson
(See page 13)

David Woolford
"Modelling Globular Cell Colony Growth"
Supervisor: Kevin Burrage
(See page 10)

2004/2005 Projects

Archie Chapman
"Murray-Darling Basin modelling project"
Supervisors: John Quiggin & David Adamson
(See page 15)

Bangjun Chen
"Model translation in XML"
Supervisors: Kirsten Winter & Lars Grunske
(See page 18)

Dale Clutterbuck
"Porting Qu-Prolog to Windows"
Supervisors: Peter Robinson & Colin Ramsay
(See page 13)

Katherine Duczmal
"Extending ATM Models"
Supervisors: Peter Robinson & Colin Ramsay
(See page 13)

Benson Li Gene Heng
"Power system transmission network service pricing using probabilistic analysis techniques"
Supervisor: Zhao Dong
(See page 16)

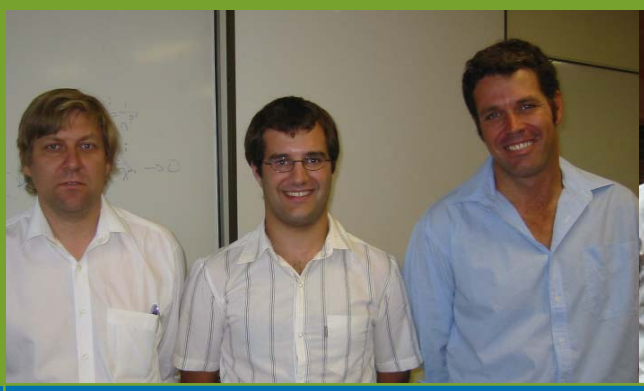
Robert McLeay
"Porting Qu-Prolog to Windows"
Supervisors: Peter Robinson & Colin Ramsay
(See page 13)

James Patterson
"Murray-Darling Basin modelling project"
Supervisors: John Quiggin & David Adamson
(See page 15)

Jianxiong Wang
"Radial Basis Function Neural Networks with Recursive Bias Field Correction"
Supervisor: Geoff McLachlan
(See page 10)

Mark Wakabayashi
"A visual framework for online biological sequence analysis"
Supervisor: Mikael Boden
(See page 10)

Six undergraduate students undertook summer internships at Boeing Australia (2004/2005).



Rodney Beard, David Leslie and Stuart McDonald

Stefano Nolfi, Lam Bui, Hussein Abbass and David Green

Outreach, Links & Service to Community

Keynote and Invited Addresses at International Conferences

Hussein Abbas, Keynote Speaker, 8th Asia Pacific Symposium on Intelligent and Evolutionary Systems, Cairns, Dec 2004, "The Lone Thinker of Céligny in Learning and Agent Systems"

David Abramson, Keynote Speaker, 2nd Workshop on Computational Grids and Application LNCC, Rio de Janeiro, Brazil, Feb 2004, "Tecnologia de programação para a grade"

David Abramson, Keynote Speaker, The International Conference on Computational Sciences, ICCS04, Krakow, Poland, June 2004, "From ICCS'2003 to ICCS'2004. Personal overview of recent advances in computational science: Making the grid work for computation science"

David Abramson, Keynote Speaker, LNCC Meeting on Computational Modelling, Petrópolis, RJ, Brazil, Aug 2004, "Robust science and engineering using parametric computing. Ciêia e engenharia robust usando computacao paramétrica"

John Foster, Keynote Speaker, Economic and Social Research Council (UK) funded NEXUS/CRIC Conference on Organisations, Innovation and Complexity: New Perspectives on the Knowledge Economy, University of Manchester, UK, Sep 2004, "Why is economics not a complex systems science?"

