Issue 2 • January 2006

Newsletter

UNIVERSITY OF CAMBRIDGE
Department of Engineering

In this issue...

Executive Introduction

Since the introduction of the Department strategy two years ago, we have been busy bringing our plans to fruition.

The Electrical Engineering Division has moved to its new home on the West Cambridge Site bringing together its 20 academics, 52 postdocs, 160 PhD students and 12 support staff in a new state-of-the-art facility. The Nanoscale Science Laboratory is nearby along with the Whittle Laboratory and Schofield Geotechnical Centre. Plans for the Institute for Manufacturing to move to a new building close by are also progressing well, now that it has outgrown its space in Mill Lane.


The new Electrical Engineering Building

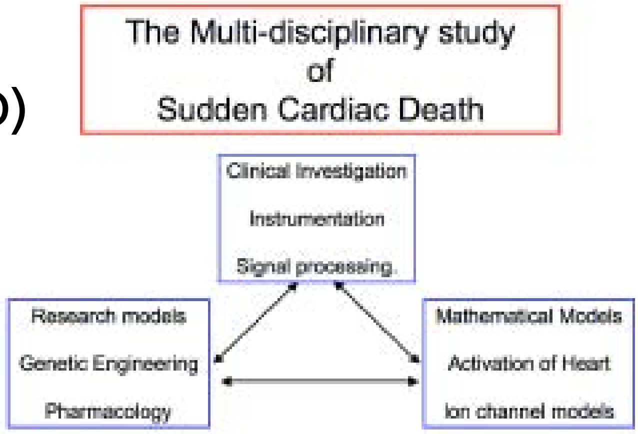
Meanwhile, we have secured funding for significant work to improve the Trumpington Street Site and the moves to the West Site have created enough elbow room for us to get started on these. Structural Engineering and the Language Unit already have new facilities. Lecture Theatres 1, 2 and 4 are being refurbished. The fast-growing Engineering Design Centre (EDC) will get new space. Sustainable Development, which is one of our strategic themes, and Computational Fluid Dynamics will move alongside the EDC to enable closer collaboration. Our other two themes, Engineering for Life Sciences and Cognitive Systems, will also benefit from new facilities.

Many other improvements to our teaching and research space are planned to benefit the core strengths represented by our Divisions and Groups. We have done well to win funding so far, but much more is needed to complete the programme of work. We are tying these needs together with those for funding academic posts, undergraduate bursaries, PhD studentships, developments in teaching, outreach, new lines of research, etc. into a fundraising plan which is closely coordinated with the University's 800 year anniversary campaign.

The articles in this newsletter give just a flavour of the many exciting developments, which have taken place in the Department over the past six months.

Further information:
If you want to learn more about the Department's plans and activities, then please visit our website www.eng.cam.ac.uk, or contact Philip Guildford, Director of Research 01223 332671, pg28@cam.ac.uk

Predicting the risk of Sudden Cardiac Death (SCD)



Dr Richard Saumarez, a medic and engineer here in the Department, is working with a multidisciplinary team to find a method of predicting the risk of sudden cardiac death, using a combination of mathematical models, research studies and clinical investigations.

One of the aims of his study is to find out which patients at risk of sudden cardiac death are in need of an Implantable Cardioverter Defibrillator (ICD) and which patients are not. Like a pacemaker, ICDs are implanted under the skin. Leads run from the ICD into the heart, and the device monitors the heart to detect any abnormal rhythms. If a dangerous arrhythmia is detected, the ICD delivers an electrical discharge between the lead inside the heart and the casing of the ICD to restore the heart's normal rhythm and prevent sudden cardiac death. The ICD can also act like a pacemaker if the heart is beating too slowly.

ICDs are implanted when tests indicate that a problem with abnormal rhythms may occur. Unfortunately the current tests do not allow reliable predictions of future heart condition. This means that many ICDs are implanted on a precautionary basis, but no heart problems occur and they are never required to deliver a corrective shock. This is a serious issue as an ICD is a very expensive piece of equipment costing approximately £25,000, the procedure to implant the device carries risk, it can trigger unnecessarily causing pain, and patients with ICDs have been found to have a high rate of depression. An improved test would help ensure that only those patients who really need an ICD get an ICD, with clear benefits firstly for the patient and secondly for the health service.

Sudden cardiac death occurs when the heart's abnormal rhythm – ventricular fibrillation – cannot pump an adequate amount of blood to sustain life. Richard's research has shown that the risk of sudden cardiac death can be predicted by measuring how the response to a controlled electrical stimulus spreads through the heart. The heart's response is recorded showing, in the case of patients at risk of sudden death, delayed and fragmentary conduction through the heart in response to a stimulus. This technique is called 'paced electrogram fractionation analysis' (PEFA). In the course of a number of studies, the PEFA technique has been tested in over 680 patients and has been shown to apply to all diseases that have been studied and to be predictive of sudden death, and hence the need for an ICD, in Hypertrophic Cardiomyopathy, which is one of the commonest causes of sudden death in young adults.

Animal models of some diseases that cause sudden death, created in Dr Andrew Grace's laboratory (Biochemistry) show a striking similarity to humans when investigated using the PEFA technique. A new generation of equipment is being developed to refine the accuracy of the PEFA results. Professor Bill Dawes is working with Dr Saumarez to construct mathematical models to simulate behaviour of the heart and its response to electric impulses, so that the equipment and analytical methods can be refined to deliver more accurate results. Professor Dawes' role exemplifies the multidisciplinary nature of this work, as his skills and experience of mathematical modelling are founded on his world-leading work on the mathematics of fluid mechanics.

