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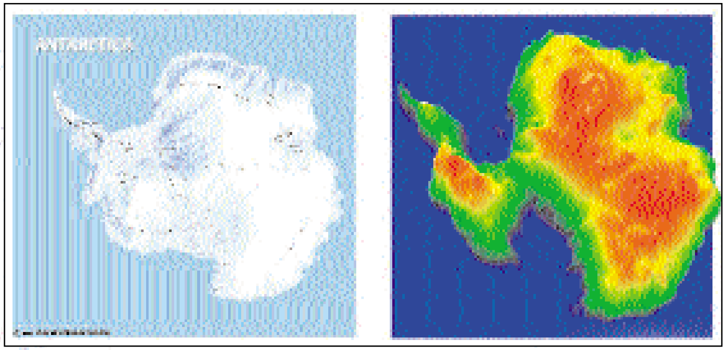
High Performance Computing



Electronics and Computer Science

University of Southampton

Contents

High Performance Computing

We develop technology (hardware, algorithms and software) to deliver cost-effective computational results. Our objectives are:

- Design, development and deployment of cost-effective high performance computing systems. Our technical innovations have led to a University decision to install a 200-300 node commodity cluster in 2000, which will be the largest such system in the UK.
- Development of advanced programming environments for high performance and parallel computing.
- Collaborative development of high performance computational algorithms and application programs within major research programmes in Engineering and the Physical, Environmental and Social Sciences.

Projects in progress:

- Sonar Systems
- Numerical modelling of Ice Sheets and Ice Caps
- Adaptive Antenna Arrays
- Fast Spectral Eigenvalue solvers
- Electrical Impedance Tomography
- Long Term Coastal Evolution
- Programming Environments for Real Time Sensors
- Evolutionary Stable Reproductive Strategies
- Commodity Supercomputing
- Satellite Remote Sensing of Glaciers
- Web interfaces to Scientific Databases
- Parallel Grid Generation Methods
- Liquid Crystal Devices
- Quantum Computing
- Molecular Dynamics and Monte Carlo simulation of High Temperature Superconductors
- Models of Cooperation in Anthropology
- Maximum Entropy Data Analysis
- Problem Solving Environments
- Computational Electromagnetics for Electro-Optic devices (Photonic Band Gap systems and Liquid Crystals)
- Data Intensive Visualisation
- VLF band radio emissions in space plasma
- VLF radio scattering in the ionosphere
- Cloud-ionosphere electric discharges (sprites)
- Numerical simulation of space plasma
- O(N) Fast Multipole Methods

We have opportunities for collaborative research with a number of departments and are keen to attract students from a wide range of numerate disciplines. Current members of the group have backgrounds in Physics, Maths, Computer Science, Geography, Oceanography, Biology, Geophysics and Electronic Engineering.

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Academic Staff	Research Interests
Dr Simon Cox	Computational Modelling and Engineering Informatics
Professor Tony Hey	Performance Engineering and Quantum Computing
Dr Denis Nicole	High Performance Computing Architectures and System Software
Dr David Nunn	Space Plasma Simulation and Sonar Systems
Dr Ken Thomas	High Performance Numerical Methods.
Mr Ed Zaluska	Advanced Computer Architectures, Distributed Computing Systems

Staff Profiles

Dr Denis Nicole is a University Reader and is Head of Group. He is interested in all aspects of parallel computing. In the distant past, he designed two series of commercially exploited parallel "supercomputers." More recently, he led the technical benchmarking and acceptance trials for the current UK national research supercomputer in Manchester. His own current architectural work is attempting to drive down the cost of high performance computing, data repositories and visualisation using commodity (consumer or games) components. This includes lightweight networking over Ethernet, fast networking over Giganet, and collaborations with cluster manufacturers, networking vendors and Microsoft Research.
He also works at the language level, and supplies a compiler for the occam parallel programming language to a commercial customer in Norway. Current effort involves using symbolic model checking to assure the correctness of parallel constructs in occam and Java. He is also working on lightweight Java implementations for parallel programming and embedded systems. His collaborative work on data repositories is developing a natural distributed web-based framework for maintenance of large-scale simulation data. This is integrated into visualisation and knowledge discovery facilities that make efficient use of the UK networking infrastructure.

Professor Tony Hey is Professor of Computation and is presently Dean of the Faculty of Engineering and Applied Science at Southampton.
He is currently a member of the EPSRC's Technology Opportunities Panel and also of the Joint Research Councils HPC Technology Watch Panel. He is European Editor of the journal Concurrency: Practice and Experience, and a member of the IFIP Working Group on Parallel and Distributed Systems. He has been a member of the Programme Committee for many international conferences and is currently a member for the IEEE and ACM sponsored IPDPS conference in Cancun, Mexico and the EuroPar2000 conference in Munich, Germany.

Tony Hey is the co-author of two 'popular' science books - The Quantum Universe and Einstein's Mirror - and a graduate level text on Gauge Theories in Particle Physics. With Jeanne Ferrante, he co-edited a research monograph on Performance and Portability for Parallel Processing. He also edited The Feynman Lectures on Computation and a collection of articles entitled Feynman and Computation.
Future research directions include the development of close links with the Faculty's Computational Engineering and Design Centre and research into performance engineering issues for pervasive distributed computing systems such as the GRID. Tony Hey is also pursuing more speculative research towards the development of coherent quantum devices which could lead to the construction of small-scale quantum computers.

Dr Simon Cox is a Research Lecturer and joined in 1998 after completing his Ph.D. He has degrees in Maths and Physics. His research focuses on computational modelling of devices and systems. Most of his projects are collaborations with other researchers at Southampton in various departments across the University. Current research projects include commodity supercomputing, computational electromagnetics in complex media, databases, and environmental/ biological modelling. His input on these projects is concerned with the fundamental physics/ science of the system and with the development of suitable numerical algorithms to implement solutions for the resulting models. In each of these projects new algorithms are being developed, and parallel computation is being exploited to solve large-scale problems in interdisciplinary collaborations. He recently spent 6 months at the National Science Foundation Supercomputer Centre in San Diego.