Jim Hanan, Invited speaker, Workshop on Development of Plants: genes, structures and models, Wroclaw, Poland, Sep 2004, "Long distance signalling and regulatory networks"

Geoff McLachlan, Invited Speaker, Interface 2004: Computational Biology and Bioinformatics, Baltimore, USA, May 2004, "Supervised and Unsupervised Learning Methods for Gene-Expression Data"

Geoff McLachlan, Keynote Speaker, Psychometric Society International Meeting, Pacific Grove, California, USA, June 2004, "Mixture Model-Based Clustering of High-Dimensional Data"

Geoff McLachlan, Invited Speaker, 2004 Joint Statistical Meetings, Toronto, Canada, Aug 2004, "Robust Mixture Modelling"

Geoff McLachlan, Keynote Speaker, International Conference on Bioinformatics 2004, Auckland, NZ, Sep 2004, "Classification of Microarray Gene Expression Data"

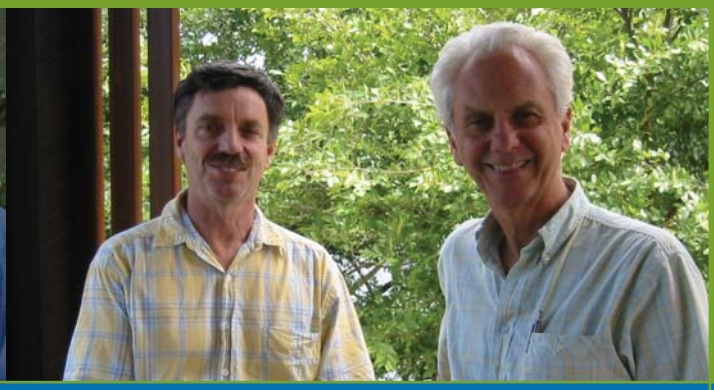
Bernard Pailthorpe, Invited Speaker, 8th Asia Pacific Symposium on Intelligent and Evolutionary Systems, Cairns, Dec 2004, "Complex Structures - in space and time"

Serving the Research Community

Centre participants served on a considerable number of International Conference Program Committees:

Hussein Abbass was a member of the Program Committee for the 8th International Conference on Parallel Problem Solving from Nature (PPSN VIII), IEEE Conference on Cybernetics and Intelligent Systems (CIS'04), 17th Australian Joint Conference on Artificial Intelligence (AI2004), the Fifth Asia-Pacific Industrial Engineering and Management Systems Conference & The Seventh Asia-Pacific Division Meeting of the International Foundation of Production Research, the Ninth International Conference on the Simulation and Synthesis of Living Systems (ALIFE9), the Genetic and Evolutionary Computation Conference (GECCO-2004) [Artificial Life track], the Congress on Evolutionary Computation, 8th International Conference on Knowledge-Based Intelligent Information and Engineering Systems (KES2004), and the 27th Australasian Computer Science Conference (ACSC2004).

Rodney Beard, Peter Campbell, Peter Lindsay



Peter Robinson and Keith Clark

David Abramson was a member of the Program Committee for CCGrid 2004 (Vice Chair), High Performance Computing Symposium 2004, First International Workshop on Programming Paradigms for Grids and Metacomputing Systems PPGaMS'04, HPC Asia 2004, IEEE Cluster 2004, Grid 2004, the 5th IEEE/ACM International Workshop on Grid Computing, 11th European PVMMPI Users' Group Meeting, Second International Symposium on Parallel and Distributed Processing and Applications (ISPA-2004).

Margot Brereton was a Doctoral Colloquium responder at OZCHI: Annual conference of the Computer-Human Interaction Special Interest Group of the Human Factors and Ergonomics Society of Australia..

Geoff Dromey was a member of the steering committee for SEFM 2004, Second IEEE International Conference on Software Engineering And Formal Methods

David Green was Co-Chair of the Organising Committee for 8th Asia Pacific Symposium on Intelligent and Evolutionary Systems.

Jim Hanan was a member of the Scientific Committee, 4TH International Workshop on Functional-Structural Plant Models.

Ian Hayes was a member of Program Committee for Mathematics of Program Construction (MPC 2004) and a member of the editorial board of the BCS/Springer journal, Formal Aspects of Computing. Also worthy of mention is that Ian was invited to participate in the IFIP 2.3 meetings, Prato, Italy

Peter Lindsay was a member of the Program Committee for the International Conference on Engineering of Complex Computer-based Systems (ICECCS) 2004 and the International Conference on Formal Engineering Methods (ICFEM) 2004. He was also on the editorial board of the Science of Computer Programming journal, and co-editor of a special formal methods issue of International Journal on Software Tools for Technology Transfer (STTT) published by Springer.