There has been a high regional take up of the PEFA technique established at Papworth Hospital NHS Trust and East Anglian cardiologists now refer patients for assessment. The technique enables patients requiring ICDs to be identified more reliably. In addition, test results giving the all clear can provide invaluable reassurance to patients who had previously held concerns about their family's history of sudden cardiac death. It seems likely that the PEFA technique will be adopted within the NHS.

The design of equipment for commercial exploitation of PEFA has been facilitated by a Medlink Grant that has had Papworth NHS Trust and Cambridge University as partners. The Medlink programme has now been successfully completed and the Department of Health is satisfied with the result, giving it a highly successful rating. The success of the project will accelerate the uptake of the technique and will be used to guide clinical decision making on ICD prescription.

Multiple studies have identified family history as a strong and independent risk factor for sudden cardiac death. Dr Andrew Grace and his team have the largest international collection of DNA samples from patients with a family history of sudden cardiac death, which will be analysed in collaboration with the Wellcome Trust Sanger Institute. This will contribute to a recently established international network to pool databases, sample collections, technologies and expertise to further the understanding of sudden cardiac death.

Further information:
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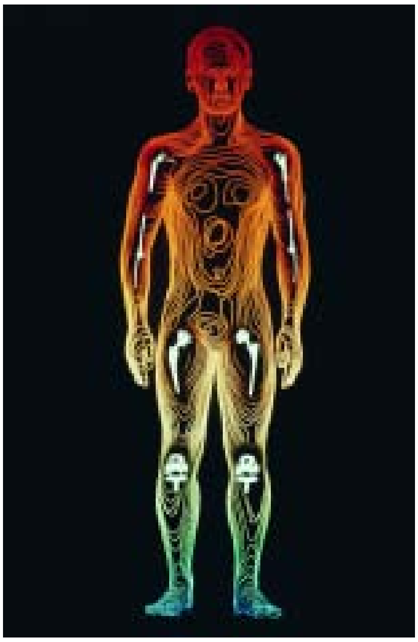
The Puppet Master: How the brain controls the body



This year's Francis Crick Lecture was given by Professor Daniel Wolpert from the Department of Engineering. The Francis Crick Lecture is a prize for outstanding biologists and was established in 2003 following an endowment by Dr Sydney Brenner CH FRS, joint winner of the 2002 Nobel Prize in Physiology or Medicine.

Daniel is developing Engineering for the Life Sciences here in the Department, co-ordinating research and teaching that relate to the interplay between Engineering and the Biological and Medical Sciences. Engineering for the Life Sciences is a key theme within the Department's strategy and offers a significant opportunity as the demand grows for a quantitative mechanistic understanding of biological systems.

The effortless ease with which we move our arms, our eyes, even our lips when we speak masks the true complexity of the control processes involved. This is evident when we try to build machines to perform human control tasks. While computers can now beat grandmasters at chess, no computer can yet control a robot to manipulate a chess piece with the dexterity of a six-year-old child. A major factor that makes control hard is the uncertainty inherent in the world and in our own sensory and motor systems. Daniel explained how the brain deals with this and demonstrates that a key feature of skilled human motor performance is the ability of the brain to perform optimally in the presence of uncertainty.

Further information:
The Royal Society, Francis Crick Lecture, website http://www.royalsoc.ac.uk/

A new liver tissue probe to help save lives

Dr Paul Robertson, Dr Tim Wilkinson and PhD student Bryan McLaughlin from the Department of Engineering have recently secured funding from the Medical Research Council (MRC) to develop a probe that can be used to determine the quality of human livers prior to organ transplant. Throughout the organ transplant procedure, liver tissue undergoes irreversible thermal and chemical changes that are detrimental to the recipient. In severe cases, this tissue degradation can be fatal. Sometime ago, Paul was approached by Mr Chris Watson from the Department of Surgery at Addenbrooke's hospital to develop such a sensor, and this project follows on from an initial study using a prototype electronic probe built in the Department of Engineering.

Fatty Liver Disease, inflammation, and fibrosis of the donor organ are known to be key factors in determining the pre-transplant suitability and post-transplant health of an organ. The screening process would benefit from an accurate, rapid and point-of-use instrument to provided surgeons with a quantitative assessment of the tissue quality. Donor organs are a scarce resource, hence it is crucial to use as many as possible of those organs available; but this must be balanced by the fact that making the wrong decision about the quality of a liver may be fatal.

Paul and his team are working on a dual sensing electro-optical system which combines Radio Frequency (RF) and Near-Infrared (NIR) sensing techniques. Diseased or fatty tissue has very different physical properties to healthy tissue and so the sensor should be able to discern tiny nuances between them. Hybridizing these two sensing techniques will yield superior measurements to those obtained by using either of these techniques independently.

Prototype probe with calibration solutions

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Digital Pygmalion project: from photographs to 3D computer model

Professor Roberto Cipolla's Digital Pygmalion project brings a handful of photographs of a sculpture to life as a high-resolution 3D computer model. Together with Dr Carlos Hernández Esteban, they have produced breathtaking results, which will guide Antony Gormley in scaling up his sculpture from life-size to be over 25 metres high.

"Roberto's work is unique in the world: it's extraordinary to get a fully rotational model from a standard single-lens digital camera." Antony Gormley.