Dr David Nunn is a Reader and joined the department in 1979. Prior to this he worked on developing the fundamental theory of nonlinear interactions between electrons and plasma waves in inhomogeneous media. From 1974-9 Dr Nunn worked for MOD(PE) at RAE Farnborough, devising algorithms for adaptive processing of sonar data from sonobuoys and assessing future anti submarine warfare systems. Research on adaptive processing of sonar array data has continued at Southampton and in collaboration with Plessey Naval Systems, Ferranti

and DERA novel algorithms have been devised for the optimal and robust processing of broadband data from sonar arrays.
His main research interest at Southampton is numerically intensive computing, particularly applied to space plasma simulation and radio propagation in the VLF band. A novel and highly efficient plasma simulation methodology termed VHS has been invented, which is far more efficient than the classical 'particle in cell' method. This has been successfully applied to the problem of the generation of nonlinear radio emissions such as dawn chorus. Another intensive NIC application area has been the modelling of VLF radio scattering from ionospheric inhomogeneities, particularly from 'Sprites' or cloud to ionosphere electric discharges. Current research is funded by NATO and INTAS and involves collaborators from the University of Tokyo and Kyoto, SGO Finland, British Antarctic Survey and Leeds University.
There is now a growing interest in the communications area. He has been a consultant to INMARSAT on power control in mobile radio, and has interests in adaptive antennas in the UHF band.

Dr Ken Thomas joined Southampton University in 1977. His main area of research is in Numerical Analysis and his early research was in the numerical treatment of integral equations by Galerkin's method. He has been interested in the programming language Ada for many years and was one of the first people to run Ada programs on a transputer. A tool was developed that automatically distributed Ada programs across transputer arrays. More recently, he published a binding of MPI to Ada95. His latest area of research is on the calculation of eigenvalues of large matrices. The methods construct the power spectrum of a density function defined as a Riemann Stieltjes integral by Fourier series techniques and maximum entropy. The user of such methods only needs to implement matrix vector multiplication. Thus large sparse problems can be tackled effectively.

Ed Zaluska has undertaken research into distributed computing systems over the past twenty years and has been a senior lecturer in the department since 1984. Current research interests include systems-level architectures for high performance computing and visual systems for real-time animation.

Thrust Areas

Research in our group covers three main areas: distributed computing, tools and techniques, and collaborative computational science and engineering. Our strength lies in this mix of sophisticated computer science with both commercial and scientific applications.

Commercial Distributed Computing

Commodity Computing

The entry price of supercomputing has traditionally been very high. As processing elements, operating systems, and switch technology become cheap commodity parts, building a powerful supercomputer at a fraction of the price of a proprietary system becomes realistic. The group owns a number of dedicated computational clusters based around Compaq Alpha workstations and Intel processors. They are fully competitive with systems from major vendors for a wide range of applications, but at a cost lower by a factor of three. We are researching the long term goal of delivering an effective remote and local parallel computing service directly under Windows NT, with all the commensurate benefits of commercially supported software and integration into a mainstream commercial IT environment. We are extending the usage of commodity systems to areas such as databasing and data intensive visualisation. The group hosts the www.windowsclusters.org website for Microsoft.

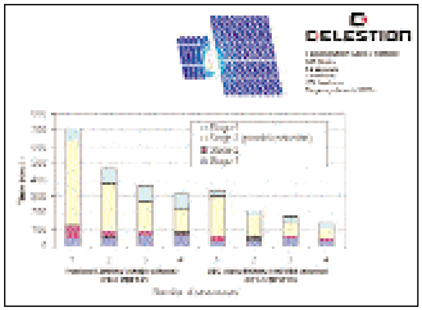

Figure 2 Working with our IT-Innovation Centre, Celestion and Microsoft, we have demonstrated the use of office PCs to design loudspeakers using the PAFEC finite element code

Web interfaces for distributed databases.

The information age has resulted in an explosion of information, most of which is stored, classified and managed within databases. While databases are the perfect vehicle for storing data, retrieving data from them is non-intuitive to all but experienced users. We have developed a number of novel methods for querying and browsing databases on the web. This has been achieved by using automated methods which exploit meta-data available in the database. We use Java Servlets and sandboxed Fortran as secure ways to dynamically execute post-processing code on the archived data. Users can perform operations such as array slicing through a web interface. This reduces bandwidth by only delivering the data of interest. Further research is directed at developing novel user interfaces and data post-processing tools for all types of databases, including object-oriented databases, together with investigating the need for additional metadata to support such interfaces.

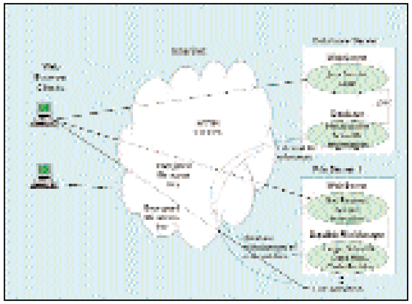

Figure 3 System architecture for distributed database system

Database Integration into PSEs

A particular challenge for engineers is to encapsulate and exploit knowledge gained through past use of their Problem Solving Environments (PSEs) to enable new designs to be developed more rapidly or at lower cost. Any attempt to archive this knowledge must be sufficiently flexible to cope with the changing landscape caused by evolution of the PSE and its use. With the School of Engineering Sciences, we are developing systems which address these issues using Java and XML to automatically generate a database from files which log information about the engineers' use of the PSE.