Geoff McLachlan was a member of the Scientific Committee of the fifth international conference for the Critical Assessment of Microarray Data Analysis (CAMDA 2004), and organiser of invited paper session on Mixture Modelling at the XXIInd Meeting of the International Biometric Society

Bernard Pailthorpe was a member of the Program Committee and Chair of a panel session at 7th International Conference on High Performance Computing and Grid in Asia Pacific Region.

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.

Professor Peter Allen
Professor of Evolutionary Complex Systems and Head of the Complex Systems Management Centre, Cranfield University, UK
December

Professor Peter Campbell
Argonne National Laboratory, Illinois, USA
November

Dr Tan Kay Chen
Dept. of Electrical and Computer Engineering, National University of Singapore, Singapore
July

Professor Keith Clark
Dept. of Computing, Imperial College, London, UK
March, November

Professor Roger Eggleton
Dept. of Mathematics, Illinois State University, USA
July

Dr Elizabeth Garnsey
Dept. of Engineering, Cambridge University, UK
December

Professor Melvin Hinich
Dept. of Government, University of Texas, Austin, USA
August

Professor Dean Hoffman
Raybould Fellow, Maths Dept, Auburn Uni, Alabama USA
July

Dr John Kapeleris and Dr Rowan Gilmore
Australian Institute of Commerce
December

Dr Karl Lermer
Zurich, Switzerland
July-August

Dr David Leslie
School of Economics, The University of New South Wales
November

Dr Alan McKane
Theory Group, Department of Physics, University of Manchester, UK
August

Professor Maureen McKelvey
Dept. of Industrial Dynamics, Chalmers University of Technology, Sweden
April

Professor Gregory J. McRae
Bayer Professor of Chemical Engineering, MIT, USA
May, November

Professor J. Stanley Metcalfe
Policy Research in Engineering, Science and Technology, University of Manchester, UK
April

Mr Martijn Mooij
Human Automation Integration Laboratory, San Jose State University, California, USA
January - December

Professor Stefano Nolfi
Institute of Cognitive Sciences and Technologies, National Research Council, Italy
December

Dr Alla Seleznyova
HortResearch, Palmerston North Research Centre, New Zealand
December

Professor Ah Chung Tsoi
ARC Executive Director, Mathematics, Information and Communications Sciences
March

Assoc. Prof. Anne van den Nouweland
Dept. of Economics, University of Oregon, USA
July

Dr Peter Whigham
Dept. of Information Science, Otago University, NZ
February-March

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, three are of particular note because of the high standing of the laboratories visited in the complex systems field: Peter Lindsay's Boeing Welliver Fellowship, Geoff McLachlan's visit to SAMSI, and Janet Wiles' visit to the Salk Institute at UCSD.

David Abramson was invited to present a seminar on "Software Engineering for the Computational Grid" at the Universities of Oxford, Cambridge, Southampton, and Cardiff, UK.

John Foster visited the University of Bocconi, Milan, Italy

Jim Hanan was invited to visit three institutions in France: INRIA Sophia-Antipolis Research Unit (seminar presentation: "Modelling Biological Systems"), CIRAD, Montpellier, and INRA-AGRO.M, Montpellier.

George Havas visited Pingree Park, Colorado State University, USA, the Rensselaerville Institute Conference Center, Rensselaerville, NY, USA, City College of the City University of New York, NY, USA (Colloqium presentation: How hard is computing with matrices?), Centre for Interdisciplinary Research in Computational Algebra, University of St Andrews, St Andrews, Scotland (Colloquium presentation: 4-Engel groups are locally nilpotent), University of Auckland, Auckland, NZ (Seminar presentation: On Proofs In Finitely Presented Groups), and York University, Toronto, Canada (Seminar presentation: Breadth-first search and the Andrews-Curtis conjecture).

Peter Lindsay
Peter Lindsay was awarded a Boeing Welliver Fellowship and spent 2 months observing systems engineering processes in different divisions of The Boeing Company including Shuttle Return to Flight, Boeing ATM and AEW&CS.

While in California, Peter was also invited to visit Kevin Corker's lab at San Jose State University, NASA Ames Research Centre, Moffett Field, and SRI Palo Alto. Peter also visited the Centre for Air Transportation Research, George Mason University.

