


DEPARTMENT OF ENGINEERING
NEWS

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Wireless sensor networks:
creating 'smart infrastructure'
wins Telford Gold Medal

The University's first wind turbine

Awards and Prizes

Departmental News



UNIVERSITY OF
CAMBRIDGE

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Cover photo: Professor Neil Hault, Telford Medal winner (article on page 9).
Photo courtesy of Professor Neil Hault

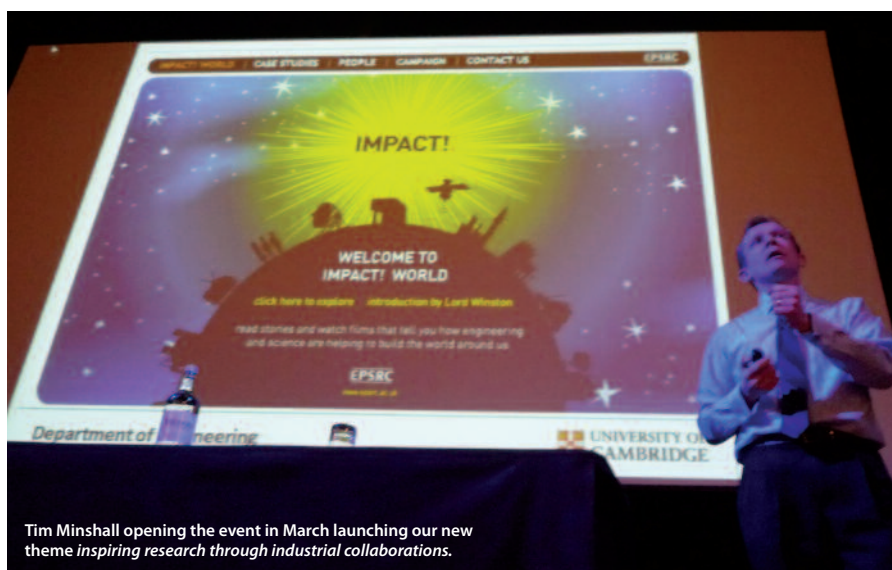
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The Department's new research themes

The world is facing many challenges and engineering lies at the heart of many of the much needed solutions.



Four new research themes bring structure to the department of Engineering's approach, gathering together multidisciplinary teams to find new ways forward:

- *energy, transport and urban infrastructure* aims to make our cities truly sustainable, which is an important objective now that more than half the world's population are city dwellers and this proportion will continue to grow.
- *uncertainty, risk and resilience* aims to better understand and engineer systems so that they can cope with automatically managing traffic in busy air space, protecting cities against earthquakes, spotting irregular financial activity, etc.
- *engineering for life sciences* aims to open a channel for creative research between biologists, clinicians and engineers leading to breakthroughs in the understanding of biological systems, clinical solutions, wider issues of healthcare and biologically-inspired solutions elsewhere in engineering.
- *inspiring engineering through industrial collaborations* aims to nurture the productive dialogue between industry and academia that escapes the clichéd dichotomy of blue skies versus applied research and development to create leading academic research with high industrial impact, a great tradition in this Department.

The Department is developing these themes together with government, industry and academics across a wide range of disciplines. The initial work is very encouraging. Recent events with industry and review by the distinguished members of our International Visiting Committee suggest that we are on the right track. Our position in the latest QS World University rankings shows that we are very well placed to make a difference. We are ranked top in general engineering. The latest *Guardian* UK University rankings place the Department as best for teaching engineering.

New Department of Engineering alumni web pages

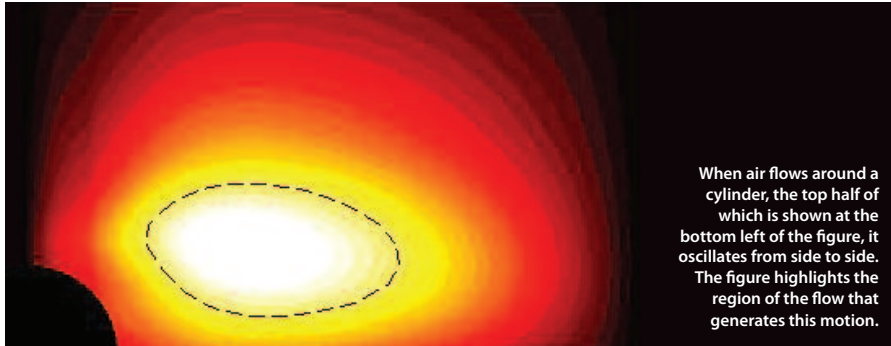
Keeping engineering alumni up-to-date with all the latest news and events within the department, the new engineering alumni web pages are now available at: www.eng.cam.ac.uk/alumni/. These web pages also offer a way for Engineering Alumni to stay in touch, get involved and give something back to the Department. If you have any comments or suggestions about the new pages, please contact the Engineering Research Office at research-office@eng.cam.ac.uk

An integrated engineering department founded on core strengths spanning all engineering disciplines and also cross-connected by four strategic themes:

- Energy, transport and urban infrastructure
- Uncertainty, risk and resilience
- Engineering for life sciences
- Inspiring engineering through industrial collaborations.

Cambridge leads Indo-UK Network into Advanced Instability Methods

Cambridge academics from the Engineering Department and the Department of Applied Maths and Theoretical Physics (DAMTP) have been organising workshops across India and the UK on new techniques in flow instability that could provide powerful new insights for engineers.



These techniques are similar to Computational Fluid Mechanics but, instead of showing how a flow behaves, they show the regions of a flow that are most influential in generating or eliminating a particular behaviour.

For instance, when air flows round a chimney, air can flap from side to side rather like a flag, causing oscillations in the chimney itself. If an engineer wanted to stop this flapping, these techniques would show exactly which parts of the flow are responsible and how they should be modified to prevent the flapping.

The same techniques can be applied to more complex situations, such as flames and, eventually, gas turbine fuel injectors.

The Advanced Instability Methods (AIM) Network was set up in January 2009 by Dr Matthew Juniper at the Department of Engineering, together with researchers at IIT Madras, DAMTP, Imperial College London, Ecole Polytechnique and the Nehru Centre in Bangalore. It is funded by Engineering and Physical Sciences Research Council. Since then, over 170 researchers have attended AIM Network events in the UK and India and six further workshops are planned in the next academic year.

The first grant arising from the Network, worth £800,000 over three years to Cambridge and Imperial College, has just been awarded. The proposed work is to apply these techniques to the flow around wind turbines and to the oscillations inside rocket and aircraft engine combustion chambers.

The AIM Network website: www2.eng.cam.ac.uk/~mpj1001/AIM_home.html

Cambridge academics named among most important figures in British science

The Times newspaper has named 12 Cambridge academics in their inaugural list of the 100 most important contemporary figures in British science.

The first ranking of contemporary figures in British science was released in *Eureka*, *The Times'* monthly science magazine.

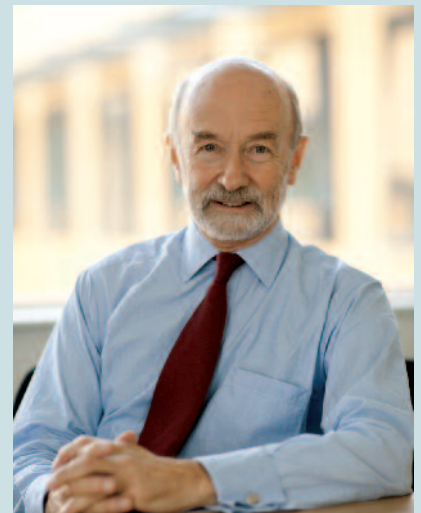
Professor Dame Ann Dowling, Head of Engineering, is included in the list. As the UK lead for the recent 'Silent Aircraft' initiative, Ann aimed to develop a conceptual design for an aircraft whose noise would be almost imperceptible outside the perimeter of a daytime urban airport. She is a Fellow of Sidney Sussex College.

Also on the list from the Department of Engineering is Professor Mark Welland, Director of The Nanoscience Centre. His research encompasses a number of aspects of nanotechnology ranging from sensors for medical applications to understanding and controlling the properties of nanoscale structures and devices. He is also Chief Scientific Adviser at the Ministry of Defence.



Knighthood in the Department

Professor Mike Gregory knighted in New Year Honours



After an early career in manufacturing engineering and management in the machine tool industry, Professor Gregory was the founder member of the Manufacturing Engineering Group at Cambridge, the forerunner of the Institute for Manufacturing (IfM), which he established in 1998. Professor Mike Gregory, Head of the IfM at the Department of Engineering, has received a knighthood in the New Years Honours for services to technology.

A strong advocate of the need to take a broad view of manufacturing, integrating management, technology and policy issues, Professor Gregory's work has always been closely linked with industry and government. He has published in the areas of manufacturing strategy, technology management, international manufacturing and manufacturing policy.

Professor Gregory said he was surprised and delighted to receive the honour. "I welcome this recognition of the important role that manufacturing industry plays – and will continue to play – in the economy," he said.

Professor Gregory's external activities have included membership of various government and institutional committees. He was Springer Visiting Professor at University of California Berkeley in 2008-2009. He chairs the UK Manufacturing Professors Forum and is a member of the UK Government's Stakeholder Group on Manufacturing.

Dr Gopal Madabhushi wins the British Geotechnical Association best publication medal

The British Geotechnical Association (BGA) has awarded its annual medal for the year 2009 to Drs Knappett and Madabhushi.

This medal is given for the best publication by a BGA member. This year the BGA committee has decided that the publication 'Knappett, J.A. & Madabhushi, S.P.G., (2009), Influence of axial load on lateral pile response in liquefiable soils, Part I: Physical modelling, Geotechnique, Vol.59, Issue 7, pp 571-581' should win the BGA medal. The award was made at the BGA Annual Conference held at the Institution of Civil Engineers.

