Global Partnerships, Local ICT Solutions

Over the last decade, UCT's researchers have contributed to the rapid evolution of processors, high performance computing and information systems, which is pushing the boundaries of research paradigms.

High Performance Computing at UCT

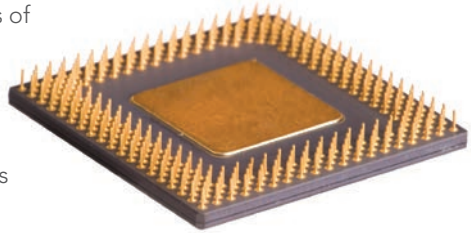
From supercomputers to mobile technology, the field of High Performace Computing has opened up a host of new possibilities for researchers, with some having played a key role in the development of industry-standard computing languages and software, and others contributing to emerging technologies in taking healthcare to the next level.

High Performance Computing (HPC) is an enabling technology that seeks to improve the performance of computing applications. The interdisciplinary nature of HPC research impacts on a wide range of applications; for example, a carbohydrate simulation might be reduced from years to months, or digital 3D content produced in real time rather than requiring minutes to generate. At UCT there are number of researchers working on HPC, and a major theme of their research is improving the speed of discipline-specific computational solutions.

The Centre for Research in Computational and Applied Mechanics (CERECAM) has been in existence in various forms since 1981. During this period, it has grown into a flagship research centre comprising 13 full-time academic staff members from six departments spanning three faculties, and with networks across the world. Consequently, inter-disciplinary thinking and activity have become firmly embedded in the objectives of the centre.

The principal objective of CERECAM is to provide a coherent focus and point of interaction at UCT for research and applications in the general area of non-linear mechanics by promoting and supporting fundamental research, applied research, and industrial interaction in the mechanics of structures, solids, and fluids. The application of research that is facilitated through CERECAM is both broad and varied: this ranges from the development and utilisation of HPC tools to study the biomechanics of myocardial infarction (heart attacks) and the production of biodegradable stents, to the computational aspects of flotation, leaching, precipitation and crystallisation, which are important to the chemical process industry, the mining industry and the environmental field.

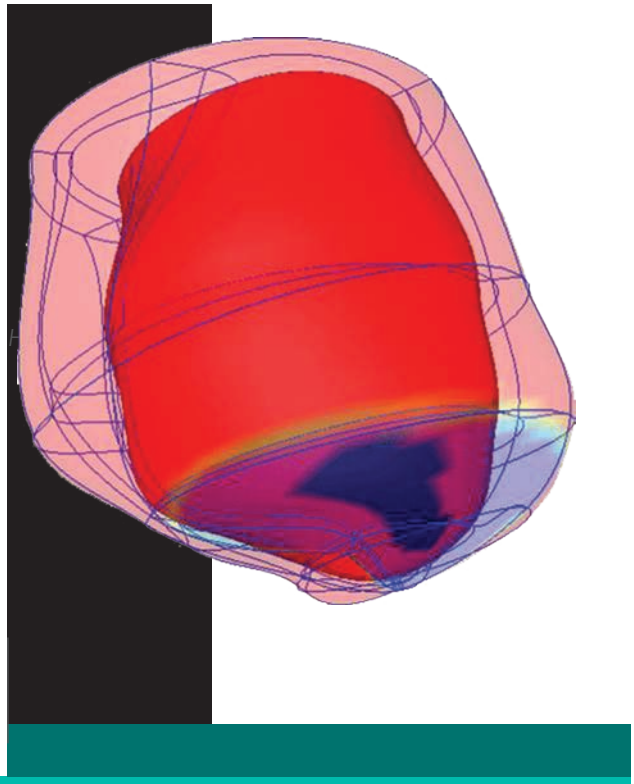
Research areas of interest thus span a wide range that includes theoretical, computational and experimental investigations in solid and fluid mechanics, with corresponding research activities organised into a number of research programmes which range from those of a fundamental nature to projects having a direct link to industry and other applications. Areas of activity in solid mechanics include plasticity, structural mechanics and fracture mechanics. In the domain of fluid mechanics, much activity is motivated by problems in aerodynamics and in the mining industries. Beyond these traditional areas of interest, biomechanics is a major area of activity, and particulate flow characterisation has become established as a major focus in its own right.