Stuart McDonald was invited to Keele University, UK
Seminar presentation: "The Design and Maintenance of Secure Communication Networks"

Geoff McLachlan was invited to visit the Statistical and Applied Mathematical Sciences Institute (SAMSI), Research Triangle Park, North Carolina, USA (Invited Talk: "Model-Based Clustering of Microarray Gene-Expression Data") and also the Department of Statistics and Operations Research, University of North Carolina, Chapel Hill , USA (Invited Talk: "Discriminant Analysis of Microarray Gene-Expression Data").

Kate Morrison and Jason Potts visited the Santa Fe Institute, USA

Bernard Pailthorpe visted the San Diego Supercomputer Center, University of California, San Diego and the JVC R&D Laboratory, Hurihama, Japan

Janet Wiles spent almost 8 months at the Salk Institute for Biological Studies at the University of California, San Diego. While in the USA, she was also invited to visit the Santa Fe Institute, and the Houston Worm Lab, Houston University

Ken Gray visited the Open University at Milton Keynes, UK. He attended the Open University Winter Meeting on Combinatorics, and was invited to present a talk on "Proportionally Balanced Designs".

Seminars

Seminars presented by Centre visitors in 2004 included:

26 March

Keith Clark - Imperial College, UK
"Go! for multi-agent simulation"

8 June

John Finnigan - CSIRO Centre for Complex System Science, Canberra
"Earth System Science in the Early Anthropocene"

9, 13, 16 July

Dean Hoffman - Auburn University, USA
"A problem of mixed differences"
"The Grundy colouring number of the n-cube"
"An f-factor theorem for signed graphs"

26 July

Anne van den Nouweland - University of Oregon, USA
"Network formation models with costs for establishing links"

19 August

Alan McKane - University of Manchester, UK
"Evolving Complex Food Webs"

12 November

David Leslie - The University of New South Wales
"Reinforcement learning in games using value-based learners"

23 November

Peter Campbell - Argonne National Laboratory, USA
"Application of the Dynamic Information Architecture System (DIAS) to the simulation of several complex adaptive systems using agents."

25 November

Jonathan Roberts & Philip Valencia - CSIRO ICT Robotics
"Robotics and Complex Systems"

1 December

Peter Allen - Cranfield University, UK
"Modelling dynamic interactions between complex economic, social and ecological systems"

Professional Courses

Two RHD Centre participants benefited from participation in professional courses:

John Hawkins participated in the NESCI Summer School in Cambridge, Mass, USA. June 28-July 9. John attended the summer school's intensive courses on complex systems concepts including Complex, Physical, Biological and Social Systems, and Modelling, Networks and Evolution.

Stuart McDonald attended the GERAD Summer School on Differential Games and Applications, 14-18 June at HEC Montreal, Montreal Canada.

Workshops

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

STEP 2004 Science, Technology and Economic Progress Workshop
Hosted by the University of Queensland, Faculty of Business, Economics and Law, and the ACCS.
29th November – 3rd December

About 25 PhD students from a diversity of Australian universities, disciplines and stages of progress with their PhD research projects participated in the workshop.

STEP2004 had as its theme - "Embracing Complexity". The purpose of this theme was to have students reflect on a number of perspectives on complexity and complex systems.

The theme was woven into the workshop by presentations by a number of international and local guest speakers; by requesting students to consider complexity in relation to their individual research projects; and by undertaking student team projects to explore complexity issues in one of a number of Australian contexts.

Big Complexity Day II
1st October

A workshop for research-in-progress on evolutionary economics and complexity.

Free Flight ATC Workshops
Two workshops presented by ACCS Researchers were held in February and October. Civil Aviation Safety Authority, Airservices Australia, and Qantas personnel participated.

Genetic Regulatory Network Workshop
Researchers working in the Centre's Genetic Regulatory Networks program presented a GRN workshop in August. It was targeted at computational modellers working on ACCS Genetic Regulatory Network projects. CSIRO personnel were in attend ance.

Government, Industry and Business Briefings

The Centre feeds ideas, discoveries and techniques to government and industry to improve their current practices and seed innovation.