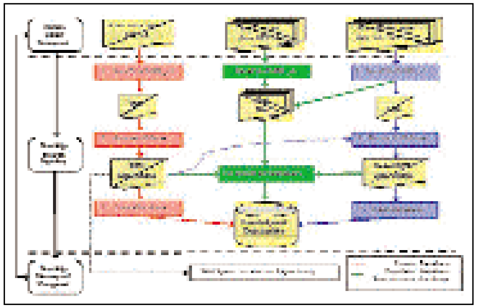

Figure 4 The internal structure of the knowledge and data repository and its relationship with the PSE. Flexibility is built-in by using an XML Schema representation of the database which is automatically generated from the flat file output of the PSE. This schema can also be used to generate a customisable web/agent-based interface to the database for subsequent knowledge discovery

Postgraduate studies

Postgraduate study in Commercial distributed computing will suit candidates looking for industrially relevant research opportunities in a rapidly expanding field. During their research, students will acquire extensive knowledge of network programming using Java, Java Beans, JDBC, XML, distributed object technology such as CORBA, ActiveX/DCOM and RMI, and object oriented programming and analysis methods.

Tools and Techniques

We maintain a strong interest in the development of advanced software systems to support parallel programming.

Commodity Lightweight Networking

The rapid development of commodity personal computers, often used for games, has given us cheap processing, memory and 3D visualisation. The only impediment to building very cheap parallel computers from these parts is the cost of fast, low-latency networking. We are pursuing this problem on a number of fronts in collaboration with Microsoft (we have source licenses for Windows NT/2000 and host the Windows clusters web site for them), Giganet (a networking hardware company) and Insilico (a clusters company). We are developing new Giganet drivers for MPI and are working on improving the reliability of the Gamma system, which delivers very low latency over Ethernet, so that it can be used for routine large-scale computations.

The SPOC occam system.

Occam is a parallel programming language especially well suited to the development of small embedded systems. Our compiler, implemented using advanced vector dependency analysis technology, is now used in, for example, embedded applications in the marine industry. Our principal customer is eager to develop the system to provide integration with the VxWorks real time kernel and as an efficient distributed implementation over Windows NT clusters. Future research in this area is focussed on assurances of parallel correctness by model checking for occam and for Java.

Problem Solving Environments

This current EPSRC-funded research project is concerned with the construction of Problem Solving Environments (PSEs) for science and engineering applications. The project is being undertaken with Cardiff Computer Science Department and the IT Innovation Centre located at Chilworth. Prototype PSEs are being built for Molecular Dynamics and Finite Element applications and the goal is to develop a modular, component-based approach for constructing such environments. An important element of such PSEs is resource management for both parallel and distributed computing systems. This involves the development of reliable and fast performance benchmarking, performance modelling and performance estimation techniques. The project will build on earlier work in the group on the 'Parkbench' parallel benchmarks and the 'PERFORM' performance estimation tool. The IT Innovation Centre will also further develop their 'INTREPID' distributed resource manager software.

Postgraduate studies

Postgraduate study in tools and techniques would suit students interested in compiler development, model checking, system programming, parallel hardware architectures and problem solving environments. Students will get the opportunity to develop state-of-the-art parallel hardware, programming languages and paradigms, and work with leading researchers in this area.

Applied Computational Algorithms

Our research work in applications of High Performance Computing is almost all collaborative; we bring our expertise in efficient computational techniques to bear on a wide range of problems in several disciplines. This exciting collaborative work allows our students to be part of an active research team working on computational algorithms and application programs in major areas which lie in the following broad areas.

Computational Electromagnetics

We are developing new algorithms to allow complex electromagnetic systems to be modelled along with the next generation of optical, electro-optic and superconducting devices. These focus on significantly improving the performance of the simulation by reducing the time complexity of the algorithms used.

VLF radio scattering in the ionosphere.

Parallel codes have been developed in the group to numerically model the scattering of VLF radio band signals (kHz) by ionospheric irregularities and by Red Sprites or cloud to ionosphere electric discharges. Precise modelling of the scattering of signals from high power US Navy VLF transmitters has enabled discoveries to be made re the detailed physics of Sprites. This work is in close collaboration with British Antarctic Survey in Cambridge, the University of Otago in New Zealand, UEC in Tokyo, and Stanford University in California.

Cloud-ionosphere electric discharges (sprites).

In this project, we aim to use a full wave VLF propagation code, developed at Kanazawa university in Japan for the numerical modelling of VLF band radio wave scattering from ionospheric irregularities, such as those which arise from lightning and earthquake precursor effects.

Numerical Simulation of Space Plasma

A plasma is a very thin fully ionised gas which exhibits a very complicated behaviour, particularly when a radio wave propagates through it. As part of a long term research project, a novel and highly efficient simulation method termed Vlasov Hybrid Simulation has been developed which makes possible modelling that previously required unreasonable amounts of computer time. The methodology has been applied to the simulation of radio emissions in space – particularly the well known 'dawn chorus' in the kHz radio band. This research program is the focus of an ongoing international collaboration financed by NATO and INTAS in Brussels, involving partners in Nizhni Novgorod and Murmansk (Russia), Sodankyla Geophysical Observatory in Finland, British Antarctic Survey and the University of Kyoto in Japan.

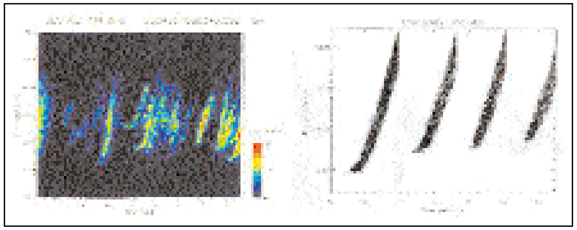

Figure 5 A well-known radio phenomenon in the Very High Frequency (VHF) radio band is that of a series of chirp sounds, which result from interactions between radio waves and electrons in space trapped in the Earth's magnetic field. If these were replayed in the audio spectrum, they would sound like bird song-hence they are often referred to as 'dawn chorus'. The results from our numerical model compare well with observations from a US/Japanese satellite showing that we have been able to explain the origins of the 'dawn chorus.'