During 2012, twelve postgraduate CERECAM students graduated, two of whom were registered at the doctoral level. Thirty-three students continue their studies through the centre, approximately two-thirds of whom are PhD candidates.

Biomechanics of the Upper Airway

Sleep apnoea is a type of sleeping disorder characterised by pauses in breathing or instances of shallow or infrequent breathing during sleep. Each pause in breathing is called an apnoea, and can vary in duration from at least ten seconds to minutes. There are three types of sleep apnoea and, according to the World Health Organisation, more than 120 million people worldwide suffer from this chronic respiratory disease.



In another CERECAM project, Professor Daya Reddy and PhD student Jean-Paul Pelteret are concerned with the use of modelling and computational techniques to develop a better understanding of the mechanisms of obstructive sleep apnoea. The initial phase of this work involved the development of a model for the non-linear anisotropic behaviour of the tongue, which comprises a number of muscle groups, as well as of other relevant soft tissues. Further work has entailed the simulation of fluid-structure interaction involving the tongue and soft palate, and upper airway flow.

Myocardial Infarction and Heart Failure

Cardiovascular diseases (CVD) will become the leading cause of death by 2020, superseding infectious diseases such as HIV, TB, and malaria. The risk of CVD has been reported to increase with the improvement of economic wealth and social environment, in particular in Africa.

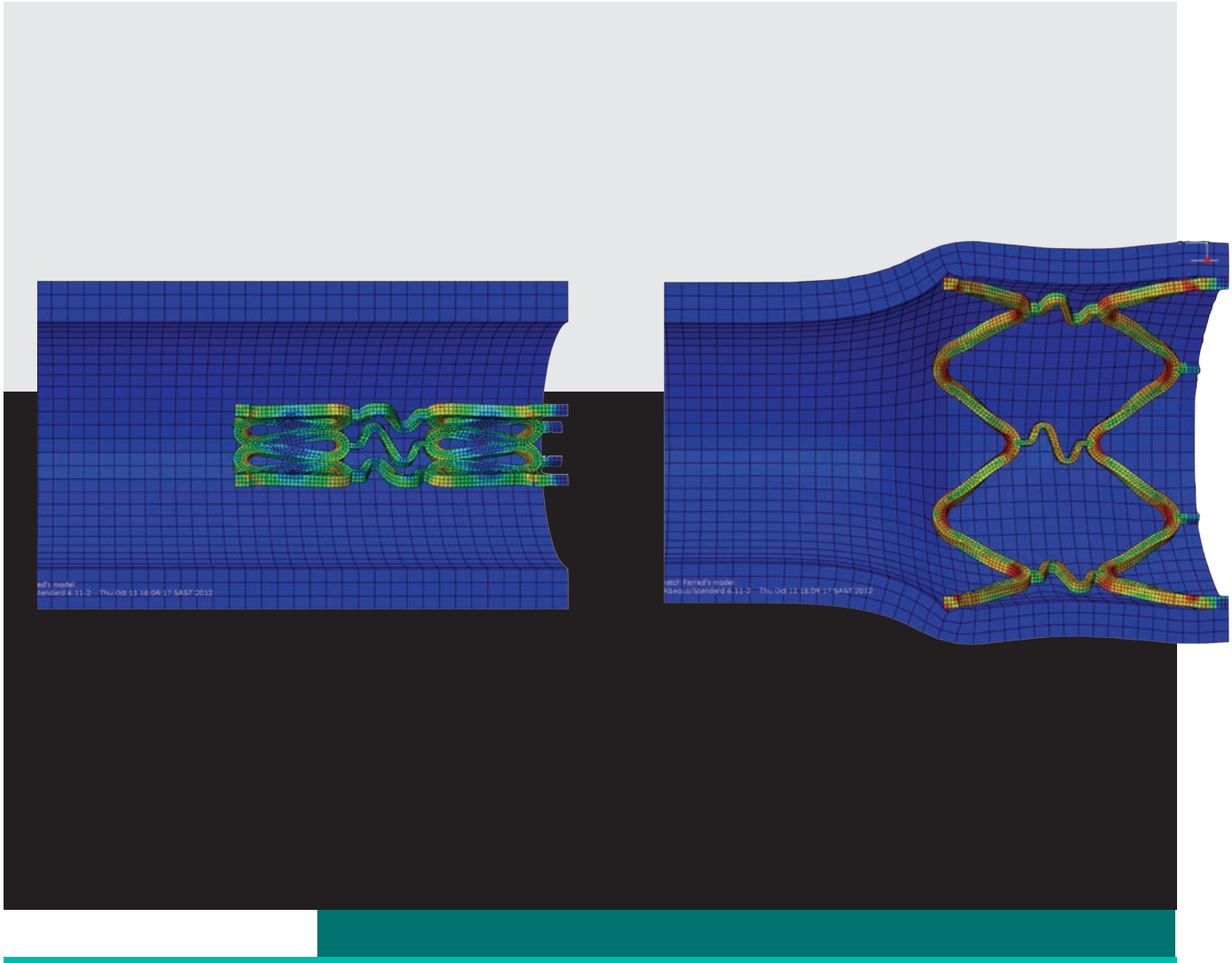
A higher risk for acute myocardial infarction, the leading causes of congestive heart failure, has been reported in the black African group in sub-Saharan Africa due to an increased level of hypertension. Similarly, the American Heart Association expects in the near future a dramatic increase in CVD incidences in Africa, in particular in the younger population, in conjunction with the emergence of a new epidemic of obesity, diabetes and uncontrolled hypertension. Up to one-third of infarct patients develop heart failure, making myocardial infarction the most common cause of heart failure. The fact that 30 to 40% of patients die from heart failure within the first year after diagnosis, even with optimal modern treatment, indicates the urgent need for alternative therapies.