Hussein Abbass was invited to brief the Department of Veteran Affairs in Canberra in February on "Data Mining"

John Foster was invited to brief personnel from the Department of Industry, Tourism and Resources Innovation Policy Forum in Canberra in April on "Why should governments support innovation? The economic rationale."

Bernard Pailthorpe, at the Chair's invitation, briefed the Australian Research Infrastructure Information Council in February.

Janet Wiles was an invited participant in the US National Cancer Institute Think Tank on Cancer Modelling in September 2004.

Industry Visitors

Gerard Champion, Airservices Australia
Walter Dollman, Regulatory & Industry Affairs, Qantas Airways
Joel Gray, Industrial Participation Programs, The Boeing Company
Vanessa Jacobsen, AEW&C Program, Department of Defence
Bill Lyons, Phantom Works, The Boeing Company
Ken McLean, Air Traffic Management Planning, Airservices Australia
Keith Orkney, Airservices Australia
Warren Parker, AgResearch Ltd, New Zealand
James Ross, Telelogic
Jorge Woods, Airways and Airspace Standards Branch, Civil Aviation Safety Authority

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.edu.au) and mailing list to assist in its task of raising public awareness of complex systems.

The Centre has supported the development of Monash University's Artificial Life Virtual Lab (www.complexity.org.au/vlab/). VLAB presents simulations to help people understand how complex organisation and behaviour emerges in living systems. VLAB will prove to be a valuable tool for raising awareness of complex systems.

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

John Foster & Jason Potts
"The other side of economic evolution"
International Workshop on Innovation Research & Policy, Sponsored by Chalmers University, Sweden and held at the UQ Business School, March 2004

George Havas
"Algorithmic problems dating back to Euclid and Euler"
International Centre of Excellence for Education in Mathematics, and Australian Mathematics Sciences Institute Winter School in Mathematics and Computational Biology, University of Queensland, July 2004.

Geoff McLachlan
"Multivariate Techniques in the Statistical Analysis of Gene-Expression Data"
New Zealand Summer School of Bioinformatics, Auckland, NZ, February 2004.

Geoff McLachlan
"The Classification of Microarray Data"
BioInfoSummer 2004, Canberra, December 2004.

Undergraduate & Postgraduate Courses

Introduction to Complex Systems
(UQ COMP4001/7001)
Presented by Jennifer Hallinan
Level: Undergraduate/Postgraduate

Complex Adaptive Systems (Short course)
(UNSW/ADFA)
Presenter: Dr. Hussein A. Abbass
Level: Postgraduate research

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

Advanced Algorithms & Data Structures
(UQ COMP4500/7500)
Presenter: George Havas
Level: Undergraduate/Postgraduate coursework

Systems Engineering (UQ ENGG4000/7000)
Presented by Peter Lindsay
Level: Undergraduate/Postgraduate coursework

Mathematical Biology (UQ MATH3104)
Included material on modelling genetic regulatory networks
Presented by Kevin Burrage and Jim Hanan
Level: Undergraduate

Modelling and Visualisation (UQ COMP3202)
Included a section on plant modelling
Presented by: Jim Hanan
Level: Undergraduate

Scientific Computing: Advanced Techniques and Applications (UQ MATH3201)
Co-ordinator: Bernard Pailthorpe
Level: Undergraduate

System Safety Engineering (UQ ENGG7020)
Included dependability analysis for complex engineered systems
Presented by Peter Lindsay
Level: Postgraduate coursework, also offered as a public course to industry

Publications 2004

Books

Foster, J., Holzl, W., Applied Evolutionary Economics and Complex Systems, Edward Elgar, 2004.

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McLachlan, G., Do, K., Ambroise, C., Analyzing Microarray Gene Expression Data, Wiley, 2004.

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Foster, J., Holzl, W., "Introduction and overview", in Foster, J. and Holzl (editors), Applied Evolutionary Economics and Complex Systems, Edward Elgar, 2004, 1-15.

Kirley, M., Abbass, H., McKay, R., "Diversity mechanisms in Pitt-style evolutionary classifier systems", in Triantaphyllou, E. and Felici, G. (editors), Data mining and discovery approaches based on rule induction techniques, Kluwer Academic Publishers, 2004.