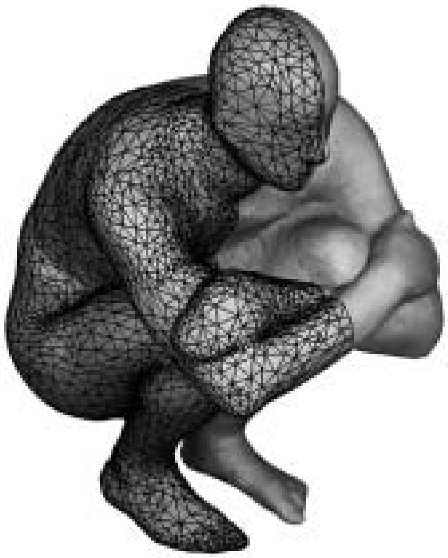
Roberto and Carlos visited the artist recently to take photographs of the sculpture and then used their world-leading computer vision techniques to construct a complete 3D model of the piece. The results are not only technically impressive but are also visually stunning.

The picture of the sculpture gives an idea of the underlying mathematical mesh. The software allows the user to look at the structure from any view point. The original texture of the sculpture can be overlaid on this skin. Lighting effects can be added. A full resolution image on a good screen looks perfect.

High resolution colour photos of the object in natural light are taken with a standard off-the-shelf camera. The silhouettes and the main interest points on the object are detected automatically in each of the different photos that have been taken. The position of the camera when each photo was taken can then be calculated.

The silhouette and texture in each photo is then used to guide the 'digital sculptor' to carve out the 3D shape. An accurate geometry and an accurate depiction of the appearance of an object is achieved automatically. In summary it is a new approach to high quality 3D object reconstruction. Starting from a sequence of colour images, an algorithm is able to reconstruct both the 3D geometry and the texture.

Highly accurate 3D modelling is very much in demand for:
- digital archiving of objects particularly items from museum collections
- face acquisition which is an important area for the movie and computer games industries
- Internet shopping, where low resolution 3D models are required to sell products successfully online.



Antony Gormley sculpture

The software was recently used to build a 3D model of a Henry Moore sculpture so that it can be viewed by potential buyers from around the world before its auction in London later this year.

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Dr Zoubin Ghahramani joins the Department

Zoubin Ghahramani has been elected to the Professorship in Information Engineering in the area of Cognitive Systems Engineering, a key theme within the Department's strategy. The Department is promoting a number of research themes that address major global challenges and are likely to attract high levels of external interest. Cognitive Systems Engineering addresses the problem of designing highly usable, fully integrated computer-based information systems that exhibit cognitive qualities. Zoubin has joined the Department to help co-ordinate research and teaching in this field.

Zoubin attended the University of Pennsylvania where he obtained a BA degree in Cognitive Science and a BSEng degree in Computer Science. He obtained a PhD in Cognitive Neuroscience from the Massachusetts Institute of Technology, then moved to the University of Toronto where he was a Postdoctoral Fellow in the Artificial Intelligence Lab of the Department of Computer Science. For the last seven years, he has been at the Gatsby Computational Neuroscience Unit, University College London, most recently as a Reader in Machine Learning. Zoubin also has an appointment as Associate Research Professor in the School of Computer Science at Carnegie Mellon University.

Zoubin's current research focuses on using Bayesian statistics as a framework or artificial intelligence and machine learning. Zoubin also works on applications of Bayesian machine learning to problems in bioinformatics, information retrieval, and pattern recognition. "I am excited by the possibilities that joining Cambridge University offers", he says. "Cambridge has great strength in areas related to machine learning, Bayesian statistics and cognitive systems, both within and outside the Engineering Department. I look forward to working with my colleagues in the Department and with the broader research community here to help establish Cambridge as a world leader in these areas."

Detecting and tracking individual people in a crowd

Professor Roberto Cipolla and Gabriel Brostow here at the Department are working on a project to detect and track individuals in crowd situations. Roberto and Gabriel met with London Transport and West Anglia Great Northern Railway (Wagn), who have different reasons to need to detect and track people in crowds.

London Underground use cameras at each of their stations to watch their passengers. The cameras are filtered to some extent; if no one is moving, those cameras are not shown on the monitoring screens. Hundreds of cameras are monitored by staff watching the images, as they switch from one camera to the next. It is impossible to have the manpower to observe all these cameras closely enough to watch for all suicide attempts. Approximately two thirds of suicide attempts are stopped by Underground staff. Tracking individuals more efficiently in crowd situations could improve this figure.

Ian Legg of Wagn needs information about when people travel. People buy tickets and may use them that day or the following month. Planning the number of compartments on each train and when to run trains would be more accurate if detailed pedestrian-traffic information was available.

In both scenarios people counting is required.

There have been various approaches in the past to tracking more than one person at a time. One method was successful at tracking three people. More recently there has been success at tracking up to 33 people. But crowds are often much larger.

A high level model for detecting one person would portray the person as a 'stick-figure' model and the camera would be looking for the body parts in relation to one another. If the camera detected these body parts in the correct order, the object is recorded as a person.

Predictably, to detect people in crowd situations, this high level model was tried but it does not transfer very well. In a crowd you may only see the top of a head or maybe a torso.

There is a need for accurate people detection in order to be able to move to the next step of tracking those people.

There is a method of detecting features based on recording each point where light meets dark. Such corner detection is a standard algorithm.

A new algorithm clusters the corner features, giving collections of dots that represent individuals. The dots are joined depending upon their proximity to one another and their coherent motion. The method can fail at times, for example, detecting two people as one when they are moving in unison like soldiers. If a person has a backpack or a rolling suitcase with them, the motion of these items may be slightly different to that of the pedestrian, and the luggage may be recorded as a separate person.