The aim of this collaborative research project, which is sponsored by the national Centre for High Performance Computing, is the development and utilisation of HPC tools to study the biomechanics of myocardial infarction (MI) and emerging MI therapies based on biomaterial injection into the infarct. The presented problem is highly complex, including the representation of the architecture of cardiac soft tissue with dispersed biomaterial at micro- if not nano-scale, the highly non-linear elastic myocardial mechanics, and the electro-sensitivity of the myocardial muscle. Comprehensive treatment exceeds conventional computing resources in terms of problem size and complexity of the developed codes to capture the physical phenomena with sufficient accuracy. HPC will form an imperative platform for this research towards the advancement of MI therapies and prevention of heart failure.

The project is led by Associate Professor Thomas Franz and Professor Daya Reddy, in close collaboration with UCT's Dr Sebastian Skatulla, Dr Dieter Legner, Associate Professor Neil Davies, Dr Jeroen Kortsmit and Laura Dubuis, and Dr Carlo Sansour of the University of Nottingham, and provides an excellent framework within which seven postgraduate students are being trained and mentored.

Designing Biodegradable Stents

In modern society, advances in biotechnology have made it possible for the quality and length of human life to be vastly improved. One such advancement has been the development of the stent, a tiny mesh 'tube' which, when inserted into a natural passage in the body, serves to prevent or counteract a disease-induced constriction in the flow of blood or other bodily fluids.