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Teo, J., Abbass, H., "Evolutionary multi-objective robotics: evolving physically simulated quadruped using the Pareto-frontier differential evolution algorithm", in Tan, K.C. et. al. (editors), Recent Advances in Simulated Evolution and Learning, World Scientific Publishers, 2004.

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Adams, P., Eggleton, R., MacDougall, J., "Structure of graph posets for orders 4 to 8", Congressus Numerantium, Vol. 166, 2004, 63-81.

Adams, P., Eggleton, R., MacDougall, J., "Degree sequences and poset structure of order 9 graphs", Congressus Numerantium, Vol. 166, 2004, 83-95.

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Baumslag, G., Cleary, S., Havas, G., "Experimenting with infinite groups", Experimental Mathematics, Vol. 13, 2004, 495-502.

Beasley, J., Krishnamoorthy, M., Sharaiha, Y., Abramson, D., "Displacement problem and dynamically scheduling aircraft landings", The Journal of the Operational Research Society, Vol. 55, 2004, 54-64.

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Bryant, D., Maenhaut, B., Quinn, K., Webb, B., "Existence and embeddings of partial Steiner triple systems of order ten with cubic leaves", Discrete Mathematics, Vol. 284, 2004, 83-95.

Campbell, C.M., Havas, G., Ramsay, C., Robertson, E.F., "Nice efficient presentations for all small simple groups and their covers", LMS Journal of Computation and Mathematics, Vol. 7, 2004, 266-283.

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Performance Indicators Report

P1. Research findings Description	2004 Actual	Details	2004 Target
Number of publications	109	See Publications, page 31.	10
Invitations to address and participate in international conferences	11	See Keynote & Invited Addresses, page 26.	5-6
Invitations to visit leading international laboratories	3	See Visits to International Centres, page 28.	3
Number and nature of commentaries about the Centre's achievements	3	These three publications are highlighted on pages 7, 11 and 19.	3

P2. Research training and professional education Description	2004 Actual	Details	2004 Target
Number of postgraduates recruited	37	See Research Students, page 23.	14 over the life of the Centre
Number of postgraduate completions	0	It is expected that the first postgraduate degrees from the Centre will be awarded in 2005.	14 over the life of the Centre
Number of honours students	6	See Research Students, page 23.	30 over the life of the Centre
Number of professional courses	0	A Winter School is planned for July 2005.	1
Participation in professional courses	2	See Professional Courses, page 29.	2
Number and level of undergraduate and high school courses in the complex systems area	2	See Undergraduate & Postgraduate courses, page 30.	

P3. International, national and regional links and networks Description	2004 Actual	Details	2004 Target
Number of international visitors	18	See Visitors, page 27.	4
Number of national and international workshops	4	See Workshops, page 29.	2
Number of visits to overseas laboratories	12	See Visits, page 28.	5
Examples of relevant Social Science & Humanities research supported by the Centre	2	See the Director's Report, page 2.	1 publication

P4. End-user links
See the Director's Report, page 2, for details of end-user links.

P5. Organisational support
See the Financial Statement, page 36, 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 2004

INCOME	
ARC Centre Grant	922,757
Host Institutions funds	325,000
Funds carried forward from previous year	575,000
TOTAL INCOME	**1,822,757**

EXPENDITURE	
Salaries	595,895
Equipment	132,784
Travel	56,246
Maintenance/Consumables	82,121
Scholarships	121,538
TOTAL EXPENDITURE	**988,583**

Funds carried forward to 2005	**834,173**

Activity Plan for 2005

The Centre's goals for 2005 are to build on the strong foundations that were established in 2004.

More specifically, the following initiatives are planned:

- Appoint postdoctoral research fellows in each of the three core application areas
- Hold a Winter School for honours students and early-program PhD students from around Australia, to encourage them to take up research careers in complex systems science and engineering
- Appoint a Tools Coordinator to coordinate the use and development of software tools across the Centre
- Institute a weekly seminar series by videoconference with the non-Brisbane nodes of the Centre
- Continue to foster cross-disciplinary research across the Centre by undertaking projects to explore domain-independent notations and modelling techniques
- Work with identified end-user organisations to develop collaborative projects, to trial and evaluate the Centre's research
- Train Centre staff in technology transfer and commercialisation, and identify opportunities for 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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