Another of the collaborators in this research is Niccolò Caderni of Legion International Ltd. Legion simulates how massive numbers of pedestrians would move within a public venue such as a transport terminal or sports stadium, footstep by footstep. Detailed models of how people walk and interact in crowds and in open spaces underpin their software. Legion simulations provide an understanding of crowd behaviour which substantially impact on the design and operation of crowded places. It is the algorithms for learning people-traffic models from real world video footage of crowds that Gabriel and his team are refining.

For more information and videos of the work contact:
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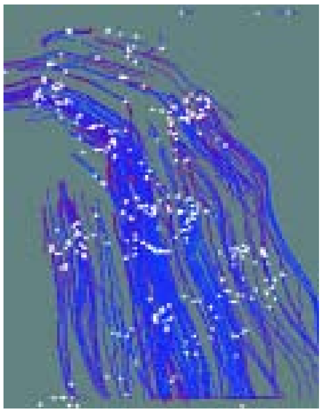
Individuals in this crowd are detected as shown in the image below



Detecting features by recording each point where light meets dark

An algorithm clusters the corner features, giving collections of dots that represent individuals

Augmented maps

Printed maps can be designed and printed to show fine detail and yet remain easy to take in at a glance. They are also simple to use in group discussions. However, a new map needs to be printed whenever information changes. Computer-based maps on a screen can change dynamically to represent a changing situation, but are not as easy to use. Dr Tom Drummond, Dr Gerhard Reitmayr, and Ethan Eade are combining the benefits of printed maps with the benefits of computer based dynamic maps, creating a dynamic high resolution map by augmenting printed maps with digital graphical information.

Tom's demonstration of the dynamic paper map comprises of a camera and a projector looking down at a paper map from above. The system performs interactive tracking of the map on a table top environment using the live video stream captured by the camera. Once the locations of the maps are known, the projector displays extra information directly on the maps.

The system also tracks user interface devices which can be placed on the map and which enable access to information that is linked to locations on the map. A simple physical prop, for example a piece of white card, becomes a selection tool and projection surface at the same time. Images referenced by the location pointed at are displayed in the white card.

The system also lets the user interact with real and virtual assets on the map using devices such as a personal digital assistant (PDA).

Tom and his team have implemented a flood control application for the city of Cambridge to demonstrate possible features of augmented maps. The River Cam running close to the city centre of Cambridge can flood the surrounding areas, which are lower than the water level of the river in a number of cases. In the event of real flood, the water line needs to be monitored, threatened

An augmented map showing the flooded River Cam. The image browser to the right shows views corresponding to locations and different stages of the flood.

areas identified and response units managed. Information provided by local personnel helps to assess the situation. An augmented map provides the ideal frame for presenting and controlling all the relevant information in one place and for a team of people to manage the situation.

A map of the interesting area is augmented with an overlaid area representing the flooded land at a certain water level. The image above shows details of a map of Cambridge overlaid with the current expansion of the River Cam.

The overlay changes dynamically with the water level which is controlled by an operator on the PDA device. Certain endangered compounds are highlighted in red with an animated texture when the water level reaches a critical level. Other information sources include images provided by ground personnel

An active entity brings up the control user interface on the PDA device

at various locations. Green icons represent the locations and directions of these images. Using the image browsing prop an operator can see the image and assess the local situation immediately. An emergency unit represented as a helicopter is visible on the map as well. By placing the PDA next to it, a corresponding graphical user interface appears on it to present more status information and give orders to the unit. Here its direction and speed can be controlled. Another function of the PDA interface accesses web pages of relevant places on the map. Purple circles represent corresponding locations and placing the PDA next to them presents the associated website.

Augmenting paper-based artefacts offers the advantages of high-resolution printing, familiarity to users, and tangible qualities with the flexibility of digital information. For future work, Tom and his team will further automate the calibration of the setup to make it readily deployable and mobile.

The project is supported by Boeing Company.

For more information contact:
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Mondialogo Engineering Award prize winners

Mike Khaw, Zern Chu Tay and Andrew Lamb from the Department's Solar Electronic Power course and Francis Mills from the Department's Centre for Sustainable Development are Mondialogo Engineering Award prize winners, with special jury recognition awarded for the outstanding quality of the project proposals. The competition is for projects that provide sustainable technical improvements in developing countries.

Mike Khaw, Zern Chu Tay and Andrew Lamb's proposal is to provide solar power to supply electricity for information and communication technologies to an isolated community in Malaysia.

Francis Mills is working with a team on improvement of modern energy services in rural areas of Ghana improving people's standards of living, while reducing forest depletion. The aim is the establishment of a small scale industry pilot project for the development of Jatropha diesel formulation that serves rural communities in Ghana.

Assessment of the projects was based on the following criteria: technical excellence, sustainability, feasibility and intercultural dialogue within the project group. More than 1,700 young engineers and students from 79 countries registered for the contest and formed 412 international teams.

For more information on the projects visit http://www.mondialogo.org/engineering-award/winners/

Tele Centre with photovoltaic-technology
Photo courtesy Mike Khaw

Jatropha fruit

Traffic pollution – measuring the real damage

Traffic fumes from individual vehicles are decreasing every year as engines become cleaner, but there are more vehicles on the road and the number continues to grow. The long term effects of living in urban areas and breathing in traffic fumes is widely studied, particularly in cities such as Athens and Los Angeles, where there is a lot of sunlight and not much air movement, resulting in photochemical smog from traffic fumes and industrial gases hanging in the air.