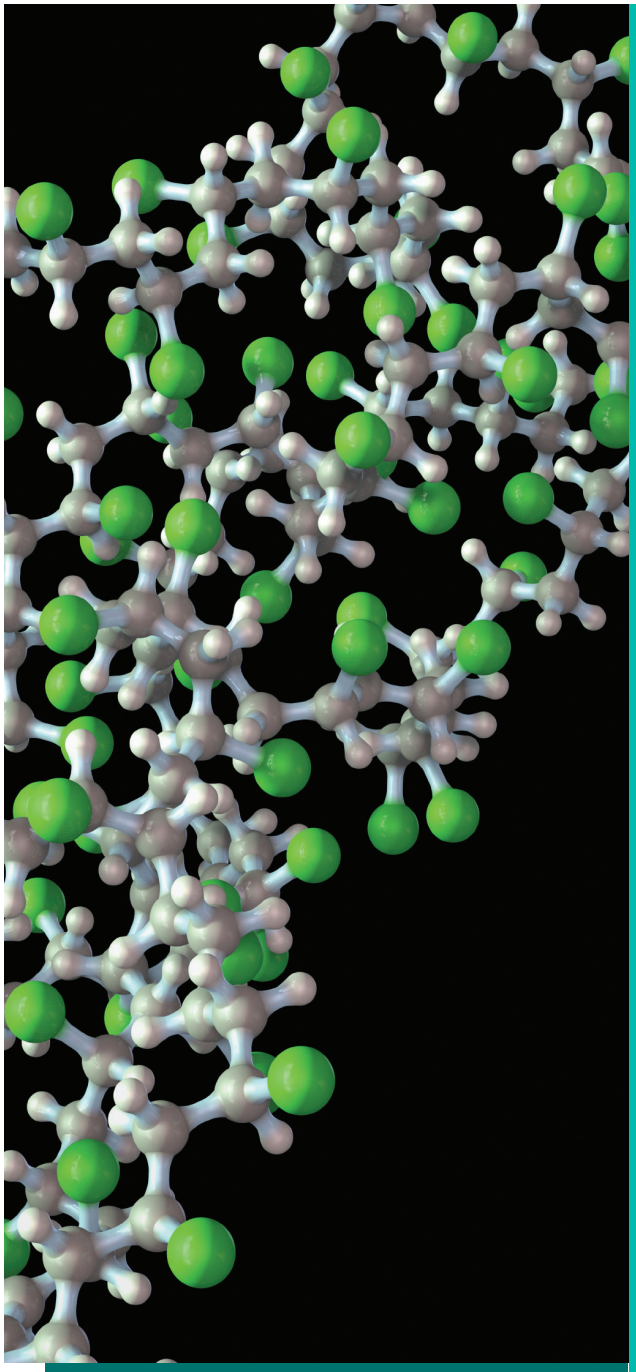
Permanent metal drug-eluting stents, i.e. stents which slowly release a drug, are the best-performing stents in clinical use today. There are, however, drawbacks to using permanent stents: they induce a chronic foreign-body stimulus in the host artery, obstruct future cardiac interventions and also prevent normal artery mechanical behaviour, to name but a few. If the stent can maintain its strength long enough to assist in the healing of the artery, and gradually transfer load onto the native vessel as it degrades, a fully healed artery may be restored. Thus there is much interest in the design of biodegradable stents.

Current research is concerned with a preliminary investigation into the properties of materials suitable for use in stent manufacture, the design of associated stent geometries, and computational simulations. This project is supported by Disa Vascular, and led by Professor Daya Reddy, with one master's student Richard Pauck.

Research Project

Computational Electromagnetics: Electro-Mechanical Coupling of Electro-active Polymers

Functional or active materials are those materials whose physical and chemical properties are sensitive to change in the environment, such as temperature, pressure, or the presence of an electric field. These materials are used to develop smart structures which are capable of sensing and adapting to changes in their environment, and smart systems, which comprise smart material, a smart structure, and intelligent processing. As such, they have a broad range of applicability and play an essential and important role in everyday life.



In recent years, functional or active materials have played an increasingly important role in the design of advanced and smart structures as well as intelligent and micro-electromechanical systems. Amongst these kinds of smart materials are the smart hydrogels used in the development of therapeutic devices and drug delivery, piezoelectric polymers which produce an electric current upon being subjected to mechanical strain (and have industry and manufacturing as their largest application market, followed by the automotive industry), and conducting polymers which are collectively known as electroactive polymers (EAP). EAP have a wide range of applications, with one of the most common being in the development of artificial muscles.