Sonar Arrays

By combining signals from an array of sensors it is possible to obtain better directional information about the location of source signals and increase the signal to noise ratio. Using an array therefore dramatically increases the effective resolution with which it is possible to pinpoint a target source. We have developed a suite of novel and highly efficient algorithms for adaptive processing of the signals from sonar arrays (particularly naval towed arrays), which perform better than previous techniques. These give excellent performance but can be non-robust in the presence of array deformations, correlated multipath and sensor errors. We now wish to develop 'third generation' algorithms in which the array is self tuning, compensates for these errors and locks onto a strong target.

This work is in collaboration with the Defence Research Agency (DERA) at Winfrith and the Australian Department of Defence.

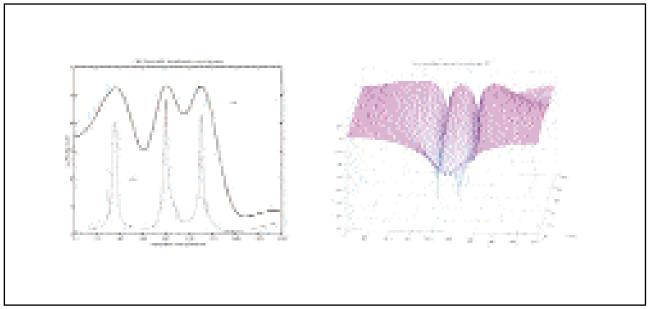

Figure 6 Our adaptive processing algorithm provides a robust method for analysing the signals from a sensor array. (Left) Improved resolution of targets compared to 'conventional beam-forming' techniques. (Right) Interference between the signals from different sources is reduced: when the analysis is focused on the source at 35 degrees, the signals from the two other sources are significantly attenuated.

Adaptive Array Algorithms

In this new project, we are employing advanced adaptive array algorithms and applying them to the processing of UHF data from antenna arrays at mobile radio base stations, in particular aerial platforms as proposed by the Communications group (ECS).

Modelling Photonic Band Gap Devices using Vector Finite Elements

We are working with the Microelectronics group and the Physics department on a new finite element based method to model photonic crystals, circuits and devices (PcCADs). Southampton has developed fabrication techniques suitable for manufacturing these devices in its Silicon Fabrication Facility which promise to revolutionise the field of optics in the same way that semiconductors, electronic circuits and devices changed the whole of electronics. Where other algorithms require 100Gb of memory to model a device, ours typically requires 1Gb. This takes practical calculations from the supercomputer to the desktop. Next year we will move on to begin to model the flow of light as it passes through PcCADs and also to study non-linear and active devices.

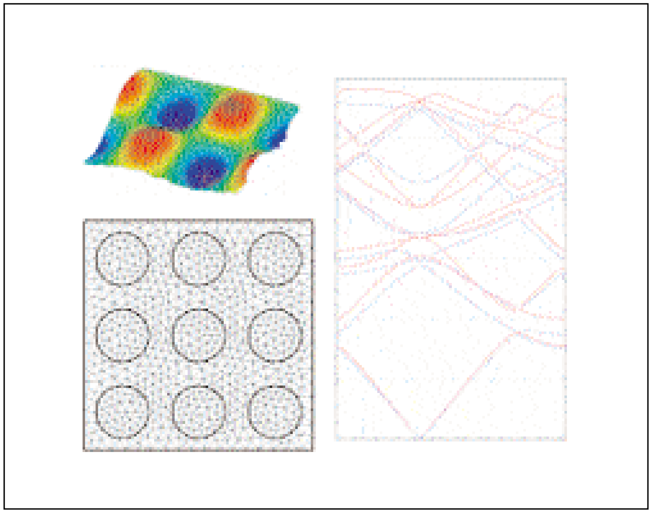

Figure 7 Bottom left: Finite element mesh of a photonic crystal.
Right: Photonic crystal band structure.
Top left: Electric field in a photonic crystal.

Molecular Dynamics and Monte Carlo simulation of High Temperature Superconductors

A High-Temperature Superconductor consists of copper oxide planes and is penetrated by thin tubes carrying magnetic flux. The intersection of the planes and the flux gives rise to circulating supercurrents known as vortices. Electric transport currents cause a Lorentz force to act on vortices and any resulting drift of the vortices will produce a voltage across the superconductor and hence dissipation. Fortunately, vortices can be pinned, for instance by atomic impurities or defects in the material. The competition between vortex-vortex interactions and pinning interactions makes simulation of the system a computationally intensive many-body problem.
We are using molecular dynamics and Monte Carlo simulations to study these systems. We have developed a novel hybrid Monte Carlo method to study phase transitions and vortex pinning in these materials, which requires considerably less computing power than regular Monte Carlo methods. We are using molecular dynamics techniques to integrate the coupled differential equations of motion for the system, which allow us to investigate the dynamic behaviour of the system in the presence of a Lorentz force and a pinning potential. An understanding of the vortex state and its pinning is crucial in our endeavours to develop superior superconducting materials in collaboration with experimentalists in the Physics department of the University of Southampton.

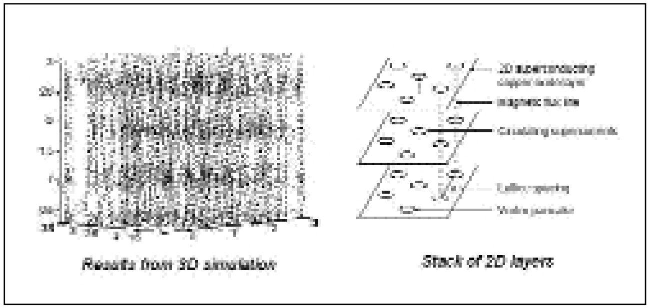

Figure 8 Monte-Carlo simulations of a layered high temperature superconductor.