In the 1970s the Harvard Six Cities Study looked at morbidity and mortality and the correlation with diesel and gasoline particle levels in the environment and found a correlation which subsequent studies have born out.

In an urban environment typically 60–70% of the particles that we breathe in are from diesel or gasoline engines. Millions of particles are taken into our lungs with every breath we take, most of these pass back out again when we breathe out. The particles that are not exhaled travel in the human body, passing from the 'air side' to the 'fluid side' very quickly. Research elsewhere is being carried out to find out more about the tiny diesel particles that are able to travel through the lung walls into the bloodstream, what the body does with them and what the long term damage might be.

Here in the Department Professor Nick Collings and his student Jason Olfert are working on a new method to measure extremely tiny particles in exhaust gas. Vehicle engines continue to be designed to be cleaner and the particles that need to be measured are extremely small. The old method of analysing vehicle exhaust fumes would be to pass exhaust gas through a filter, weighing it both before and after. This method is not relevant for tomorrow's cleaner engines since there is too little mass collected to be reliably measured.

The tiny particles are given an electrical charge and they are then passed through a centrifugal machine that Nick and Jason have designed and built, that will separate the particles depending on their mass and the amount of electrical charge that they are carrying. Particles of the same mass-to-charge ratio can be separated using the machine and the particles can then be counted with an optical detector. Being able to measure the number and mass across the particle size range (approximately 5nm – 200nm) will help to better characterise, and more reliably measure the quantity of, the particle emissions from engines. While the precise mechanisms by which particles damage health remain unclear, it is important to measure the differentiating characteristics, and thus help the epidemiologists to disentangle cause and effect, followed by more cost-effective legislative action.

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Smart infrastructure taking the strain

Pipeline and BOTDR positions at Chingford

One of the challenges facing engineers in the 21st century is the maintenance, upgrading and safe operation of ageing infrastructure. Most high profile civil engineering projects specify the use of extensive monitoring systems to observe the influence of new construction on existing infrastructure. The successful evaluation of the effects of construction and also the long-term behaviour of infrastructure hinges on the availability and quality of appropriate measurements. The aim of a new project being conducted here in the Department of Engineering, funded by the Cambridge MIT Institute, is to contribute to the development of Smart Infrastructure by the commercialisation of an innovative but proven low cost fibre optic sensing system enabling continuous strain measurement by means of Brillouin Optical Time-Domain Reflectometry (BOTDR).

The critical deterioration of civil infrastructure has driven the search for new methods of rehabilitation and repair by incorporating sensors and developing remote systems that would allow monitoring and diagnosis of possible problems occurring. In the context of underground infrastructure, such as tunnels and pipelines, it is envisaged that structures will eventually be able to monitor themselves and inform owners of their state (Smart Infrastructure). Design limits are frequently based on strain developing in the structure. Although strain measurement is well established, current practice has until recently been restricted to measurement of point strains only by means of vibrating wire (VWSG) or metal foil strain gauges and more recently fibre optics utilising Fibre Bragg Grating (FBG) technology.

When instrumenting building components, such as columns or beams where the strain distribution is merely a function of the end conditions and applied loading, point sensors are suitable to define the complete strain profile. However, where structures interact with soil, (e.g. underground infrastructure such as foundations, tunnels or pipelines) or indeed in the case of a soil structure (road or dam embankments), the state of the structure is not fully understood unless the complete in situ strain regime is known. In the context of monitoring strain in piled foundations, tunnels, pipelines, slopes or embankments, capturing the continuous strain profile is often invaluable to pinpoint localised problem areas such as joint rotations, deformations and non-uniformly distributed soil-structure interaction loads.

BOTDR offers very exciting possibilities for major advances in strain measurement. The novelty of the technology is vested in the ability to measure strain along the full length (up to 10km) of a suitably installed optical fibre. When the fibre is strained, some of the light travelling down the optical fibre is scattered back to the source. In the case of Brillouin scattering, the frequency of the backscattered light is shifted by an amount proportional to the strain at the scattering location, which upon analysis provides the complete strain profile along the full length of the fibre (readings at minimum 50 mm spacing). This is a major advantage over conventional 'point sensing' techniques.

For extensive application to develop 'smart infrastructure', in which strain measurement becomes more routine than at present, cost is particularly important. The cost of a standard optical fibre is very low (from £0.1/m) compared to other point measurement sensors and can be employed over distances of several kilometres using a single continuous fibre. Most of the capital investment relates to the analyser (£68k), which can be connected to a number of fibres or be shared at different sites. BOTDR can be used with standard cheap telecommunication optical fibre cables wrapped around or embedded in structures, where a single optical fibre potentially replaces a very large number of point sensors, providing an economic and effective solution and having considerable potential as a system for long-term monitoring (an important criterion for 'smart' underground structures).

Research conducted here at the Department has focussed on developing BOTDR fibre optic technology for application to underground structures.

In London, the following installations have been made to date:

- **Bankside 123** (Cementation Foundations Skanska)
- **Thameslink Tunnel, King's Cross Station** (Railtrack and RailLink Engineering)
- **Chingford** (RWE Thames Water)
- **Farringdon CrossRail, Geotechnical Consulting Group** (GCG) **and Cementation Foundations Skanska**

There is also new work being carried out with the Highways Agency on monitoring slope failures along the M25 motorway.

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Inclusive Design

Professor John Clarkson Director of the Department's Engineering Design Centre (EDC) gave the opening presentation on 'Inclusive Design' at an Horizon seminar. Academics and some of their industrial collaborators were brought together to talk about design, technology, usability and the problems that seem to emerge whenever teams of professionals from different disciplines try to work together.