These materials are used to develop smart structures which are capable of sensing and adapting to changes in their environment.

A research project being led by Dr Sebastian Skatulla of the Department of Civil Engineering intensively studies the properties of EAP in experiments, and has developed a number of mathematical models. In contrast to existing theories, Dr Skatulla's work seeks to address nonlinear electro-mechanical coupling in a very fundamental manner, that is, to formulate a continuum mechanical approach which directly links electric stimulus and resulting deformation of the polymer material. As the theory is kept very general, it is applicable to a high diversity of electro-mechanical coupling problems.

Dr Skatulla's collaborators include Dr Carlo Sansour (University of Nottingham) and Associate Professor Arunachalakasi Arockiarajan (Indian Institute of Technology Madras).

Strain Gradient Plasticity

In physics and materials science, plasticity describes the change in the shape or size of a material undergoing non-reversible changes in response to an applied force or change in temperature. Perfect plasticity is a property of materials to undergo irreversible deformation without any increase in stresses or loads. Plastic materials with hardening require increasingly higher stresses in order for further plastic deformation to occur. Generally plastic deformation is also dependent on the speed of the deformation; such materials are said to deform visco-plastically.

Because the constitutive relations of classical plasticity do not possess a natural length scale, they are therefore unable to account for size effects. Gradient theories represent a popular and well-established extension which allows for physically relevant length scales to be introduced.

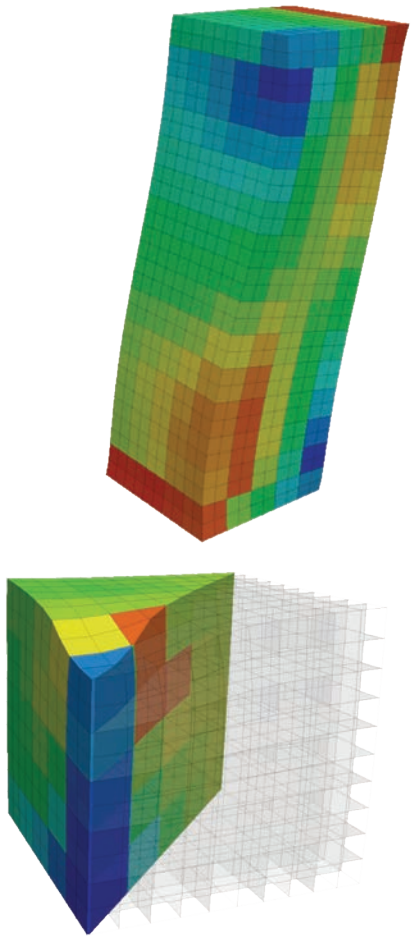
Current research in this area is devoted to problems of single- and polycrystal plasticity. A crystal has atoms in a near-perfect arrangement where a 'pattern' is repeated in regular intervals, whereas a polycrystal is composed of many microscopic crystals. However, the arrangement of atoms or molecules in most crystalline materials is not perfect. The regular patterns are interrupted by crystallographic defects. One focus has been on the development of variational formulations, where the role of particular choices of defect energy and of dissipation functions has been investigated. Also of interest are new hardening relations.

Perfect plasticity is a property of materials to undergo irreversible deformation without any increase in stresses or loads.

Another area of research is on modelling the influence of the grain boundary on the overall response of the continuum. A grain boundary is the interface between two crystallites in a polycrystalline material. Grain boundaries are defects in the crystal structure, and tend to decrease the electrical and thermal conductivity of the material.

Computational work has been concerned with the development and implementation of finite element approximations for visco-plastic crystal problems involving large deformations, and in which both energetic and dissipative microstresses are present. Both single crystals and ensembles of crystal grains are considered.