Dr Knappett is a Lecturer at the University of Dundee (and a former student at the Department of Engineering, University of Cambridge). Dr Madabhushi is a Reader in Geotechnical Engineering at the University of Cambridge.

The award-winning publication forms a part of the book titled 'Design of Pile Foundations in Liquefiable Soils' authored by Madabhushi, Knappett and Haigh and published by Imperial College Press in 2009 www.icpress.co.uk/engineering/p628.html.

Dr Bill O'Neill is elected as Fellow of the Laser Institute of America

The Laser Institute of America has elected Dr Bill O'Neill as Fellow.

The grade of Fellow is the highest level of membership in the LIA. It is awarded to recognise members of the institute who have attained unusual professional distinction in the LIA mission areas of laser science and technology, and laser applications, and who have provided outstanding service to their field. Dr O'Neill was presented with his award at the 29th International Congress on Applications of Lasers and Electro-optics held in September 2010 in California, USA.

You can find out more about Dr O'Neill's research at: www.ifm.eng.cam.ac.uk/pp/projects/wo-research.html

Cise Unluer wins Dow Sustainability Student Award

Cise Unluer, a second year PhD student in the Geotechnical and Environmental Research Group, has won the Cambridge University 2010 Dow Sustainability Innovation Student Challenge Award.



Cise is pictured here with Peter Berns (right), Dow's Site Leader at their Kings Lynn plant

The competition is organised by The Cambridge Programme for Sustainability Leadership, for Dow, a company that connects chemistry and innovation together with the principles of sustainability to help address many of the world's most challenging problems.

The Challenge recognises and rewards students and universities for their innovation and research of sustainable solutions to the world's most pressing social, economic and environmental problems. Dow established the award to encourage and promote forward thinking in social and environmental responsibility and acknowledges the energy, commitment and enthusiasm of the students and their university professors, sponsors and facilitators who support their efforts of sustainable innovation and continued excellence.

Cise's work focuses on the sustainability optimisation of reactive magnesia cement porous blocks. Portland Cement, the most widely used construction material in the world with global production of over 2.5 billion tonnes/year, is responsible for 5-7% of global anthropogenic CO₂ emissions. As a result, one of the three major sustainability initiatives in the cement industry is the development of alternative more sustainable cements.

Reactive magnesia cements have emerged as such an alternative. They are manufactured at much lower temperatures; then, during the hardening process, they capture significant quantities of CO₂. This means that they not only save energy during manufacture but soak up CO₂ during their lifetime. Capturing significant quantities of CO₂ leads to significant strength gain. They are also potentially completely recyclable, can utilise significant quantities of wastes and are also expected to have excellent thermal properties and durability performance. Cise's work is investigating the contribution that changes in the cement and aggregates components, as well as inclusion of additives and admixtures and varying curing conditions, moves towards optimising the sustainability together with enhancing the technical performance of the blocks.

Cise will join the winners from the other five participating universities (Northwestern University, University of Michigan, Tufts University, Peking University, University of Sao Paulo) in the finals competition at Tufts University in October.

Cise's PhD work is partially funded by the David Ball Group, a local construction company.

Popcode

A new mobile phone application that adds virtual reality to real world objects



Have you ever struggled to follow a set of assembly instructions for flat-pack furniture? Simon Taylor, a PhD student in the Computer Vision group in the Machine Intelligence laboratory, and Connell Gauld, a graduate of the MEng course in 2010, have been working on a framework for adding virtual content to real world objects. They can bring written instructions to life using a technique called Augmented Reality (AR).

Augmented Reality has been a key research interest in Dr Tom Drummond's (a former member of the Computer Vision and Robotics) group for over 10 years. Recent advances in the performance of mobile phones along with continued development of computer vision techniques now make it possible for engaging AR content to be delivered straight into the hands of users.

Tom, Simon and Connell formed Extra Reality Limited in June 2010 in order to pursue commercialisation of the technology. Their first product is called Popcode. They released the first version of their Popcode application and a free Developer Kit at the end of August 2010. Popcode is a logo that when scanned with a mobile phone allows 3D models, animations, and interactive elements to be added to any textured flat surface. Unlike some existing "AR Browsers" that use GPS to provide the rough position of the phone, Popcode uses computer vision techniques developed during Simon's PhD to calculate accurately the position of the phone relative to the target surface. This more accurate position information can lead to more engaging and believable AR applications.

Objects with AR content are identified with the small Popcode logo which contains a unique ID for the content. When the application recognises the Popcode it will download the related content from the Internet and display it to the user. Connell's 4th Year Masters project looked at the method for embedding an identifier into a logo and the language used for describing the content, and this work has been directly incorporated into Popcode.

A demonstration video put together by the team shows how Popcode can help to make assembly instructions for flat-pack furniture more understandable by showing the exact steps required in 3D. This and other demo videos can be watched at: www.popcode.info/demos

The Popcode website at www.popcode.info shows some other possible uses of the platform. Some of the ideas include augmented business cards that can be updated over the internet and adding interactivity to static maps such as those displayed in cities.

Simon says "Although we've put together a few pieces of content ourselves to give some ideas about what is possible, we're really interested to see what uses other people will think of for the technology. The Developer Kit <http://www.popcode.info/developers> contains examples and documentation, so developers can get started working with Popcode and we'll be happy to help out with any problems people come across through our forums."

The team are continuing to work on improving the performance and capabilities of Popcode, as well as making the application available on more mobile phones.

Acknowledgement: The computer vision research behind Popcode was supported by The Boeing Company.

If you'd like to know more, you can find contact details for the Popcode team at www.popcode.info/about.

Distinguished lecture celebrates launch of construction research centre

Professor Dame Ann Dowling, Head of the Department of Engineering, recently welcomed more than 250 invited guests from the construction industry and academia for the inaugural Laing O'Rourke Distinguished Lecture.

Bill Baker, Structural Engineering Partner at Skidmore, Owings & Merrill LLP was the speaker. Bill has worked on a number of innovative structures during his career. His best-known contribution has been to develop the 'buttressed core' structural system for the Burj Khalifa in Dubai, at over 828m the world's tallest man-made structure.

His lecture, entitled "Inspired Dreams or Wilful Excess: the Ethical Dilemma of Iconic Structures", explored the challenges facing designers on both the technical and ethical front and examined the rationality underpinning the design and construction of a range of structures from the simplest to the iconic.

Professor Robert Mair, Head of Civil Engineering at Cambridge, thanked Bill for his inspiring lecture which illustrated the excitement and challenges of modern structural engineering.

The Distinguished Lecture Series has been established to recognise and honour excellence in the global construction engineering profession.

After his presentation, Bill was presented with the Inaugural Distinguished Lecture Award by Ray O'Rourke, Chairman and Chief Executive of Laing O'Rourke, who reaffirmed his view that our future is inextricably linked to the sciences and engineering.

The evening was also an opportunity to celebrate the launch of the newly-established Laing O'Rourke Centre for Construction Engineering & Technology in the Department of Engineering at the University of Cambridge.

This new multi-disciplinary academic centre of excellence has been made possible by the vision and generosity of Laing O'Rourke who have made a multi-million pound commitment towards its establishment and operation. The Centre aims to promote innovative thinking, research and teaching to provide a new vision for the shape of tomorrow's construction industry.

At a celebration dinner at King's College after the lecture, the Vice Chancellor, Professor Sir Leszek Borysiewicz, welcomed this new initiative and highlighted the impact of construction on all aspects of civilisation. He cited the potential advantages to be gained from expanding the outlook of the centre to interact with a broad spectrum of disciplines spanning not only all the engineering sciences but also the biological and social sciences and the humanities as these can also offer insight into how our built environment impacts societies.

To conclude the evening, Dr Campbell Middleton, Director of the new Centre, invited those present to help develop the vision for its future. He also took the opportunity to promote the new part-time Masters degree in Construction Engineering at Cambridge which will admit its first students in September 2011.

Laing O'Rourke Centre for Construction Engineering website:
www.construction.cam.ac.uk/

Student-led Projects and Industry Partnership

Student-led projects at the Engineering Department showcase the initiative, technical brilliance and team-working skills of our best students.

The projects have been of great value in terms of: educational and personal growth of the students; seizing public imagination around the World, raising the profile of modern engineering; and developing some really creative engineering solutions. The Student-led Projects and Industry Partnership (SPIP) exists to support student-led engineering projects at Cambridge and to facilitate interaction between industrial experts and students. The Partnership is generously funded and supported by Boeing, BP, Jaguar Land Rover and National Instruments.

The Department has a growing number of student-led projects each with a thriving team of students actively involved and making headway within their chosen field of interest. All of the student projects have their own individual sponsors, but the Department of Engineering provides an umbrella organisation called the Student-led Projects and Industry Partnership to make it easy for industry to learn about the projects and build links with the students involved. Industrial sponsors pay an annual subscription and are invited to regular forums. At each forum the student teams present the latest progress on their projects. The subscription money is allocated to the projects based on these performances and used to enhance specific facilities that the projects require in the Department.

A forum event took place last month. The industrial members present at the event were Richard Mills of the Boeing Company and Ajit Gokhale, David Baker and Hannah Wade of National Instruments.