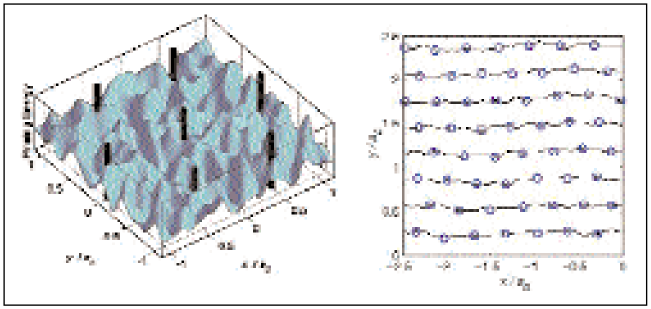

Figure 9 Molecular Dynamics simulation. (Left) The pinning potential employed for 2d-simulations of a driven vortex system. The vortices are shown as black lines. (Right) A snap shot (blue circles) of vortex positions. The grey lines show the paths along which vortices move when driven from left to right. The dynamic phase visible is the Moving Bragg Glass.

Fast Multipole Methods

We have recently developed a particle simulation algorithm suitable for Molecular Dynamics and Monte Carlo simulation of superconductors which is a factor of a million faster than the methods currently used. This will lead to a significant change in the size and complexity of the systems which can be modelled, and will lead to simulations which, for the first time, can be accurately compared with experimental results.

Electrical Impedance Tomography

Electrical Impedance Tomography (EIT) is an imaging method which exploits the differing conductivities of complex media to form an image of the inside of a system. By injecting a small current and analysing the voltage pattern measured on the surface of this sample, the inner material structure can be reconstructed. For medical applications, this proves to be a low-cost non-invasive alternative to other imaging methods and hence its market acceptance is rising continuously. Besides medical applications, EIT is also of potential use in geological exploration and non-destructive material testing.

In collaboration with the Physics department, we are researching existing algorithms and developing new algorithms, which will allow real-time three-dimensional EIT imaging. This involves the design of parallel finite element code (as part of a group project FEMLIB) and implementation of a suitable non-linear inverse solver.

The interdisciplinary nature of this venture and the implementation of the code on the groups workstation cluster make this a challenging and future-oriented project. This work is a collaboration with Physicists and with clinicians at Southampton General Hospital.

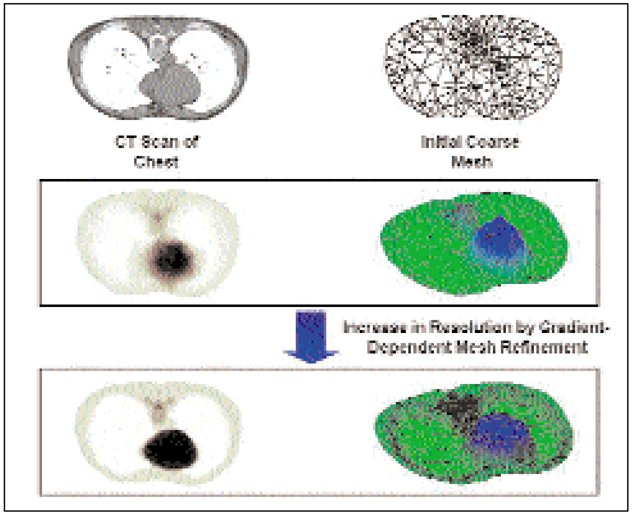

Figure 10 Use of adaptive mesh refinement to improve algorithm efficiency and reconstruction quality in Electrical Impedance Tomography

Polymer Dispersed Liquid Crystals (PDLCs)

We have made a theoretical study of the light scattering properties of Polymer Dispersed Liquid Crystal (PDLC) films. These devices have a number of applications including direct view and projection display technology, switchable windows, electro-optic shutter devices, large-scale flexible displays, and high resolution active matrix addressing systems. A PDLC film consists of a random ensemble of micrometre-sized liquid crystal droplets dispersed in an isotropic polymer matrix. In the absence of any external electric field, the film has a milky white translucent appearance. However, when a field is applied, the film becomes clear. In contrast to polarization devices, there is little loss of light in the transparent state, making them highly desirable. The contrast between the off and on states relies on an optical mismatch between the liquid crystal droplets and the polymer matrix, which disappears when the field is applied. This work is in collaboration with the Mathematics department and the Institute of Surface Chemistry, Kiev.

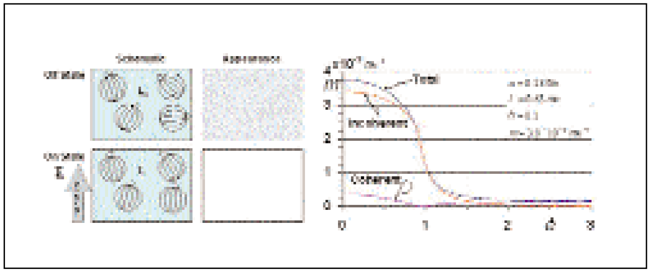

Figure 11 (Left) When an electric field is applied, the molecules line up and the appearance of the liquid crystal changes from opaque to clear (Right) Computer calculation showing decreased scattering at higher fields

Flexible Displays

Twisted Nematic liquid crystal systems are used in many optical devices. By simulating these devices on a computer their characteristics can be found prior to manufacture, thus saving both time and money during the design phase. One particular device in development is a flexible liquid crystal panel that could be worn on clothing or used as a replacement to newspaper. This device has to be very stable under distortion so that the display does not change colour when it is compressed, as happens to current liquid crystal displays.