This large, multi-institution project, led by Professor Daya Reddy, spans a network of five institutions across the globe, and has already produced one master's student. Two doctoral students and a second master's student are currently engaged in research in this area, while Professor Reddy's collaborators include Dr Francois Ebobisse and Dr Andrew McBride from UCT, Professor Swantje Bargmann (Technische Universität Hamburg-Harburg), Emeritus Professor Morton Gurtin (Carnegie-Mellon University), Dr Britta Hirschberger (Leibniz Universität Hannover), Professor Paul Steinmann (Friedrich-Alexander-Universität Erlangen-Nürnberg) and Professor Ali Javili (Friedrich-Alexander-Universität Erlangen-Nürnberg).



Information technology solutions for The Developing World

ICT4D is a multidisciplinary field which investigates the design and creation of computer systems for the developing world. These systems could cover any sub-discipline in ICT, for example, virtual environments, computer security, interaction design, artificial intelligence, and information retrieval. However, such systems need to be designed and configured according to the needs of the developing world within which power is limited, networks are scarce, and users can be illiterate. ICT4D thus focuses on the creation of ICT solutions that address defined developmental and social challenges such as education, medical care, identity and human dignity.

The work of the UCT Centre in ICT for Development (ICT4D) is about bringing digital technology to bear on the challenges facing society. The centre creates new forms of technology to directly address the developmental problems within society, problems that do not exist in developed economies where most of the world's technology is created.

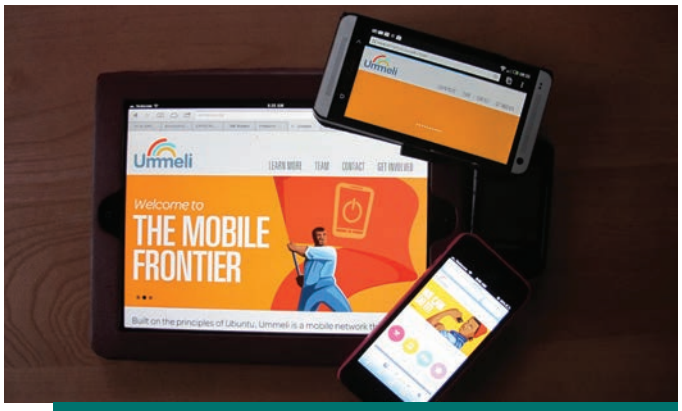
In order to ensure the efficacy, relevance and sustainability of the centre's work, it has partnered with a variety of departments throughout the university – the spectrum ranges from recent projects with the Department of Civil Engineering to others with the Centre for Film and Media Studies in the Faculty of Humanities. The centre also engages with NGOs and civil society through developing digital technology to enhance and improve the work that they are doing.

As educators and researchers, staff affiliated with the centre also take a long-term approach to the problem of creating technology relevant to Africa. The best and most sustainable way to reach that goal is to impart those skills to students and educators throughout Africa. To this end, the Hasso Plattner Institute in Germany sponsors nine PhD bursaries in the centre, specifically for African postgraduate students to visit UCT and conduct research in ICT4D.

The centre is also helping define this field of research internationally by co-hosting the ICTD conference in 2013. This is the first time it will be held in Africa, and it is expected to attract some 500 delegates from across the world, drawn from commercial organisations, government, NGOs and a wide variety of academic disciplines. The work of the centre is further supported by technology companies, the most recent of which is Nokia, which will open a research lab within the centre in 2013.

Ummeli

Ummeli is a system aimed at finding jobs and training opportunities for the unemployed. The idea for this project came from an NGO based in Khayelitsha called Learn to Earn, which trains people in a variety of skills.



When trainees leave, however, they often battle to find jobs. One of ICT4D's HPI bursary students, Shikoh Gitau, spent several months visiting the Learn to Earn site, observing and interacting with the trainees to see if she could discover how better to find them jobs. Over time, she realised that employers were posting jobs on websites; however, the trainees did not look at these websites – their Internet access was mediated through basic-feature mobile phones. In instances where they did find a relevant job advert, they did not have access to computing facilities to create a CV, and were therefore unable to e-mail these to the potential employers.