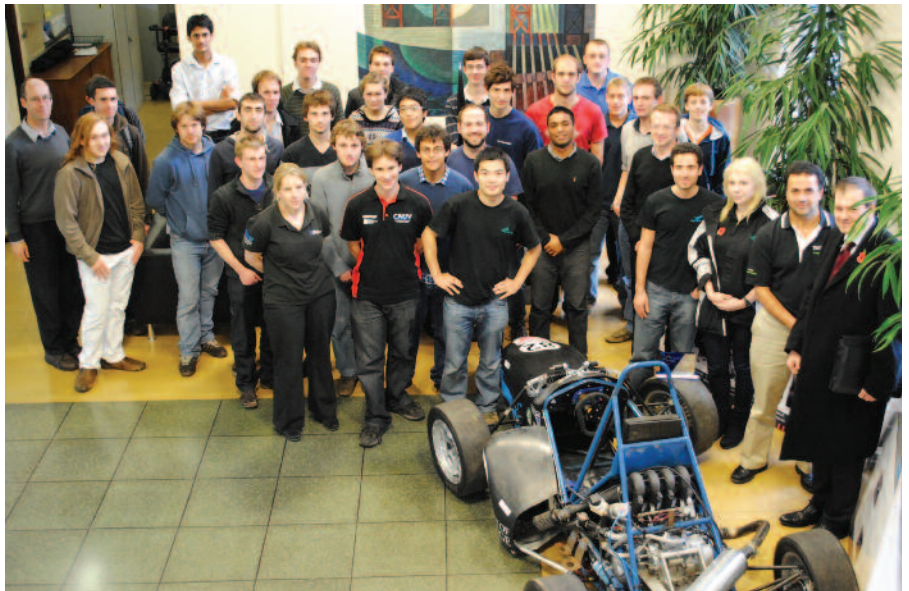
Project presentations were given by the respective project leaders:

Cambridge University Eco Racing

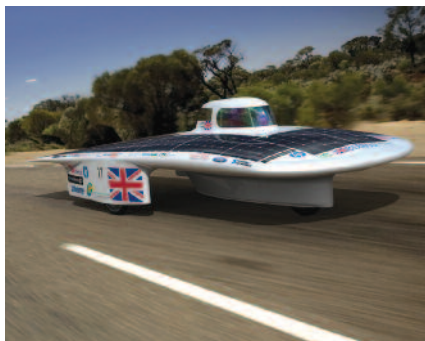
Cambridge University Eco Racing design, build and race solar and electric powered cars. They have recently driven a vehicle across Australia, completing 1616 km under solar power. Fourth-year (MEng) projects are regularly run on topics which benefit the design of the car. **Alisdair McClymont and Emil Hewage:** www.cuer.co.uk

Cambridge Autonomous Underwater Vehicle

The Cambridge Autonomous Underwater Vehicle team are working on a vehicle that can operate under the arctic ice. They have so far developed a stable and reliable hardware platform which was able to reach the final in the Student Autonomous Underwater Challenge Europe 2010 competition. **James Rickenbach:** www.srcf.ucam.org/cauv



Industrial sponsors and students meet at the recent forum



Cambridge University Eco Racing



Cambridge University Spaceflight

Cambridge Spaceflight

The Cambridge Spaceflight team work on the design and construction of low-cost systems, for low cost suborbital access to space. They use a helium balloon to take the payload up to an altitude of over 30 km. From there, they plan to use a rocket to complete the journey to outer space (100 km up). The picture shows the launch of a balloon carrying the teddies from a local school as part of the group's outreach activities.

Daniel Strange: www.cuspaceflight.co.uk

Full Blue Racing

Full Blue Racing is the Cambridge University Formula Student racing team. They design and build racing cars powered by motorcycle engines, and compete against other University teams at events in the UK and Europe. This year they competed in Formula Student UK on the Silverstone circuit and at Formula Student Germany on the Hockenheim circuit.

Yunlong Xu: www.fullblueracing.co.uk

Cambridge University Autonomous Flight

Cambridge University Autonomous Flight is an exciting new project started by a group of 15 enthusiastic engineering undergraduates aiming to design and build a micro autonomous air vehicle (MAV) and sharpen their skills in the fields of embedded systems, control theory, aerodynamics, project management and teamwork along the way.

John Ginger: www.srcf.ucam.org/cuaf

CUEWH engineering world health

Engineering World Health Cambridge is based at the Engineering Department working with local NGOs, in particular the Humanitarian Centre and Engineers Without Borders UK. CUEWH's primary aim is to use the team's engineering skills to help their partners meet healthcare needs in developing countries. To achieve this, they work with partner organisations who are able to effectively assess a healthcare need and highlight a problem, or set of problems, for CUEWH to try and solve.

Arron Rodrigues: www.ewh.org/cambridge

If you have a great idea for a new student-led project or you are a company wanting to get involved please contact the coordinator, Dr David Cole email: djc13@cam.ac.uk

PhD student Sam Bennett wins national volunteering award

Four students at the University of Cambridge have received Gold Awards from Volunteering England in recognition of their contribution to voluntary work.



Sam Bennett demonstrating engineering principles

A Student Volunteering Gold Award is presented for exceptional leadership, dedication and/or achievement and is a prestigious mark of excellence in student volunteering. This year's winners have demonstrated their commitment to volunteering across a range of areas.

Sam Bennett, an Engineering PhD student, is one of the four Gold Award winners. He has been an active volunteer for the Department of Engineering's Outreach team for a number of years.

As Science and Engineering Ambassador he has helped to promote engineering to local young people, through assisting groups of children to complete design-build-test projects, and mentoring gifted and talented students.

His nominator Joy Warde, the Department's Outreach Officer, said: "Sam has been an active student volunteer for the Outreach team from October 2006 when he joined the University as a PhD student. The Engineering outreach programme aims to promote the fun and excitement of Engineering to local young people. Teams of undergraduate and postgraduate students help make engineering and the University of Cambridge accessible through hands-on design-build-test projects.

"As part of our educational outreach programme, Sam is registered as a Science and Engineering Ambassador. The Science and Engineering Ambassadors scheme forms part of a UK National STEMNET programme to enhance young people's scientific and technical capabilities and raise awareness of the importance of these skills to society.

"Sam is a very enthusiastic, energetic and reliable volunteer who has participated in numerous outreach events involving school-aged children (aged 8-18) and their parents and/or teachers. So far he has donated over 350 hours of his time to the outreach programme over the last three and a half years. As part of his role as a Science and Engineering Ambassador he has:

- led whole class teaching for both primary and secondary schools,
- mentored gifted and talented school students,
- assisted small groups of children and their teachers or parents to complete a design-build-test project,
- given tours of the Engineering Department for schools,
- worked as part of the outreach development team to design new outreach resources,
- designed and delivered other University outreach projects e.g. at the Whipple Museum and on the Arts bus.

"Sam is a brilliant volunteer who works professionally and efficiently with the participating school children as well as other Science and Engineering Ambassadors, teachers and parents. He has demonstrated enthusiasm and commitment to all of the many activities for which he

has volunteered. He left Cambridge in August 2010 and he is greatly missed by the outreach team."

Emma Wenborn, Community Affairs Officer at the University, said "The Gold Awards are a fantastic opportunity to recognise the outstanding achievements of our student volunteers. Around 5,000 University of Cambridge students volunteer each year, giving 85,000 hours of time to community initiatives. The four winners have demonstrated exceptional dedication, leadership and achievement in their voluntary endeavours. They are an inspiration".

The Awards were judged by the University's Committee on Community Activities, which oversees community engagement activity across the University.

The Department of Engineering's Outreach webpages are at:
www.eng.cam.ac.uk/outreach

Excellence Award

Dr Tim Wilkinson receives a Mid Career Research Excellence Award from the International Liquid Crystal Society



The International Liquid Crystal Society (ILCS) has awarded Dr Tim Wilkinson with a Mid Career Research Excellence Award for pioneering work in liquid crystal device engineering, including many aspects of the application of liquid crystals in novel liquid crystal on silicon diffractive modulators for telecommunications, the revolutionary class of microdisplays capable of real time video projections of two-dimensional and three-dimensional holographic images, and application of nanomaterials in liquid crystal on silicon devices.

The award, sponsored by LG, is in particular recognition of his contributions to the field of LCOS devices for microdisplays and holography. He was presented with his certificate and prize at the 23rd International Liquid Crystal Conference.

Tim's details can be found at:
www.g.eng.cam.ac.uk/CMMPE/people.html

Royal Academy of Engineering Fellows

Royal Academy of Engineering elected Professor Roberto Cipolla and Dr Ivor Day to a Fellowship



Congratulations to Roberto Cipolla, Professor of Information Engineering and Dr Ivor Day, Senior Rolls-Royce Research Fellow, at the Whittle Laboratory, who have been elected as Fellows of the Royal Academy of Engineering. Their citations read:

Professor R Cipolla: Distinguished for his contributions to computer vision, especially the recovery of 3D shape from images and its translation into novel commercial applications, and for his leadership of the Toshiba Cambridge Research Laboratory.

Dr I Day: Ivor Day has contributed greatly to the gas turbine by his innovative and skilful use of engineering techniques. In the age of computation he continues to demonstrate that experiments are indispensable, tackling the problems that numerical analysis cannot reach. His work has contributed to the aerodynamic, combustion and mechanical aspects.

Academy President Lord Browne of Madingley says: "The expertise of our Fellows is a unique national resource. We want to see that expertise brought to bear at a much earlier stage of policy development – to ensure that policy is workable, sustainable and affordable. "While business itself remains the prime vehicle for wealth creation, government can and must do a lot more to foster the right climate for success. Thanks to our network of Fellows with their unrivalled experience in engineering business and research, we are uniquely well placed to help government understand the needs of business."

For more information about Roberto and Ivor's research please visit: <http://mi.eng.cam.ac.uk/~cipolla/index.htm>
www-g.eng.cam.ac.uk/whittle/current-research/ijd/ijd.htm

Dr. Julian Allwood appointed as a Lead Author of the next Intergovernmental Panel on Climate Change report

The authors for the next Intergovernmental Panel on Climate Change (IPCC) report (due 2014) have been announced.



Dr Julian Allwood has been appointed as a Lead Author of the Chapter on Mitigation in Industry. Julian leads the Department's Low Carbon and Materials Processing research group, which explores a wide range of opportunities by which engineering can contribute to a low carbon future, particularly through reduced energy demand in industry. Commenting on the announcement Julian said, "I am very pleased to be involved in something that has the potential to make a big difference, and it's a great opportunity to share our work with key leaders in this area."