In order to fine-tune the properties of such a device we must model the behaviour of liquid crystal defects as the device operates - this virtual prototyping is highly cost effective. We solve a coupled set of Euler-Lagrange equations to determine the equilibrium state of the liquid crystal system using a non-linear multigrid method. This work is in collaboration with Mathematics and the Defence Research Agency (DERA, Malvern).

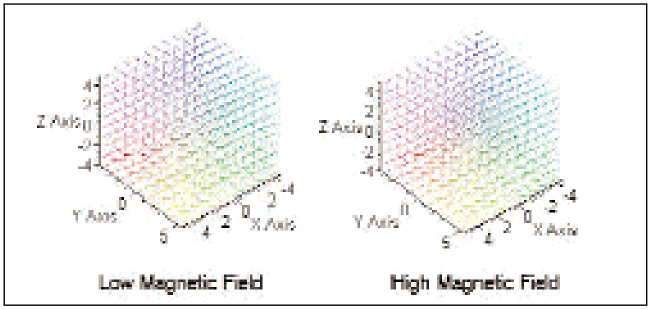

Figure 12 Molecular Director orientation at (left) Low magnetic field (right) high magnetic field. As the field increases, the molecules line up with the magnetic field which is point along the z-axis.

Multi-level Algorithms & Data Analysis

Fast methods for determining approximate solutions to equations governing a system are used extensively in computational steering. An engineer or scientist designing a new device is able to explore novel new material designs interactively by modifying the properties of the device and obtaining an approximate characterisation. If the design looks promising a more detailed and accurate calculation may follow. We are developing a number of 'multi-level' algorithms for eigenvalue problems and the solution of partial differential equations.

Fast Spectral Eigenvalue solvers

In collaboration with the Physics department, we are developing methods for estimating the eigenvalue spectra of large matrices. The methods construct the power spectrum of a density function using both Fourier series and Maximum Entropy reconstruction methods. The user of such methods only needs to implement matrix vector multiplication. Thus large sparse problems can be tackled effectively.

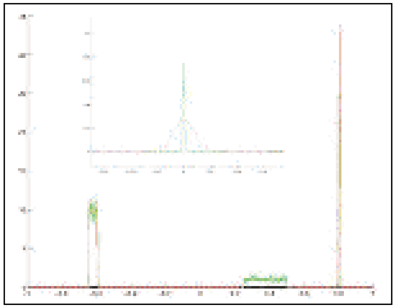

Figure 13 The true spectrum of this 7000 square matrix is shown in green, and the spectrum reconstructed using the Maximum Entropy method is shown in red. The inset shows that even the single eigenvalue at zero is successfully located using only 50 iterations with 50 different starting vectors.

Maximum Entropy Data Analysis

We have used the Maximum Entropy method to estimate the probability of each of the 14 million tickets being chosen by players in the UK National Lottery. As data, we used the numbers of winners in the 3, 4, and 5-match categories and the total number of tickets sold in each of the first 113 draws. We have computed the marginal distributions for players choosing single numbers and pairs of numbers. A striking conclusion is that players preferentially pick numbers towards the centre of the ticket. By choosing unpopular combinations of numbers, one's expected winnings can be doubled. This work was performed in collaboration with the Physics department.

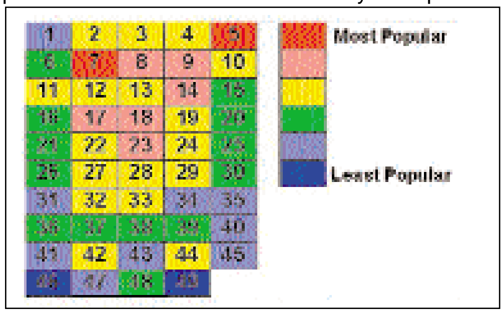

Figure 14 From our estimate of the popularity of each of the 14 million tickets in the UK National Lottery, we deduce the popularity of individual numbers. The results were derived using a commodity supercomputer designed and built in our research group. Players prefer to pick lower numbers and those towards the centre of the ticket

Environmental & Biological Modelling

The behaviour of large scale environmental and biological systems, such as coastlines, ice sheets and interacting populations, is often governed by complex non-linear equations. This requires high performance computing to allow the system to be modelled to sufficiently high accuracy and over realistic timescales. We are developing a number of parallel computational models which reduce the computing time required for solution. Understanding and modelling the potential environmental impact of climate change is one of the key challenges of this century. In the long term our research will enable the development of sophisticated coupled models for a range of environmental and biological systems.

Interferometric Synthetic Aperture Radar

Interferometric Synthetic Aperture Radar (InSAR) is used to derive Digital Elevation Models of formerly glaciated terrain, from which volumes of sediment are used to study subglacial flux. We are currently calibrating our estimates of drumlin volumes using a region around Malham Tarn and a site in South Western Scotland by comparing OS digital elevation maps and spot heights against our InSAR generated maps. We are also investigating the ability of InSAR mapping at different frequencies (C and L bands) to penetrate tree cover. This will allow us to study the effects of glacial action on the landscape in previously remote areas. Our particular interest is in the Canadian Shield, which is both inaccessible and largely tree covered, but has an interesting glacial history. This work is in collaboration with the geography department.