Thus, obtaining design input from the Learn to Earn community, Gitau set about building a mobile service for mobile handsets which took job advertisements from popular websites and modified them so that they could be accessed on smart phones. Furthermore, the system would ask users a series of questions, the answers to which it used to generate a CV from a template, which could be sent to potential employers. Although the system started with twenty users, it soon went viral. When the number of users reached into the thousands, another technology-based NGO, the Praekelt Foundation, offered to invest in the system and launch it as a free service on the Vodacom network. This became the Ummeli system, which currently has more than 100 000 users. Gitau has gone on to work for Google in Kenya, designing systems that should improve the lives of people throughout Africa.

The Transformation of Information Systems at UCT

A decade ago, the information-systems research agenda at UCT seemed clear: statistically driven empirical research in how information systems functioned (or, sometimes, not) inside corporate organisations. Since then, three key trends have emerged in the way in which research is conducted and students are trained.

Firstly, the democratisation of Information and Communication Technologies (ICTs) has ensured that computerised information systems are no longer the domain of large corporates, but rather extending to small and medium-sized organisations. Even more dramatically, information systems are changing the way governments work and many students now investigate e-government systems. These environments have proved to be different from those of a large corporate, with much of the current information-systems research being undertaken in these settings.

Secondly, Web 2.0 tools such as wikis, blogging and social networking have wrested the control of Internet content generation from big business and yielded it much more democratically to ordinary individuals. At UCT, researchers were thrust into the social sciences by having to investigate how individuals and communities were reacting to information technologies. With this came a change in mindset about the nature of data to collect, the underlying paradigms, and the theories to use to frame an analysis.

Finally, mobile phones hold the promise to give every African his or her own computing device, and with it, access to previously unimaginable amounts of information and computer power.

The transformation of the discipline does not stop there. New information technologies such as cloud computing, 3-D printing and biometrics, virtualisation, augmented reality, and big data emerge at an ever-faster rate, forcing us to relook the way we work and train students. Applying a transdisciplinary approach puts researchers in the prime position to explore topics such as technology innovation and entrepreneurship, security, and governance approaches.

DST/NRF SARChI Chairs
associated with this theme

Professor Kevin J. Naidoo

Scientific Computing

Professor Kevin J. Naidoo has held the Scientific Computing SARChI Chair since 2007 and is director of the Scientific Computing Research Unit at UCT. His research has two interlinked objectives. Firstly, he develops state-of-the-art high performance computing software to provide a modelling and informatics platform creating a life-science virtual laboratory. This includes the development of accelerated software for high-speed chemical and chemical biology computations. A second research objective is to use the life-science virtual laboratory to identify enzyme targets and investigate their detailed molecular action. Professor Naidoo's current focus is the implementation of his gene-to-molecule rational approach to answering key questions that will lead to solutions in microbial and neoplastic (cancer) diseases.

Computational Mechanics

Professor Daya Reddy, who holds the SARChI Chair in Computational Mechanics, is a member of the Department of Mathematics and Applied Mathematics, and Director of the Centre for Research in Computational and Applied Mechanics (CERECAM). He is a graduate of UCT and Cambridge University, and served as dean of the Science Faculty between 1999 and 2005. There are three major, inter-related foci of the research chair: the mathematical modelling of complex material behaviour; analysis of the resulting models to determine their well-posedness; and the development and implementation of algorithms for computational solution. Examples of recent and current work include the behaviour of metals at the micro structural level, non-Newtonian fluids such as polymers, and a variety of applications in cardiovascular biomechanics. The research is highly multidisciplinary and includes collaborators in the mathematical sciences, biomedical sciences, and various branches of engineering.