You can access the complete author list of Working Group III – Mitigation of Climate Change and the outline of the 5th Assessment Report (AR5), as it was accepted at the 31st Session of the IPCC in October 2009 in Bali, at the following link: www.ipcc-wg3.de/news/ar5_authors

The Working Group III (WG III) of the IPCC focuses its work on the mitigation of climate change. The IPCC has the responsibility of providing policy makers with objective scientific and technical findings that are policy relevant but not policy prescriptive. The IPCC is aimed at serving as an honest broker between science and policy makers and other relevant stakeholders. The IPCC WG III assesses all relevant options for mitigating climate change through limiting or preventing greenhouse gas (GHG) emissions and enhancing activities that remove them from the atmosphere. WG III analyses the costs, benefits and risks of the different approaches to mitigation, considering also the available domestic instruments and policy measures as well as international arrangements.

For further information about Julian's work visit: www.lcmp.eng.cam.ac.uk/welcome/introduction

Telford Gold Medal winners

The Telford Medal is the Institution of Civil Engineers highest award for a paper and is awarded for an outstanding paper believed to be of the highest practical value to the profession.



Paul Fidler, Dr Campbell Middleton and Professor Kenichi Soga with their Telford Medals

Congratulations to Professor Kenichi Soga, Dr Campbell Middleton and Paul Fidler, who together with Professor Neil Hault and Dr Peter Bennett (both formerly of the Department) and 3 collaborators at Imperial College, have been awarded the 2010 Telford Gold Medal by the Institution of Civil Engineers for their paper "Wireless sensor networks: creating 'smart infrastructure'".

One of the greatest challenges facing civil engineers in the 21st century is the stewardship of ageing infrastructure. Much of the world's civil infrastructure suffers from significant levels of deterioration but there is insufficient funding available to refurbish or replace components that are deemed to be inadequate. Nowhere is this more apparent than in the networks of tunnels, pipelines and bridges that lie beneath and above the major cities around the world. Much of this infrastructure was constructed more than half a century ago and there is widespread evidence of its deterioration. Tunnels, particularly old ones, are prone to being influenced by activities such as adjacent construction, for instance piling, deep excavations and other tunnel construction. Excessive leakage and pipe bursts are frequent and usually unanticipated. Importantly, underground structures often cannot be inspected when they are being used by trains or due to other physical constraints. Bridges are susceptible to corrosion from de-icing salts and subject to ever-increasing demands as the legal weight limit of lorries has been progressively increased over the years. Vehicular impacts and scour to the foundations of both road and rail bridges have resulted in significant loss of life and major disruption to strategic supply and distribution links. Little is known of the long-term performance of such infrastructure. These uncertainties and the importance of safety to users and consumers prompted the initiation of this research project investigating the prospect of damage detection and decision-making and the use of novel sensors to mitigate damage.

Management programmes are required to optimise and prioritise available resources by establishing which structures are in adequate condition, which require maintenance and which need replacement. This is a significant challenge, particularly as data about the present condition and performance of many assets are not available.

One way to acquire data about structural performance is to install a monitoring system. Conventional monitoring systems employ a series of sensors connected together using wires to transfer the data and supply the power. These sensors are then connected to a data logger which stores the data and allows the user to access it either remotely or on site. The sensors, cabling and installation for a conventional monitoring system can represent a large capital expenditure, especially for a system with many sensors. Given the limited funds available for maintenance and replacement of infrastructure, managers would prefer to spend the bulk of the available money on the infrastructure itself rather than on monitoring systems.

As part of an Engineering and Physical Sciences Research Council-funded research project, the team of researchers are investigating the use of wireless sensor networks to see if they can offer an effective and economic alternative to conventional monitoring systems.

This paper reports on the trial installations of wireless sensor networks in a suspension bridge, slab bridge, rail tunnel and water supply pipeline. Each installation is introduced in terms of hardware, measured parameters, sensors, sampling regimes and installation and operational challenges. Preliminary results from each system are discussed to illustrate the variety of information that can be made available to managers and engineers, and how this information can be used and presented.

See the paper: www.icevirtuallibrary.com/content/article/10.1680/cien.2009.162.3.136

The state of the art and future directions

Dr Keith Seffen wins a Royal Aeronautical Society written paper prize

Dr Keith Seffen of the Advanced Structures Group here in the Department of Engineering and Dr Matthew Santer, formerly of the Department and now at the Department of Aeronautics at Imperial College, have won a Royal Aeronautical Society Silver Award for their paper: 'Optical space telescope structures: The state of the art and future directions'.

Space telescopes, such as the Hubble Space Telescope, are important observational structures. In orbit, they can observe the cosmos without atmospheric distortion and with little background illumination. The larger the telescope, the better the image: however, practical structures are limited by the available size of rocket launch fairings, resulting in a range of novel solutions. In their paper, Drs Seffen and Santer undertake a review of the current state-of-the-art technology for the design of space telescopes. They consider the relative merits of three types of telescope architecture: monolithic structures, which have a single, highly-polished mirrored surface; deployable structures, which take shape by the unfolding of hinged, rigid pieces; and thin, continuous membranes known as 'Gossamer' structures, which are pre-tensioned in orbit, to give a precise reflective surface. Gossamer structures are by far the lightest and best-packaged and thus can be the largest and most promising. Because of this lightness however, their shape is more prone to dynamic and thermal disturbances in orbit. Simple performance metrics are developed in the paper to take account of the effect of these disturbances, in order to enable designers to select appropriate materials and control mechanisms for a better overall performance.



For more information visit: www.aerosociety.com

Magnetic devices for information processing

Dr Colm Durkan (below), of the Department's Nanoscience centre, has been awarded funding from the Samsung Global Research Outreach program, for research and development of novel magnetic devices for information processing.

The world of electronics has reached a junction whereby new paradigms are continually emerging. Transistors fabricated using



conventional processes are already small enough (~ 20 nm) to be on the verge of demonstrating quantum effects involving tunnelling, localization and electron interference. One of the most promising avenues however, is spintronics, where the spin degree of freedom of the electron is utilized.

Colm and his team are interested in the fundamentals underpinning some of this technology. Colm says; 'There is a large scientific community investigating novel materials for data storage, whereas our interest is in the size effect of soft magnetic materials in general. Our expertise is specifically in the fabrication and local functional characterization of nanostructures, combined with state-of-the-art modelling. Colm has already pioneered several scanning probe microscopy developments in the field, work that led to election to a fellowship of the Institute of Physics earlier this year and promotion to a personal readership in October 2010.

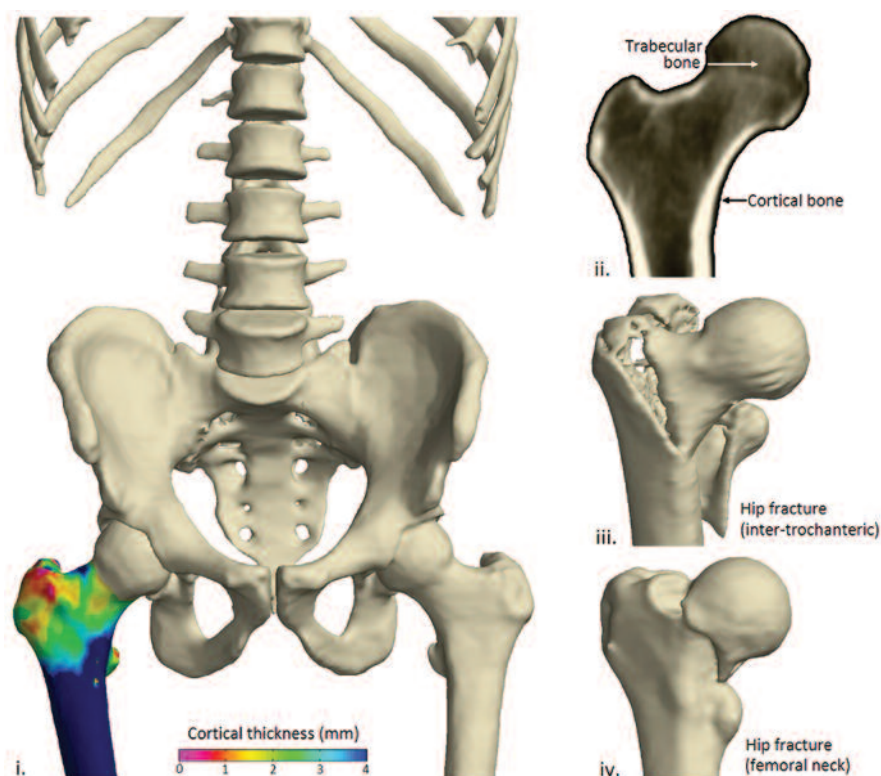
'For magnetic structures with dimensions below around 1µm, the magnetic properties are determined to a large extent by the geometry and size of the structures. Therefore, we wish to tap into this treasure chest of nanomagnetism to realize novel data storage, information processing and spin readout systems to increase the functionality of electronic components without significant cost implications.'

Some of Colm's recent work on this topic has recently been published in Physical Review B <http://prb.aps.org/abstract/PRB/v82/i8/e085404>.

For further information please contact Dr Colm Durkan, email: cd229@eng.cam.ac.uk Webpage: www.eng.cam.ac.uk/~cd229

New imaging technology predicts fracture risk

A new method for identifying which bones have a high risk of fracture, and for monitoring the effectiveness of new bone-strengthening drugs and techniques, has been developed by scientists at the University of Cambridge.



The method, developed by Dr Graham Treece and Dr Andrew Gee of the Department of Engineering and Dr Ken Poole of the Department of Medicine, uses CT imaging to accurately measure the thickness of the cortical bone - the hard outer layer of compact bone which surrounds the spongy trabecular bone. The thickness of cortical bone is a key indicator of the risk of fracture.

This work is expected to lead to advances in the treatment and management of osteoporosis, a condition that affects one in two women and one in five men over the age of 50 in the UK. Osteoporosis results in a decline in bone strength and thinning of the cortical bone, so that often the remaining bone is no thicker than an eggshell by the time an individual is in their 80s. At certain key points, this thinning can lead to bones that are so weak that a stumble, trip or fall can lead to a fracture.

