Centre for Complex Systems

The Centre for Complex Systems (CCS) plays a major role in drawing together the disparate complex systems science components of the College of Science at the Australian National University.

The aims of the Centre are:

- to provide a framework for bringing researchers together and stimulating interaction and synergy between them;
- to promote innovative, interdisciplinary research through seminars and topical workshops;
- to foster graduate education and research through summer schools.

The CCS was formed from the Centre for Theoretical Physics in late 2001, and continues its outreach activities while broadening its scope to the application of the powerful tools of modern theoretical physics and applied mathematics to problems ranging from the physical to the biological sciences, and even beyond to complex systems with a social dimension. A key feature in these systems is a large number of individual units interacting collectively and the emphasis is on the emergent behaviour beyond the elementary laws of interaction. The unifying theoretical and mathematical tools include statistical mechanics, many body theory and nonlinear dynamics, as well as numerical simulation.

The CCS initiated and hosts the ARC *Complex Open Systems Research Network* (COSNet) which was funded for five years from late 2004. The Centre now administers the Australian National University's central contribution to COSNet. Administrative support for the Centre, formerly provided by the Department of Theoretical Physics, is now also provided through COSNet.

Summer Schools

The 19th Canberra International Physics Summer School "Turbulence and Coherent Structures in Fluids, Plasma and Granular Flows" was held from16 - 20 January 2006. Convenor: Dr Michael Shats, Plasma Research Laboratory. The 20th Canberra International Physics Summer School "Granular Matter" was held from 4 - 8 December 2006. Convenor: Dr Tomaso Aste, Department of Applied Mathematics.

CCS Seminars

Professor Claudio Tebaldi, Politecnico di Torino, Italy
Low-dimensional Analysis by Proper Orthogonal Decomposition

Dr Georg Gottwald, University of Sydney
Slow Dynamics via Degenerate Variational Asymptotics

Dr Emilia R Solano, Laboratorio Nacional de Fusion, CIEMAT, Spain

Structural Stability of Equilibrium and Confinement Transitions in Plasmas

Dr Jay Larson, ANU Supercomputer Facility
Wanted: A Theory of Model Coupling

Dr Geoff Bicknell, Research School of Astronomy and Astrophysics
Black Holes, Jets and their Interaction with the Interstellar Medium

Professor Sandra Chapman, University of Warwick, UK
Complex Systems Approaches to Space and Fusion Confinement Plasmas

Dr Nicholas Watkins, British Antarctic Survey, UK
Modelling the Noah and Joseph Effects in Space Plasma Time Series Using Fractional Levy Motion

Professor Peter Robinson, University of Sydney
Quantitative Modelling of Multiscale Brain Activity

Dr Robert Niven, ADFA, University of New South Wales
Exact Statistical Mechanics and Quantum Mechanics

Dr Andrew Sullivan, Department of Theoretical Physics and CSIRO
A Brief Illustrated History of Bushfire Research and Where to from Here?

Dr Daniela Grasso, Politecnico di Torino, Italy
Magnetic Reconnection

Dr Rajaraman Ganesh, Institute for Plasma Research, Bhat, Gandhinagar, India
Global Kinetic Ballooning Modes

Staff

Coordinator

Professor Murray T. Batchelor, FAIP, FAustMS, FInstP

The Cooperative Research Centre for Functional Communication Surfaces

The Cooperative Research Centre for Functional Communication Surfaces (CRC SmartPrint) began operations on 1 July 2001, following funding from the Australian Government. Principal academic partners are located in Chemical Engineering, Monash University, Applied Mathematics, RSPhysSE, and the CSIRO Division of Forestry and Forest Products (Clayton, Victoria). Current industrial partners include SCA, Norske Skog Paper Mills (Australia) Ltd, Note Printing Australia Ltd and PaperlinX Pty Ltd (Australian Paper).

The brief of the CRC SmartPrint is to advance Australia's printing and packaging technology and expertise, with particular emphasis on advanced papers and polymeric materials (including banknotes), smart packaging indicators, improved recycling of paper and enhancement of cardboard packaging. Though these themes may sound commonplace, the vastness of the corresponding markets dictate that even incremental improvements in processes and products are of major benefit to producers, consumers and, most pertinently, the environment. Systematic improvements within these areas requires greater insight into the fundamental mechanisms occurring, chiefly within the domain of colloid and interfacial science, and the ability once having elucidated the governing structures and interactions, to propose industrial implementations. The primary role of the Applied Mathematics node has been to focus on the fundamental research aspects of the problems at hand, serving as upstream input to the industrial partners and other academic partners. As an illustration, the Department contributes accurate microstructural data of materials such as fibre networks (paper and paperboard) and granular material (model pigment coatings), as well as measurement and modeling of fluid flow into and through these, as input to improving ink receptivity of paper during printing or fluid barrier properties of packaging. Notwithstanding this focus on fundamentals, Applied Mathematics has also become increasingly active within strategic application projects, including both solution of existing problems posed by industry and open innovation to suggest future products. In particular, during the fifth complete year of the Centre, the ANU program continued work on four fundamentally based projects and a fifth strategic project.

The work is an interdisciplinary blend of experimental, theoretical and computational, in keeping with the philosophy of Applied Mathematics. Projects are making extensive use of the new X-ray micro-CT facility, Atomic Force Microscope, Ellipsometer and Quartz Crystal Microbalance, along with novel instrumentation to measure, e.g. film stress evolution during drying and local variations in topography and reflectivity of the dried films. Some highlights of research from the four fundamental projects include:

- development of three-dimensional image enhancement techniques to remove blurring and distinguish material boundaries in porous and composite media;
- image skeletonisation and generation of network equivalents of paper and coatings;

- continued development of software to model or simulate structural, mechanical and transport properties directly from 3D digitised images of complex materials;
- development of a new dynamic method to monitor fluid penetration into paper sheets using X-ray radiography (time resolved digital radiography), including software to analyse saturation profiles and density correlations;
- development of a dynamic model for spontaneous wetting fluid penetration (imbibition), based on a physically realistic and mathematically rigorous treatment of the complex dynamics of wetting front displacements;
- elucidation of fundamental interactions between key papermaking components, in particular cellulose, lignin and polymers added to enhance bond strength, through direct measurement on model films of these components.

Significantly, the year 2006 has seen the successful graduation of two PhD students within the ANU program, namely Drew Evans and Viet Nguyen (UNSW). Entering into the sixth year of the CRC, the onus is currently shifting towards the strategic projects and those with high commercialisation potential.

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