Demographic changes are leading to an increasing number of older people world-wide. Despite knowledge of this change and the considerable spending power of the older buyer, many companies are still selling products intended for a younger market. Take for example video and TV remote controls, which consistently defeat all but the most physically and mentally agile person. John and his team are currently working with Royal Mail, IDEO and the Design Council to highlight this problem, specifically by developing tools that will quantify those excluded from using a particular product. Only by advertising the scale of exclusion do they believe that they can encourage truly inclusive design. They are also developing novel approaches to computer design that will allow more disabled people to use computers.

Bill Thompson reported on John's presentation in his column on the BBC website "We can't allow our lack of interest in accessibility to go on a lot longer – independent living is an aspiration for older people today but it will be an imperative in 2050 because there will be nobody there to offer support. It's time to take usability a lot more seriously."

For more information:
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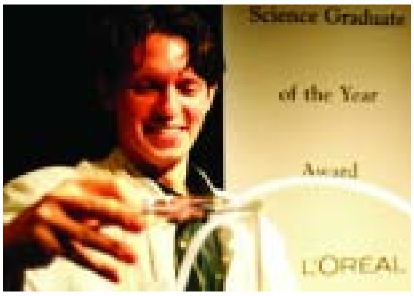
Website http://www-edc.eng.cam.ac.uk/inclusivedesign/



Tom Smith

Tom Smith wins *The Times* newspaper 'One Minute Pitch' competition

Tom Smith a Phd student here in the Department has won £100,000 as the winner of The Times newspaper 'One Minute Pitch' competition. Tom won the prize for his development of a cheap and efficient pump with no moving parts designed to help Third World farmers to irrigate their crops.

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Magnetic sensors – a new slant on an old technology

Dr. Paul Robertson and his team are working on a new slant to an old sensing technology. Flux-gate magnetic sensors have been around for many decades and are still used today for tasks such as geological surveys, aerospace instruments and even detecting submarines, as submarines disturb the Earth's magnetic field around them. These devices are usually quite large; assembled from coils wound on to magnetic cores. Paul and his team have developed new techniques to micro-fabricate flux-gate magnetic sensors, producing tiny versions of these sensors which are:

- extremely sensitive
- contained in a miniature package
- able to work over a wide frequency range

These properties allow the sensors to be used in a range of new applications including the measurement of electrical currents in circuits and the evaluation of the magnetic properties of materials – both of which can be achieved in a non-destructive manner.

One example of this is a magnetic microscope, in which the magnetic sensor is scanned over the surface of an item and the measured magnetic field is displayed as an image on a computer screen. Currently, magnetic microscopes are commercially available which use highly cooled superconducting sensors, but the sensors being developed here in the Department operate at room temperature – resulting in a much lower system cost.

Possible uses for such an instrument include surface defect detection in components and the development of ticketing, security cards, anti-counterfeiting devices and security features on bank notes, as all of these contain magnetic recording material.

Paul and his team are currently developing this technology with a local company for use in a new product – a novel type of current probe for use by electronics engineers. The project is now in the production engineering phase. Other areas of interest would be welcomed.

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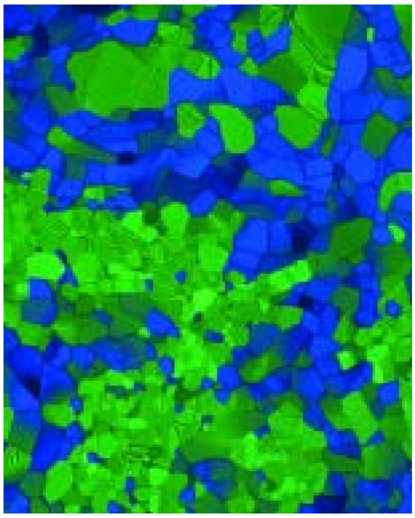
The Big Blue – Professor Coles and Dr Pivnenko publish in *Nature*

Liquid-crystal 'blue phases' can be just about any colour in the rainbow. This makes them potentially useful for all sorts of applications, from electrically switchable colour displays to light filters and lasers. But blue phases have a significant limitation: they exist over a very small range in temperature, typically no more than two degrees Celsius at most.

The Department's Professor Harry Coles and Dr Mikhail Pivnenko report a solution to this instability in the scientific journal *Nature*. They have discovered a class of blue-phase liquid crystals that remain stable over a very much wider range: from 16 to 60 degrees. The researchers show that their ultrastable blue phases could find some useful applications in optical technology. Typically, liquid crystals are made from rod-like molecules that line up in at least one direction while remaining mobile and disorderly in the others. In blue phases, this alignment of molecules takes a complicated form: the molecules assemble into cylindrically shaped arrays in which the direction of alignment twists in a helix, while the helices themselves criss-cross in three dimensions. The structure repeats regularly every several hundred nanometres, which means that it reflects visible light of a particular colour. The new blue phases are made from molecules in which two stiff, rod-like segments are linked by a flexible chain. The researchers say that this unusual structure is what makes the blue phase so stable. They show that the colour of the reflected light can be switched by applying an electric field to the material, and that this could be used to produce three-colour (red-green-blue) pixels for full-colour displays.



The colours show the differently oriented polydomain platelets.