Currently, the key technology used to assess a patient's risk of fracture is a bone mineral density test, which uses dual-energy x-ray absorptiometry (DXA) to estimate mineral levels contained in bone. An alternative is multi-detector computed tomography (MDCT), which provides more comprehensive 3D imaging of bone structure, but not at a sufficient enough resolution to provide accurate sub-millimetre measurement. The method developed by Drs Treece and Poole increases the accuracy of cortical bone measurements to the extent that clinicians can map changes in thickness over time, and produces accurate measurements of thicknesses as low as 0.3 mm.

Utilising data from a CT scan and a mathematical model of the scanning process, thousands of cortical bone measurements are obtained. This produces 3D thickness maps, which allow the identification of dangerously thin areas. Successive imaging allows maps to be produced depicting changes in the cortical bone over time in all areas of the skeleton so that the progress of osteoporosis treatments can be monitored.

"Osteoporosis is a condition which will become more and more common as the population ages," said Dr Andrew Walsh of Cambridge Enterprise, the University's commercialisation group. "This exciting technology has the potential to improve the treatment of patients suffering from osteoporosis as well as to support the development of new drugs."

Dr Poole presented this work at the Annual Meeting of the American Society for Bone and Mineral Research, held recently in Toronto. It will be further demonstrated at the annual meeting of the Radiological Society of North America, to be held in Chicago this November.

Dr Graham Treece's webpages can be found at: <http://mi.eng.cam.ac.uk/~gmt11>

Innovation and Knowledge Centre

New 'Innovation and Knowledge Centre' worth a total of £17million awarded to Engineering Department

Funding has been announced for two major new research centres, one of which is to be based at the Department of Engineering. This 'Innovation and Knowledge Centre' (IKC) on Smart Infrastructure and Construction will combine business knowledge with the most up-to-date research to harness the full potential of emerging technologies - ensuring the UK is first to develop this cutting-edge research. The centre is funded by the Engineering and Physical Sciences Research Council (EPSRC) and the Technology Strategy Board, and by industry.

Professor Robert Mair, the Principal Investigator of the grant, says "Much of our infrastructure is more than 100 years old. Resilience against systemic failure of UK infrastructure is significantly weakening through ageing. Infrastructure owners therefore have a strong interest in emerging technologies in sensors and data management, to quantify and define the extent of ageing and the consequent remaining design life of their infrastructure. The application of emerging technologies to advanced health monitoring of existing critical infrastructure assets will address these needs, improve the management of infrastructure and reduce the risk of failure. By providing cradle-to-grave health monitoring, combined with innovative manufacturing processes, these technologies will also lead to more efficient and economic construction of new infrastructure. The IKC will focus on smarter construction and production processes, employing the latest research developments in intelligent sensing and information processing, decision support, manufacturing strategy and reconfigurable building blocks."

The Cambridge IKC will combine research in sensor and data management with innovative manufacturing processes to provide radical changes to the construction and management of infrastructure. The aim is to transform the industry through a whole-life approach to achieving sustainability in construction and infrastructure, covering design and commissioning, the construction process, exploitation and use, and eventual decommissioning. The IKC will complement the Laing O'Rourke Centre for Construction Engineering and Technology at Cambridge, a new multi-disciplinary academic centre of excellence to advance the engineering profession and leverage innovative thinking to benefit the construction industry.

Talking about the new centres, EPSRC's Chief Executive, Professor David Delpy, said: "Taking exciting research from the university laboratory to the commercial sector through close collaboration with user stakeholders is vital to ensuring the UK's economy continues to be innovative and globally competitive. EPSRC is strongly committed to supporting universities in commercialising their outstanding research and I applaud the innovative approach taken by the successful applicants, and all competing universities."

The Technology Strategy Board's Chief Executive, Iain Gray, said: "These two new Innovation and Knowledge Centres are highly important for the UK and economic growth because they harness specialist academic knowledge and business expertise in areas where we have proved capabilities and we know that we can do well. By pooling know-how, capability, and expertise in one centre, the UK maximises the opportunity to innovate effectively and generate economic growth."

The Cambridge IKC on Smart Infrastructure and Construction will be led by Professor Robert Mair and Professor Kenichi Soga of the Civil Engineering Division of the Department of Engineering. Professor Duncan McFarlane of the Department's Institute for Manufacturing (IfM) will also play a leading role. Dr Paul Heffernan of the IfM will be the full-time IKC Director. The IKC will bring together four leading research groups in the Cambridge Engineering Department and the Computer Laboratory, along with staff in the Judge Business School and the Department of Architecture.

Innovation and Knowledge Centres (IKCs) are centres of excellence with five years' funding to accelerate and promote business exploitation of an emerging research and technology field. Their key feature is a shared space and entrepreneurial environment in which researchers, potential customers and skilled professionals from both academia and business can work side-by-side to scope applications, business models and routes to market.

Funding for the Cambridge IKC will be £10million from EPSRC and the Technology Strategy Board, with an additional £7million from a number of industry organisations.



Research Fellowship

Tore Butlin has recently been awarded a Royal Academy of Engineering / EPSRC Research Fellowship to work on 'Modelling the vibration of complex structures with localised non-linearities'.

The project will be in collaboration with the Bristol Laboratory for Advanced Dynamics Engineering and the Structural Dynamics and Vibration Laboratory at McGill University, Montreal.

There is a huge need for efficient and practical tools for predicting vibration in complex structures, from automotive brakes to oilwell drills. A host of simplified methods exist for studying linear systems (usually valid when the motion of the structure is sufficiently small), but linear theory can only go so far. Real structures often have regions that are significantly non-linear, such as friction forces, requiring less efficient methods of computer simulation to investigate. This is a problem that is exaggerated when trying to account for variations and uncertainties such as those resulting from a production line.

The aim of this research is to find ways of modelling non-linear behaviour efficiently by exploiting the fact that many examples of non-linearity occur in localised regions of the structure. This allows computational effort to be focussed on these regions while retaining the efficiency of linear analysis for the majority of the structure. A core objective of the research is practical relevance. Therefore the new methods developed will be assessed against experiments designed to exemplify the key features of complex structures with localised non-linearities that make their study traditionally difficult.

The benefits of a successful approach have the potential to impact a wide range of areas such as brake noise, drilling and machining, turbine blade vibration, offshore structures, MEMS devices and 'buzz, squeak and rattle' within the automotive industry, and potentially within medical contexts such as drilling in orthopaedic surgery and understanding tinnitus (spontaneous vibration in the cochlea). Such goals are long-term and require expertise in other fields. The role of this research is to develop novel tools that may open new opportunities for research in these areas.

Tore Butlin's webpages can be found at: www2.eng.cam.ac.uk/~tb267

Manufacturing Engineering Design Show 2010

The Design Show is held each year for an invited audience of local industrialists and designers. MET (Manufacturing Engineering Tripos) students put together displays to explain the technical and business ideas behind the products, together with design details and prototype models of the products themselves.

1 E3

An urban vehicle concept with a retractable wheel base that enables the vehicle to park in small spaces

Parking space is at a premium in many of today's modern and congested cities. Statistics from research at MIT show that a significant amount of fuel is used in the search for a space in which to park. Reducing this excessive, wasteful and environmentally damaging use of fuel is an important part of reducing the effects of emissions from vehicles.

Having the minimum-sized passenger compartment for 2 people and luggage, the E3 has a passenger pod of 1.4 x 1.35m. This pod size enables 3 vehicles to be parked in a normal-sized parking space. However, the size of this wheelbase causes instability at speed. We have therefore created a retractable wheelbase concept that enables stability whilst driving, but maintains the small size when the vehicle is parked.

Team: Emma Burrow, Julia Toynton, Sufyan Khan, Robert Hayes

2 Ascend

An integrated foot and ankle prosthetic offering greater flexibility at a competitive price

Although the number of devices available in the lower limb prosthetic market has grown significantly in recent years, so too have the prices. Ever-increasing high levels of technology mean that many of these devices are well beyond the price range of potential customers.

The design of the Ascend offers an integrated foot and ankle joint that gives greater flexibility to the user. The unique design of the heel and toe allow for a much livelier response, more closely mimicking the action of a human foot; it also offers greater stability. The increased functionality of the foot and ankle joint gives the user the freedom and confidence to traverse uneven terrain in comfort.

Team: Rebecca Cuthbertson, Hannah Wells, Sahil Shah, Mia Liu

3 Post-me

Your picture is worth a postcard

Getting the perfect photo on holiday can be difficult. Our product allows tourists to photograph themselves perfectly positioned in a picturesque location. The photo is instantly printed as a unique postcard to send to your loved ones or retained as a keepsake.

Post-Me is a fixed unit incorporating a camera and printer. The device has been designed to operate as simply as possible – the tourist inserts the coins, a photo is taken and then printed out as a postcard. There are no similar products that provide these functions in one system. We will work with tourist attractions to place our devices in locations that guarantee the perfect photo.

Team: Juliette Sanders, Peter Thum-Bonanno, Emma Yau

4 FlikStik

Improving quality of life for MS sufferers

There are 100,000 sufferers of Multiple Sclerosis in the UK alone, coping with symptoms such as reduced stability, balance and fatigue. Their mobility needs are currently unsatisfactorily met by products on the market, which are too ugly and unfashionable for this younger demographic, and too limited in their functionality, being a hindrance and socially awkward to use on a daily basis.

FlikStik aims to provide convenience, freedom and comfort for MS patients and those with other neurological disorders with similar symptoms. FlikStik combines a walking stick with features that allow dropped items to be retrieved and an internal mechanism that enables the stick to become self-standing when required. A strong focus on aesthetics also seeks to make this daily aid either discreet or flamboyant, to fit with the individual's character.