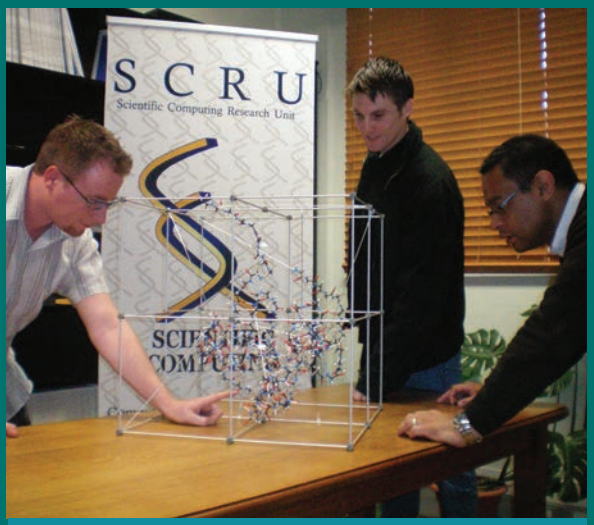
A major project has been concerned with the development of models and associated simulations for the behaviour of single crystals, in the micron range. There is substantial practical interest in such problems, given their relevance to the manufacture of MEMS (micro-electromechanical systems). The mathematical models are considerably more complex at such scales as they need to take account of size-dependent behaviour. Work during 2012 built on the results of a research programme that has been in progress for the last seven years, with collaborators based in the USA and Germany. A further achievement during 2012 has been the completion and publication of work on modelling of the upper airway. The anatomically accurate mathematical model takes account of neural stimuli to muscles in the tongue and adjacent tissues, and the resulting simulations have allowed for new insights into the mechanisms that induce sleep apnea.

Professor Daya Reddy

Research Groupings
associated with this theme

Scientific Computing Research Unit

The Scientific Computing Research Unit (SCRU) was established in 2009 and has as its core mission the development and application of computer code for scientific problems, specifically in chemistry, biophysics, physics, and engineering.



The unit has made major technical advances in biophysical computational modelling, with the development of a generalised free energy code called FEARCF. In 2009, the unit was awarded a long-term development grant from the Nvidia Corporation to advance the SCRU program to port quantum code to graphical processing unit-based computer clusters. The research group has strong links with international groups, particularly via its Scientific Computing International Lecture Series programme.

Director: Professor KJ Naidoo
E-mail: kevin.naidoo@uct.ac.za
Web: http://scru.uct.ac.za/

Information and Communications Technology Centre for Development

The Information and Communications Technology Centre for Development (ICT4D) was established in 2008 to capitalise on UCT's unique position in the ICT domain, namely, producing world-class ICT research, but being based in a developing economy. Incorporating researchers from across the university, the centre looks to create ICT solutions that can be applied in a developing-world context.

ICT4D was established to capitalise on UCT's unique position in the ICT domain.

Being the only such centre in a developing country, we have been able to attract researchers and students from across the globe. The Hasso Plattner Institute Research School in ICT4D, which provides bursaries for African students working in this field, was launched in 2009 and will be based within the wider structure of the centre.

Director: Professor G Marsden
E-mail: gary.marsden@uct.ac.za
Web: http://www.ict4d.cs.uct.ac.za/

Centre for Information Technology and National Development in Africa (CITANDA)

CITANDA is located within the Department of Information Systems. It brings together researchers, projects, funders, and programmes focused on the use of information and communication technology (ICT) in the service of national development. CITANDA researchers study, using a diversity of research approaches, the management, development, adoption, and impact of ICT in areas related to business, economic, and social development in Africa.

The centre specifically explores and investigates information systems (IS) phenomena that arise at the nexus of interaction between information technology and Africa's business, cultural, social, and economic context, in order to advance knowledge concerning IS in organisations and society in Africa. Through CITANDA, the Department of Information Systems attracts a large cohort of PhD and master's degree students from across Africa and beyond.

Director: Professor J-P van Belle
E-mail: jean-paul.vanbelle@uct.ac.za
Web: http://www.commerce.uct.ac.za/citanda