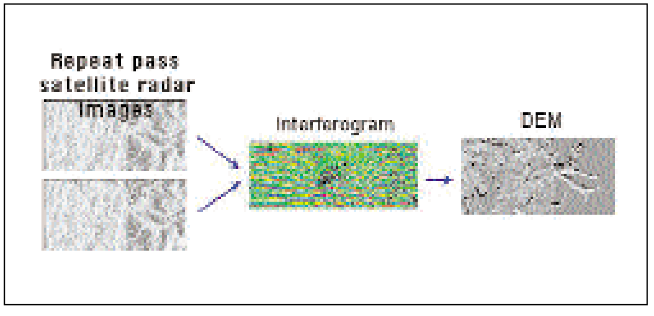

Figure 15 Two repeat pass satellite radar images are used to create an interferometric pattern, from which a digital elevation map is derived

Energy Balance of Ice Caps

An energy balance model is being developed for use on the Langjokull icecap. The model calculates the various components of the energy balance from meteorological data collected at a site on the icecap. The dataset is extrapolated to a grid covering the icecap, assuming the meteorological conditions are homogenous except for changes due to elevation. Initial use of the model with a limited data set has shown that the relative sizes of the various fluxes are reproduced well. However, the total melt rates predicted are beneath the levels expected from the scant field measurements. The aim is then to use data collected in the field this year, along with records being obtained from the Icelandic Meteorological Office, to provide a dataset covering the ablation seasons from recent years. Satellite images will be used to help constrain variables used in the model and to help assess the accuracy of the predicted energy balance. Finally, the energy balance model will be incorporated into a numerical model of the Langjokull Icecap. This work is in collaboration with the Geography department.

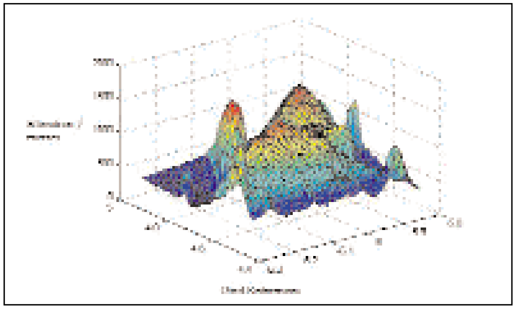

Figure 16 Digital terrain model of Langjokull icecap (exaggerated vertical scale).

Numerical Modelling of Ice Flow in Antarctica

The Antarctic Ice Sheet is the largest ice mass on Earth, with the West Antarctic Ice Sheet alone containing enough frozen water to raise global sea level by 6m. Understanding the dynamics of ice flow in such a vast region is a key issue in glaciological research. Highly non-linear equations are used to model ice flow, and these are computationally expensive to solve. By parallelising a three-dimensional ice sheet model, we can simulate flow over the entire Antarctic ice-sheet at a finer resolution than previously possible. This allows detailed analysis of the basal thermal regime, and may identify subglacial lakes and regions of fast ice flow. The effects of changes in geothermal heat from the underlying bedrock can also be assessed. This work is in collaboration with the Geography department.

Cooperation in Groups

There are three central unanswered questions in anthropology, which may be summarised as "Why isn't Homo sapiens hairy?", "Why is sex fun?", and "Why are primate brains so big?" In this project, we have addressed the third of these. The brain is an expensive organ to maintain: in humans it accounts for 2% of body volume, but consumes more than 20% of the body's resources. This is evidence for clear selection pressures favouring its increased size. It has recently been suggested that there is some evidence for a positive correlation between neocortex ratio and group size in living primates. The neocortex is the "thinking part of the brain" and is considered to be "the main anatomical index of cognitive capacity." We have constructed a model for cooperation in groups, in which players are able to base their future play on information stored about previous experiences. The results from this model show that players using a larger database of information are favoured in larger groups. This is consistent with the conjecture that living in larger social groups was one of the selection pressures which favoured increased brain size in primates. This work is in collaboration with Mathematics and Archaeology.

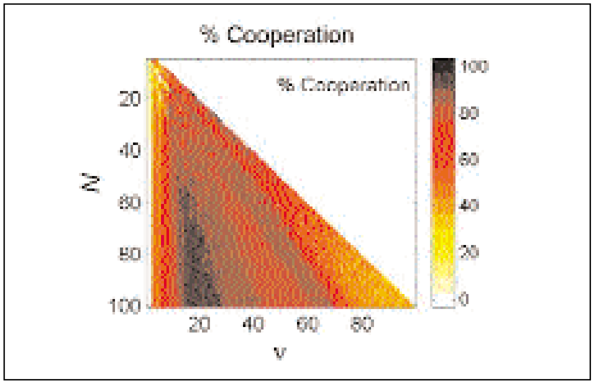

Figure 17 Percentage of cooperation in group as a function of group size (N) and number of interactions per individual (v)

Evolutionary Stable Reproductive Strategies or "The Cost of Sex"

Why sex prevails in nature remains one of the great puzzles of evolution. Sex has an immediate cost relative to a sexual reproduction, since males only express their contribution to population growth through females. With no males to sustain, an asexual mutant can double its relative representation in the population in successive generations. This is the widely-accepted 'two-fold cost of males.' Many studies have attempted to explain how sex can recoup this cost from fitness benefits associated with the recombination of parental genotypes, but these require complex biological environments that cycle over evolutionary time-scales. In contrast, we have considered the ecological dynamics that govern asexual invasion. We demonstrate for the first time the existence of a threshold growth rate for the sexual population, above which the invasion is halted by intraspecific competition. The asexuals then exert a weaker inhibitory effect on the carrying capacity of the sexuals than on their own carrying capacity. The stable outcome is coexistence on a depleted resource base. Under these ecological circumstances, longer term benefits of sex may eventually drive out the asexual competitor. This work was done in collaboration with the Biodiversity and Ecology Division in the School of Biological Sciences.