Team: Emma Dabbs, Chris Bryan, Eesa Mohammed

5 SharpSure

A solution to the need for safe and effective disposal of Auto-Disable syringes appropriate for the developing world

Each year millions of people in the developing world are exposed to the risk of infection due to the re-use of unsterilized syringes, causing an estimated 1.3 million early deaths worldwide. Mechanisms that prevent the syringe from being used more than once – so-called 'Auto-Disable' (AD) syringes - have been developed. However, the problem of safe syringe disposal remains largely unsolved. With the rapid uptake of AD technology, this is an issue which is set to become increasingly prevalent.

Our solution involves separating the 'sharps' or needles from the less dangerous plastic syringe body at the point of use, thus reducing the volume of critical waste produced. This makes appropriate incineration and transport to incineration facilities feasible where it has before not been an option. We have re-designed the syringe itself to make the separation action and the equipment as cheap, simple and safe as possible.

Team: Adrian Wallis, Harry Simpson, Luke Jesson



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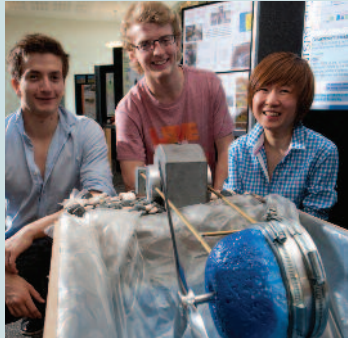
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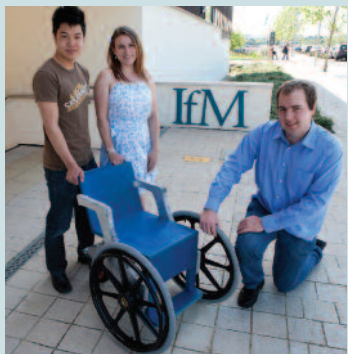
6 FloDrive Turbine

Easy-to-install hydropower generator

This design is a small run-of-river hydropower solution, initially capable of providing up to 1 kW of power in rivers. The main product offering consists of a turbine, generator unit and supporting structure. It weighs approximately 500 kg and is 12 x 0.5 x 1 m when deployed, but compacts to a box of 3 x 2 x 2 m for transporting.

The FloDrive Turbine is intended to be as easy to install as possible, with no special infrastructure required. It should take less than a day to install, require no specialist equipment, and would be possible for untrained individuals to accomplish a successful installation. The electricity generated would be output in DC to charge batteries or AC to power homes, complementing available grid power.

Team: Deniz Erkan, Ned Stuart-Smith, Li Jiang



7

7 The Mark 1

The Africa wheelchair revolution

The World Health Organisation estimates that around 150 million people in the world's poorest countries who would benefit from a wheelchair, cannot afford one. Charities struggle to address this need due to the sheer scale of the problem, and often deliver donated chairs which cannot meet the requirements of all-terrain use.

Our design aims to address these issues by designing an affordable wheelchair from scratch to meet its user's needs. Excluding the wheels, existing wheelchairs are assembled from around 100 components; the Mark 1 has only three: two sides of a chassis and the chair it supports, at a material cost of under \$10. The three-wheeled configuration allows for greater manoeuvrability over rough terrain, and front-driven wheels benefit users with limited shoulder movement and strength. By careful material selection and design for mass manufacture, the potential scale of production would make a sizeable impact on meeting the needs of those who currently cannot afford a wheelchair.

Team: Xiong Chang, Sophie Burgess, Chris Stanyon



8

8 LifeCycler

A bicycle that grows

Currently, bikes are designed for a relatively narrow body size variation. We have developed a bicycle frame that can accommodate anyone; age 10 – 100, male or female. It is a completely self-contained bike that 'grows' with the user. You will never need to throw your favourite bike away as you can now have a 'Bike for Life'. The main inspiration behind this product was to provide children in developing countries with a safe means to travel to school. Children often have to adapt to riding bikes that are significantly too big for them, by sitting on the cross bars and hoping they don't crash!

Using ergonomic data and research into the ideal riding position, we have created a V-shaped frame that can be easily extended or shortened to accommodate any user from age 10 onwards, using standard quick release clamps. Other special features include a low cross bar which will allow users to ride while wearing a dress, shorter crank length to allow maximum power transmission for most people and hub gears for differential cycling speed.

Team: CJ Hou, Oscar Chan, Jen McCann

9 MakeAShape

Combining construction and creativity in a product where imagination is the key

Young children grow up in an over-stimulating world where television and media can dominate. However, it is in these age groups that the next generation are rapidly developing their minds, personalities and imaginations through their interactions and experiences.

In contrast to most construction toys on the market, building with MakeAShape is not only a means to an end but also the play itself. Two lengths of rod and three different shapes combine into abstract sculptures, and are then transformed into dens, rockets, castles... Shapes and spaces grow as the construction continues, and the modularity of the components allows the build to evolve and change naturally as it goes on.

Team: Michael Parrott, Dominic Thompson, Silas Yuen



9

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Vice-Chancellor starts University's first wind turbine

The former Vice-Chancellor, Professor Alison Richard, started the University's first wind turbine at a ceremony at the West Cambridge site.

The new 20kW wind turbine is fitted with a revolutionary generator, known as the Brushless Doubly-Fed Induction Generator (BDFIG), which has been the subject of research at Cambridge over the past 10 years.

Designed by Dr Richard McMahon and his team at the Department of Engineering in collaboration with Durham University and Wind Technologies, a Cambridge University spinout, the BDFIG considerably improves upon the reliability of existing generators, which is an essential requirement for the next generation of offshore turbines. Dr Richard McMahon gave an excellent speech at the ceremony which is given in full below.

Following the successful completion of the 20kW project, researchers are currently building a medium-scale 250kW BDFIG, as a stepping stone to a multi-megawatt machine, which will be built and tested next year.

Speeches at the ceremony were given by Professor Dame Ann Dowling, Head of the Department of Engineering, Professor Gehan Amaratunga, Head of the Electronics, Power and Energy Conversion Group, and Dr Richard McMahon, Head of the Renewable Energy Group. Below is Richard's speech.

How we got here

About 100 years ago it became clear that electrical power would be generated and distributed as AC for compelling technical reasons. The generation side was straightforward, the preferred electrical machines were the synchronous generator or alternator, conveniently operated at fixed speed.

However, electrical drives were a problem. Tesla's induction motor had no connections between the rotor and stator so it was very robust and inexpensive, but it was an essentially fixed speed machine. Variable speed operation was necessary for many applications, machinery, mine winding etc. Variable speed was possible by making an electrical connection to the rotor via brushes and slip-rings – but this goes against the essential simplicity of the machine.

An alternative solution was patented in 1903 in which the slip ring connection was replaced via a second magnetic coupling – the machine having two independent non-interacting fields with a special rotor coupling both fields.

This machine, which became known as the self cascaded machine, gained a reputation for robustness and reliability. However, the advent of modern power electronics which can generate a variable frequency supply for standard induction machines made both the self-cascaded machine and the slip ring machine obsolete.

At the end of the 19th century there were concerns



We used the frame of a commercial induction motor but the rotor – the tricky part – was designed here.

about energy supplies: coal was running out. A combination of more efficient power stations and the discovery of new supplies alleviated this problem.

More recently these concerns have arisen again, plus the concern about climate change. In the 1980s there was the so-called California wind rush. From this chaos the modern wind power industry emerged. As part of this, the need for variable speed generation became apparent – keeping the tip-speed ratio of a turbine sensibly constant is essential for effective extraction of energy from the wind. The slip ring induction machine was brought out of retirement and is used in most variable speed wind turbines.

However, it is used in a new way. The supply to the rotor is generated electronically and there is a known relationship between mains frequency, rotor frequency and shaft speed. The main advantage is that only a relatively small part of the power need go through the relatively expensive power electronics – this has kept 'fully converted' solutions, in which all the power passes through power electronics, at bay.

Nevertheless, the brushgear and slip-rings represent both a cost – and more importantly – a reliability issue, as highlighted in studies by my collaborators at Durham University.

It is probably fair to credit Alan Wallace of Oregon State University with the realization that a self-cascaded machine could be an attractive generator for wind turbines.

The machine, rechristened the brushless doubly fed machine (BDFM), can be used in the same way as the slip ring machine – fixed speed relationship, partial power conversion – but no brushes!

Oregon did not succeed. Shortly before his death, Alan told me in a Manchester curry house that they were building a large prototype but had made some major design errors and that the project had run out of funds.

One of Alan's students came to Cambridge to study under Steve Williamson, then Professor of Electrical Power. They built a BDFM and I recall sitting in Steve's office having the theory explained to me.

I thought this machine was really interesting and following Steve's departure started a project on it, with Jan Maciejowski and Tim Flack.

At about the same time I met Peter Tavner, at the time the Technical Director of FKI – Fisher Karpark Industries – which owned Laurence Scott in Norwich, Brush in Loughborough and DeWind in Luebeck – therefore FKI had a strong interest in this machine.

Once we realized that the matrix algebra and the electrical circuits were saying the same thing we gained a good understanding – possibly the best anywhere – of the machine and 3 MPhils and 3 PhDs later here we are, and more underway. The BDFM has also spread to Durham and there have been several final year projects there.

Ehsan Abdi, the second PhD student to work on the machine should be credited with the enthusiasm for starting the commercialization of the machine.

Ehsan was successful in raising funds for Wind Technologies, beginning with our own Challenge Fund and then East of England Development Agency (EEDA), Renewables East, Carbon Connections and the Carbon Trust.

The Wind Turbine

The turbine we see before us was funded by EEDA. The basic turbine is from Gazelle in Newcastle – having a reputation as a well-engineered machine in its class.

We re-engineered the drive train with a new gearbox – discovering that mechanical kW are not electrical kW – and a BDFM of our design. We are grateful for the help and assistance of Gazelle.

We used the frame of a commercial induction motor but the rotor – the tricky part – was designed here.

We are deeply indebted to Professor Tavner of Durham and his workshop team, and their sub-contractors, for the construction of the rotor – which was not easy. However, it all came together and worked which was very encouraging.