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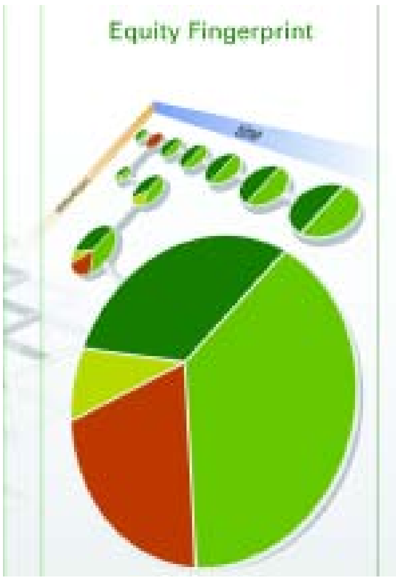
Equity Fingerprint – every business plan should have one

Q. How do you best make plans to maximise value in a knowledge-based business as it develops and grows?

A. Ensure that you fully understand the implications of how the equity in your enterprise is divided – and what will happen when you alter the balance.



The Department's Professor Bill Fitzgerald and PhD student David Excell have been working on an innovative software-based application called Equity Fingerprint which is of particular relevance to start-up entrepreneurs and young technology businesses. Bill and David are applying pattern recognition techniques developed in the Signal Processing Laboratory to recognise evolving trends within both successful and not so successful businesses. Bill saw the potential of applying pattern recognition techniques to the equity structure of company development, a unique approach to company analysis.

Equity Fingerprint is a product of the Cambridge Cluster: entrepreneurs and academics working together. It allows founders and shareholders to gain a clearer understanding of how value is being generated in the company and how they can plan more effectively for sustainable growth.

Equity Fingerprint helps answer key questions such as:

- How best to share the equity of my company at key stages in its development?
- When will I need to bring in outside expertise?
- What is the ideal stage to approach venture capitalists?
- When should I sell out?

Equity Fingerprint provides a visual representation of how shareholdings in a business change over time as outside investment is brought in and the Founders are diluted. Behind the software is a unique system for analysing data from a wide range of existing companies, allowing you to highlight the trends that are most significant for the success of your own business.

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http://www.equityfingerprint.com/

Space saving approach to satellite communications

Ken Teo and his team here in the Department of Engineering have come up with a much more efficient and compact way to send signals from satellites. They have managed to use an array of carbon nanotubes to create a device that replaces conventional heavy, bulky, high temprature, microwave amplifiers. The new electron source promises to revolutionise telecommunications and satellite communications in space.

Long range communications are a vital part of our lives for business, entertainment or just keeping in contact with friends and family. Much of this, especially to remote areas, is made possible through communications using satellite-based transmitters. There are typically 50 microwave amplifiers on board a satellite, each weighing about 1kg and measuring about 30cm in length.

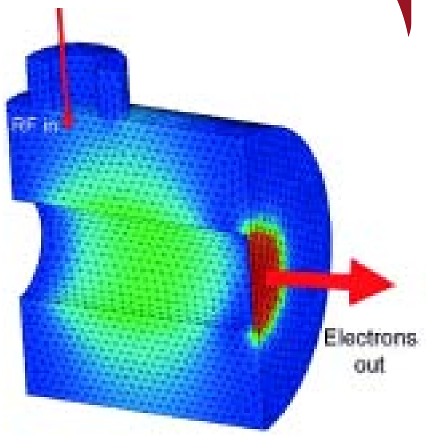
Currently it costs about 10,000 pounds sterling to send a single kilogram of payload (data) into space. There is an advantage, both in terms of cost savings and extra payload which can be carried, if the weight and size of the microwave devices are reduced.

The microwave amplification devices used in space today are based on what's known as hot cathode technology. Ken and his team have demonstrated that a cold cathode source, based on carbon nanotube technology, can deliver electrons directly at microwave, that is gigahertz, frequencies and hence can be utilized in these microwave devices without delay, with potential weight and size savings of up to 50%. This will not only reduce the cost and increase the capability of conventional satellite systems, but will also enable the drive towards very low cost micro-satellites which weigh about 10kg.

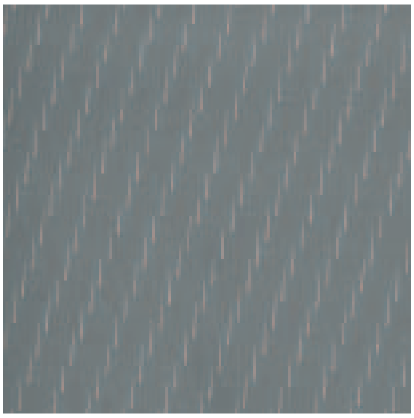
Carbon nanotubes are graphite sheets of carbon which are rolled up to form tubes. These tubes have diameters which are in the nanometer range and lengths from the micron to millimeter range. Carbon nanotubes are extremely conductive and have great mechanical strength. Ken and his team use carbon nanotubes as very sharp, highly conductive needles. The nanotubes are laid out into an array, with every nanotube having roughly the same height and diameter. They look like a bed of needles, but at the nanoscale. When these carbon nanotube needles are subjected to an electric field, such as that from an electromagnetic wave, they release electrons from their tips. By injecting radio frequency waves at the nanotubes, they are able to cycle them on and off at the frequency of the injected wave and thus create an electron beam at high frequency. They have done this at 1.5GHz and recently at 32GHz as well. Frequencies of 30Ghz and above, where there are plentiful channels, are where the communication links of the future will reside.

The new cold cathode source is very different from conventional hot cathode amplifiers. These have 4 parts: the direct current hot cathode electron source at 1000°c which generates a constant stream of electrons; an input stage to impose the signal onto the electrons; an output stage to retrieve the amplified signal from the electrons; and finally a collector stage to catch any wasted electrons. They are bulky, heavy, inefficient and slow to heat up.