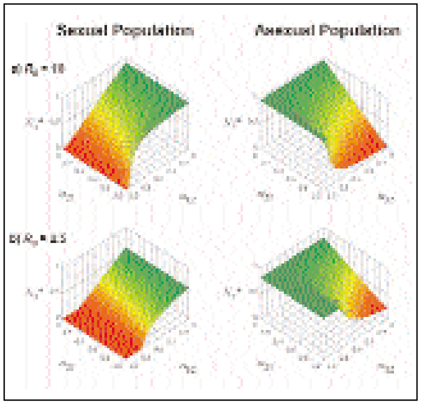

Figure 18 The influence of competition coefficients α_{12} and α_{21} on equilibrium densities of sexual and asexual populations. Sexual population with (a) high capacity for growth, (b) lower capacity for growth

Numerical Modelling of Long-term, Large-scale Coastal Evolution

Up to sixty-six percent of the world's population inhabit the coastal fringe of the world's landmass. It is no wonder then that in recent years much concern has accompanied the stories of accelerating sea-level rise and its potential physical and social consequences.
With a best estimate of a 50cm rise in sea level by 2100, it is clear that this issue demands great attention. The consequences of such an increase are not well understood and it was not until recently that the investigation of long-term, large-scale coastal evolution was deemed necessary, contrary to the growing trend of small-scale research. Understanding how the coastal system has responded to environmental forcing over the long-term during the past is essential for predicting possible future scenarios. The coastal system can be modelled by a set of partial differential equations that represent the highly complex, non-linear relationships of those physical components comprising the coastal zone. They allow the environmental forcing to be varied (e.g. the wind and wave climate), so that the sensitivity between components in the coastal zone can be identified.
These insights can be projected forward in time to provide a more complete understanding of coastal behaviour in the future.
Preliminary results using an explicit finite-difference scheme with periodic boundary conditions are shown below. A uniform beach with a transverse trough, Figure (a), and an offshore wave height of 2m at an angle of 210° degrees are used as input. Figure (b) shows the wave-induced current velocities with a clear rip current and distinctive eddies. Horizontal mixing has shifted the rip in the longshore direction. Figure (c) shows the water surface displacement (indicating zones of set-down and set-up) and Figure (d) displays the shoaling wave height. Such current patterns are significant in the long-term evolution of the coast. They are forced by stochastic phenomena (e.g. waves and wind), so Monte Carlo techniques that simulate these features probabilistically are preferable. This work is in collaboration with the Geography department.

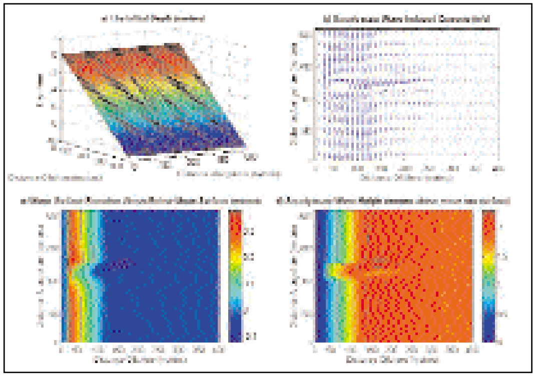

Figure 19 Results from wave model (see text for details)

Postgraduate Studies

Postgraduate studies in applied computational algorithms would suit students interested in developing new algorithms, modelling next generation devices and complex systems, using large scale parallel computational systems and advanced data intensive visualisation methods. All of this work is in collaboration with leading researchers in the particular application area.

Social Activities

We are a lively young research group and often go out for meals, to the cinema and theatre, sailing, bowling, and into the New Forest.

Resources

Within the group we have two clusters consisting of 8 DEC Alpha NT workstations and 9 Intel/ AMD Linux PCs. We also have access to Engineering Faculty's SG Origin 2000 and cluster computing facilities.

Postgraduate Research in Electronics and Computer Science

Some key facts are:

- The Electronics and Computer Science Department is the largest department at Southampton University and also probably the largest department specialising in electronics and computer science in the country.
- Our research activities are currently organised under eight research groups and three research centres:

Cognitive Sciences Centre	www.cogsci.soton.ac.uk
Communications	www.comms.ecs.soton.ac.uk
Declarative Systems and Software Engineering	www.dsse.ecs.soton.ac.uk
Electrical Power Engineering	www.epe.ecs.soton.ac.uk
Electronic Systems Design	www.esd.ecs.soton.ac.uk
Intelligence, Agents, Multimedia	www.iam.ecs.soton.ac.uk
Image, Speech and Intelligent Systems	www.isis.ecs.soton.ac.uk
Microelectronics	www.micro.ecs.soton.ac.uk
Optoelectronics Research Centre	www.orc.soton.ac.uk
High Performance Computing	www.hpcc.ecs.soton.ac.uk
Quantum Technology Centre	www.qtc.ecs.soton.ac.uk

Some of these groups are larger than other departments in the University!

- In the last national Research Assessment Exercise – the mechanism by which the Government assesses the research excellence of each University department – the Department was awarded a grade 5 for Computer Science and a 5* for Electronics. Grade 5 indicates that our research is recognised as being internationally competitive and Grade 5* is the top grade allocated to the few departments in the country that are world leaders in their subject.
- The University is currently ranked third in the UK for volume of research income from EPSRC, and is the fourth highest recipient of EU funding.
- According to statistics compiled by ISI in Philadelphia, based on their database of high impact papers in the field of Electronic Engineering, the Electronics and Computer Science Department has consistently been ranked in the top ten in the world over the past 15 years.

  Further information on how to apply for a PhD in the department, including information on fees and opportunities for financial support, can be found at the web-site: www.ecs.soton.ac.uk/admissions, or can be provided on request.

General enquiries and requests for further information should be sent to:
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Telephone +44 (0) 23 8059 2882
Fax +44 (0) 23 8059 4498
e-mail PhD_Admissions@ecs.soton.ac.uk
Web: http://www.ecs.soton.ac.uk/admissions

Further information on research in the department can be found on the world-wide web at http://www.ecs.soton.ac.uk

You can also download application forms, request further information and see the latest information on fees and funding opportunities at this site.