In addition to the hardware, we devised controllers for maximum power point tracking and the management of reactive power.

It is interesting operating your own wind turbine. You see the fluctuations in output, the effects of gusting. It forces you to think about the performance of the whole system – all parts need to work and reliably – we are not quite ready to submit this machine to Durham's failure mode analysis!

The project shows quite conclusively that it is possible to design and operate a BDFM. The turbine is a research tool – we have two PhDs working on the BDFM and have plans to collaborate with the control group.

The turbine also links in with undergraduate teaching as well as research – the recently introduced 4B19 module on wind and wave power has been very popular with students. We have had one 4th year project on the turbine and there should be more in the future.

Many people have contributed to the success of this project. Firstly EEDA for supporting the project.

The technical team – the home team (students, technicians) and Durham University and the staff of Gazelle.

The project would have been impossible without the support and encouragement of the Whittle Lab who have sacrificed some of their BBQ area. We thank the University Estate Management for their help and assistance especially during installation itself.

We thank the Department of Engineering for its support.

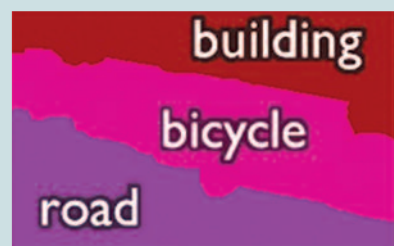
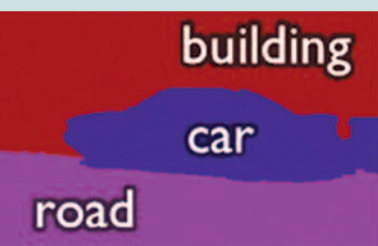
Where next?

The present turbine is rated at 20 kW. We have designed a machine for 200 kW which is about to be built at ATB Laurence, Scott with funding from the Carbon Trust. The stage after that is a 2 MW machine for installation in a wind turbine.



Further information on the West Cambridge BDFM research wind turbine can be found on the Electrical Engineering Division web pages: www-g.eng.cam.ac.uk/empg/windenergy

Alumnus Dr Jamie Shotton and the development of Kinect for Xbox 360



Jamie works for Microsoft at their Cambridge research laboratory, where he has been intimately involved in the development of Kinect for Xbox 360. Kinect makes you the controller, allowing you to jump in and play games using your whole body, without holding or wearing anything special. Jamie came back to the Department to lecture the 4th year undergraduate students on this. Below, he tells his behind-the-scenes story about Kinect.

“I joined the Machine Learning & Perception group at Microsoft Research Cambridge (MSRC) in June 2008 as a post-doc to continue my PhD research in computer vision. In this, I had focused on automatic visual object recognition: teaching computers how to recognise different types of object in photographs such as cars, sheep, trees, etc. Little did I know at that point how quickly I would get pulled into the frenzy of research and development around Kinect, and how this blue-skies research could be applied to such a practical problem.

“I had taken a machine learning approach to visual object recognition in photos, which works as follows. First, you build up a varied training set of images where you label each pixel with a colour, according to which object category it belongs to. So, for example, you hand-label all ‘cow’ pixels in blue, and all ‘tree’ pixels in green, using a simple painting application. Second, you give this training data to a machine learning algorithm that does some number crunching to automatically work out patterns of image appearance that correlate with the presence or absence of various object categories. The learning algorithm gives you a trained ‘model’ that efficiently encodes these correlations, and hopefully generalises to new unseen data. Finally therefore, you show the model a new image and it works out to which object category each pixel belongs.

“A couple of months into my post-doc at MSRC, I got a call out of the blue from the Xbox product group who, having come across some of my earlier publications from the Department of Engineering, wanted to discuss an ‘important, top-secret scenario’ with me. They described their goal, that of real-time robust human body tracking, and how it could be used

for playing computer games. Now, this had been a dream of science fiction for many years, and still is a hugely active topic in the computer vision community – several of my fellow students in Professor Cipolla’s group, including Dr Bjorn Stenger, had had this as their PhD topic. But it was always seen as being ‘five years away’ from being commercially viable. So of course I was rather sceptical anything could come of this, especially given Xbox’s ambitious plan to launch by Christmas 2010.

“But then they mentioned the new depth-sensing camera hardware they were busy developing. I had seen depth cameras before but only at very low resolution (about 10x10 pixels). The new Kinect camera worked at 320x240 pixels and 30 frames per second, and the depth accuracy really got me excited – you could even make out the nose and eyes on your face. Having depth information really helps for human pose estimation by removing a few big problems. You no longer have to worry about what is in the background since it is just further away. The colour and texture of clothing, skin and hair are all normalised away. The size of the person is known, as the depth camera is calibrated in metres. Further, since the depth camera is ‘active’, shining out its own structured dot pattern of infra-red light into the room, the camera can work with the lights turned off.

“But even with depth cameras, it’s not all plain sailing. There is still the whole gamut of human body shapes and sizes and, worse, people can get themselves into an incredible variety of poses (body positions). Just think about how many positions you can put your right arm in, then multiply by the number of positions for your left arm, your right leg, and so on, and you rapidly end up with a combinatorial explosion.

“The Xbox group also came to us with a prototype human tracking algorithm they had developed. It worked by assuming it knew where you were and how fast you were moving at time t , estimating where you were going to be at time $t + 1$, and then refining this prediction by repeatedly comparing a computer graphics model of the human body at the prediction, to the actual observed depth image on the camera and

Dr Jamie Shotton completed his PhD in the Machine Intelligence Lab with Professor Cipolla, here at the Department of Engineering from 2003-2007.

making small adjustments. The results of this system were incredibly impressive: it could smoothly track your movements in real-time, but it had three limitations. First, you had to stand in a particular 'T'-pose so it could lock on to you initially. Second, if you moved too unpredictably, it would lose track, and as soon as that happened all bets were off until you returned to the T-pose. In practice this would typically happen every five or ten seconds. Third, it only worked well if you had a similar body size and shape as the programmer who had originally designed it. Unfortunately, these limitations were all show-stoppers for a possible product.

"And so our brief back at MSRC was to overcome these limitations somehow. I sat down with colleagues Dr Andrew Fitzgibbon and Professor Andrew Blake and we brainstormed about how we might solve the problem. A first observation was that when you look at a photo of a person, you can tell where their limbs are even though the person is not moving. If we could remove the temporal dependency, we would remove the need for the initial T-pose, and be able to recover if we lost track. Another thought was that to cope with the variations in human size and shape we should use machine learning, rather than try somehow to program directly for all possibilities by hand: instead, we would encode these possibilities in the training data.

"Having studied with the Department's Professor Cipolla, I knew about Dr Stenger's research which uses a technique called 'chamfer matching' to a whole image of the body against the training set of body images. By finding the closest match (the 'nearest neighbour') you can transfer the known 3D human pose from the training image to the test image. We tried this technique out, and had some success getting a coarse human pose out without using any temporal information. The problem was, however, that to get the level of detail we needed would have required so many 'exemplar' training images to cover all possible body shapes and sizes that the matching process could not run in real-time on the limited processing hardware we had available.

"So we went back to the whiteboard. What was now clear was that we had to divide up the body into parts and somehow match each part independently to avoid the combinatorial problems with matching a whole pose at once. I hit on the idea of revisiting my PhD work on object recognition, but this time instead of object categories, we were going to use body parts such as left hand or right ankle. We designed a pattern of 31 different body parts as you see colour-coded on the left here, and then trained an efficient decision tree classifier to predict the probability that a given pixel belongs to each part of the body. If you can accurately predict these part probabilities from a single depth image, regardless of body shape, size, or pose, then you get 3D proposals for the locations of many body joints at extremely low computational cost.

"This turned out to be the winning formula, but it still needed a lot of engineering to scale up to the level of accuracy we needed. The larger and more varied we could make the training set, the better it was likely to perform in your living room. So we turned to Hollywood, which has been building advanced computer graphics models of the human body for its movies for many years. We recorded hours of footage at a motion capture studio of several actors doing various moves that could be useful for gaming: dancing, running, fighting, driving, etc. This 'mo-cap'

data was then used to animate computer graphics models of different human shapes and sizes automatically. We ended up with a vast training set of millions of synthetically generated depth images. Moreover, the graphics algorithm could easily render the corresponding body part images we needed for training as a texture map.

"The final piece of the puzzle was how to deal with these millions of training images. My previous work on recognition in photographs had taken a day or two to train from only a few hundred images, and using this approach directly on millions of images would have taken weeks if not months, prohibitive on our tight schedule. We enlisted the help of our colleagues at Microsoft Research in Silicon Valley who had been developing an engine called 'Dryad' for efficient and reliable distributed computation. Together, we built a distributed training algorithm that divided up the millions of training images into smaller batches and trained off each batch in parallel on a networked cluster of computers. Using a cluster of about 100 powerful machines, we were able to bring the training time down to under a day.

"All the pieces were in place now, and we worked with the Xbox team to put everything together. Our body part recognition algorithm gives fast and accurate proposals about the 3D locations of several body joints which are then taken and processed by the Xbox group's tracking algorithm to stitch the skeleton together (another bit of engineering magic!). This skeletal tracking, together with other new technologies such as voice recognition, gives game designers the platform on which to build the magical experiences you get with games such as Kinect Sports and Dance Central.

"But of course, gaming is just the beginning, and I foresee this technology fuelling rapid advances in augmented reality and tele-presence, Internet and personalised shopping, and healthcare, to name just a few. We are even looking at how touch-free interaction could find its way into the operating theatre so that the surgeon can navigate the patient's data much more quickly and without risk of contamination from a mouse or keyboard."