In summary the advantages of this new carbon nanotube source are as follows. No heating is required and the source can be turned on and off instantaneously. The source and input stages of the microwave amplifier are also combined, producing a size and weight reduction. Finally, the whole concept of operation is different. With the conventional hot cathode source, we have a stream of electrons in which the electrons are modulated by speed to create bunches, and it is these bunches which are extracted as useful output. With the new cold cathode carbon nanotube source, the electrons bunches are instantaneously created at the source.



High Frequency CNT cathode



CNT emitter array

Further information:
http://www-g.eng.cam.ac.uk/cnt

To read an article in the journal Nature on this work visit http://www.nature.com/nature/journal/v437/n7061/full/437968a.html

A podcast of an interview by Ken for the journal Nature can be found at this link: http://www.nature.com/nature/podcast/index.html Click 12 October 2005 and fast forward 12 minutes 15 seconds.

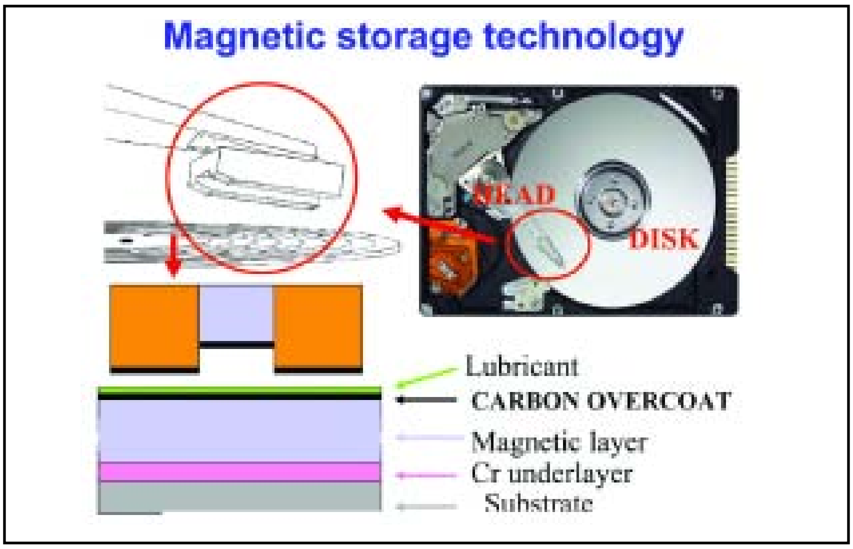
Ultrasmooth carbon for ultrahigh data storage density

Ultra-smooth diamond-like carbon surfaces are key to enable the ultimate storage density of 1 terabit / inch2 in next generation ultra-high storage density hard disks. Researchers here in the Department shed light on how these surfaces grow, the key to enabling design engineers and manufacturers to optimize the structure of these surfaces for this and other applications.

Coatings need to be smooth in order to reduce friction and prevent wear. Cinzia Casiraghi, Dr Andrea Ferrari, and Professor John Robertson from the Department have co-authored a paper with colleagues at the Fraunhofer Institute for Mechanics of Materials IWM in Freiburg and the University of Karlsruhe, published in the journal Science (Vol. 309, Nr. 5740, September 2, 2005 abstract, full text, pdf version), explaining how diamond-like carbon films grow and why they are almost atomically smooth. The ultimate purpose is to tailor the surface characteristics of coatings to any tribology application. In particular, ultra-smooth diamond-like carbon surfaces are key to enable the ultimate storage density of 1 terabit / inch2 in next generation ultra-high storage density hard disks.

Without them, PC hard disks would simply not work, bearings would wear out faster, and seals would soon start to leak. Diamond-like carbon films have a low coefficient of friction and a high resistance to wear: the ideal properties for interacting moving parts, such as those found in machine tools, racing car engines or microelectronic devices. Produced from ordinary carbon, it is the arrangement of atoms in the layer of film that determines its properties. Until now, the design of films with specific properties was based on empirical knowledge and a great deal of experimentation.

The importance of smoothness in diamond-like carbon films can be illustrated by the example of a computer hard disk. The read head spins over the surface of the magnetic disk at a height of a few nanometers. All that separates them is a thin film of lubricant and the protective carbon coating on the surface of the disk. Any roughness in this carbon film would impair the quality of the storage medium. As storage density increases, the distance between the read head and the data medium has to be reduced still further. To achieve the ultimate storage density of 1 terabit/ inch2 in next generation ultra-high storage density hard disks, every single layer of atoms counts.



Magnetic storage technology

In order to optimize the structure of films for this and other applications, and be able to deliberately manipulate their characteristics, design engineers and manufacturers want to understand how the atoms are laid down on the surface of these films and how the layer grows. The molecular-dynamic simulations and experiments undertaken by the teams of University of Cambridge and the Fraunhofer Institute for Mechanics of Materials IWM in Freiburg explain the ultra-smoothness of diamond-like carbons. In Volume 309, Nr. 5740 of the journal Science, published on September 2, 2005, the researchers present their new concept explaining the formation of almost atomically smooth diamond-like carbon films.

According to their model, the atoms pile up during the deposition process in an array of tiny heaps, rather like grains of sand being poured onto a flat surface. The next carbon atoms to land on the sides of these uneven structures pull other atoms with them as they slide downward, like someone walking on a loose gravel slope. The result is a kind of erosion on an atomic scale, leading to the much-cited extraordinary smoothness.

The mathematical formulae describing the formation and growth of diamond-like carbon films now open the way to the virtual design of surface structures with tailor-made characteristics.

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