If you are interested in finding out more, please contact Dr Jamie Shotton by email: jamie@shotton.org

The Lloyd's Register Educational Trust support for scholarships



Further to a donation from The Lloyd's Register Educational Trust (The LRET) in 2010 for the provision of fees-only scholarships to MPhil students in the Departments of Engineering, Physics and Materials Science, an award was made to Jackie Stenson, who started her graduate study on the MPhil in Engineering for Sustainable Development in October 2010.



After completing her BSc in Engineering Sciences at Harvard University and prior to coming to Cambridge, Jackie spent two years travelling overland through eastern and southern Africa, working with various organisations that focus on using technology for development. Throughout her travels, she observed first-hand that while many technologies exist that are designed for the poor, most communities lack access to them and few of the technologies are being used by their intended customers or are effectively reducing poverty.

Jackie came to Cambridge to further research how technologies designed to improve the lives of low-income customers can successfully and sustainably be brought to market. She is working with Dr Tim Minshall at the Institute of Manufacturing for her dissertation on effective new product introduction (NPI) strategies for technologies in eastern Africa. She plans to conduct case studies of successful NPI strategies currently used by businesses in east Africa whose innovations have engaged over one million low-income customers. These strategies will then be applied to a business model for other technologies designed for the poor, creating a framework that will better enable them to reach their target market and contribute towards more widespread and sustainable development.

After completing her MPhil course, Jackie will work to establish a start-up company based in Kenya that provides business and technology consulting for entrepreneurs.

The LRET is an independent charity that was established in 2004. Its principal purpose is to support advances in transportation, science, engineering and technology education, training and research worldwide for the benefit of all. It also funds work that enhances the safety of life and property at sea, on land and in the air. The Department is extremely grateful to the trustees of The LRET for its support of this new initiative and looks forward to making further scholarships available under this scheme for students on the MPhil in Sustainable Development for 2011-12.

A Suit That Fits

A Suit That Fits, the world's first online tailoring company, was founded in 2006 by engineering alumnus Warren Bennett and his school friend David Hathiramani.

Warren spent time working in Nepal and whilst volunteering at a school in Kathmandu he met a family of tailors who made him a woollen tailored suit.

"I enjoyed the idea and the experience of having tailored suits made around the world, although often with mixed results. On my second gap year travelling, I met a family of tailors in Nepal who made me a fine woollen suit. When I returned to the UK, I met up with old school friend David Hathiramani and we decided to start the business. It seemed more fun than anything else and we knew we could offer great value and improve the customer experience."



Warren and David felt there was a gap in the market for affordable, good quality, hand tailored suits and wanted to use their technical backgrounds to simplify the ordering process. It was then that they started *A Suit That Fits*, the world's first on-line, hand tailored, suit making company.

"We started the day we took one of my suits to Hampstead market in London. We had sold two suits within 20 minutes of opening. From there, over the next 24-hours, we set up the website using David's computer skills. From then on we started selling suits on a daily basis through online visitors to the site."

Using unique web technology, the service gives customers the flexibility to design and completely customise their individually hand-tailored suit at an affordable 'off-the-peg' price, starting at £200.

"Before we started, the tailoring industry was shrouded in mystery as to how a tailor makes a great bespoke suit. From an engineer's perspective, the tailoring can be broken down into a series of relatively simple measurements and processes.

"Studying Engineering at Cambridge prepared me well for the challenges of starting my own company. The analytical skills I learnt and the logical approach to problem solving is something that I use on a daily basis to tackle the challenges of a growing business where demand is often pushing our tailors to their limits. I was also lucky enough to be selected for the Department's MIT exchange programme which really opened my eyes to the possibility of making my own path and creating a company of my own. The entrepreneurial spirit is very strong in the USA and in Boston in particular.

"The business has been self-funded and in profit every year, since the start of the business in 2006. We started as the world's first online tailoring company and have since developed 30 locations nationwide. In the first year, we had one studio in London and opened a second studio in the second year. By the third year, we had a third studio in the West End of London and 15 nationwide 'TailorStops' where customers could come and visit one of our Style Advisors. We also had a head office in South London. Last year, we opened a studio in Bristol, our first permanent studio outside of London. We now have 30 locations nationwide with five new permanent studios opening this year, one of them being in Cambridge on Lensfield Road, just opposite the Engineering Department!"

www.aSuitThatFits.com

A Suit That Fits has an exclusive offer for the Department of Engineering alumni and staff; when you visit one of their 30 locations nationwide, you will receive a complimentary measurement and style consultation, worth £25. Full details can be found at: www.eng.cam.ac.uk/news/stories/2011/asuitthatfits

Engineering students go to Silverstone

On the Thursday before this year's British Grand Prix seven recently-graduated Cambridge Engineering students travelled over to Silverstone to present the findings of their final year projects to a specially invited audience of F1 engineers and motorsport journalists in the Lotus Racing motor home.



Left to right: (Back row) Matt Jones, James Allison, David Cole, Tim Johns, Robert Woolley, Mark Graham, Sean Hale; (Front row) Tony Purnell, Ho-On To, Simon Colliss, Sarah Fern, Ned Carpenter, Geoff Parks

The projects were all co-supervised by Professor Tony Purnell, a Royal Academy of Engineering Visiting Professor at the Department of Engineering, with other members of Department's teaching staff (Professor Bill Dawes, Dr David Cole and Dr Geoff Parks).

Professor Purnell was until recently a technical consultant to the FIA and through this link he has proposed a number of final year projects in which the students investigate the impact of potential changes to the technology and regulations governing F1 races.

The students and their projects:

Robert Woolley: "A Multi-Car Simulator for the Evaluation of Technical Rule Changes and Their Effect on Races"

Racing cars interact with each other. They create turbulent wakes, upwash and downwash in the airstream, all of which slow down the cars that follow around the bends, and, if they are close enough, speed them up on the straights. A surface layer of rubber is laid on the tarmac improving the grip of the follower but this sheds shards of rubber and flicks dirt to the less used part of the circuit. This less used part is critical for overtaking, one of the most hazardous moves in motor racing. Robert simulated these effects producing a tool to help regulators see the consequence of rule changes on the way races are likely to unfold.

Mark Graham: "How Far Can One Go with Kinetic Energy Recovery Systems (KERS)?"

KERS systems are back in Formula One in 2011, and consideration is being given to taking away many of the constraints on the path-finding systems being used for a new set of regulations in 2013. Just how far could one go? Ban brakes and just rely on KERS retardation, or would this be dangerous? Have no limits to the energy store, or would the system be too heavy? Go with four wheel drive/braking systems? What would the ultimate KERS system look like? One that pays for itself in terms of extra weight, complexity and aerodynamic disadvantage? Mark made significant steps in answering these questions, looking very much from the point of view of the car as one holistic system.

Ho-On To: "The Effect of Fuel Limitations on Entertainment in F1 Races"

Fuel mileage sells cars, so the manufacturers involved in Formula One like the marketing possibilities of races being run with a set quantity of fuel making it demanding to finish the race and rewarding performance through efficiency gain. Fans fear that this might lead to economy runs. What's the truth? Ho-On used simple modelling to investigate quite a complex problem, with very compelling results indicating that the fans may well be quite wrong, but only if the regulator gets the fuel limits right.

Sean Hale: "Optimisation of Car Set-Up"

Today's race professionals use their intuition and experience to find a good balance of settings

for a given circuit. Sean showed how in the future they may be able to use advanced optimisation algorithms to find the best settings. To go faster one needs the right gear ratios, choice of brakes, wing settings, damper settings, inertia settings, springs, bump rubbers, toe, camber... the real list is even longer. These can all be modelled effectively using lap time simulation software, but with so many choices what is the best set-up possible? Using advanced optimisation algorithms Sean managed to give a good steer as to how race professionals might find this Eldorado deterministically, rather than relying on the intuition and experience base used today.

Tim Johns, Simon Colliss and Matt Jones: "Use of Lateral Aerodynamic Devices to Improve Overtaking"

Robert Woolley's simulator shows clearly how cars affect one another with today's Formula One rules, but how might the rules be changed to make these interactions more benign or perhaps even exaggerate them to make races more entertaining? Tim, Simon and Matt investigated the idea of lateral 'steer' devices (rudders rather than wings) to deliver these objectives. Simon looked at the aerodynamics of a car using such a device leading to a recommendation for a viable configuration; Matt checked to see if the vehicle dynamics were stable and what changes might be needed; and Tim put it all together to explore the effect on the way the races would unfold using this 'Department of Engineering' novel solution to better overtaking and closer races.

Also in the party from the Department were Ned Carpenter and Sarah Fern, third year students who will be doing follow-on projects in the coming year. The group were given a tour of the Lotus Racing garage and welcomed by Mike Gascoyne, Chief Technical Officer for Lotus Racing and an alumnus of the Department. Another alumnus of the Department, James Allison, the Technical Director of Renault F1, was in the audience.

Tony Purnell commented: "Cambridge has rather a good track record as regards Formula One with no less than four of the twelve Team Technical Directors being former students, and there are many more waiting in the wings. To be able to actively engage present students with former ones in perhaps the ultimate engineer's playpen that is Formula One is quite a privilege and will only strengthen this Cambridge-Formula One relationship in the coming years."

Young Structural Engineer of the Year 2010

The Institution of Structural Engineers has announced the Young Structural Engineer of the Year 2010.



This year's first and second prize winners along with one of the two highly commended certificates were awarded to graduates from the Department. The winner is graduate Timothy Salmon of Structure Workshop for his submission Village Green Festival Stage. Peter Winslow was chosen as the runner up for his project Stavros Niarchos Foundation Cultural Centre, Athens. The YSE competition is regularly run and awarded to young structural engineers who have demonstrated outstanding performance and who show exceptional promise for the future. Tim received £1,500 and a certificate of commendation; Pete received £500 and a certificate.

The judges, John Busby and David Vesey said, 'we were very impressed by the quality of all of the submissions and would like to thank the candidates for their hard work. We would particularly like to commend Nikolaos Socratous of Arup Associates for his entry. Also we would like to congratulate the firms for whom they work for the support they have given in developing these young engineers who are the future of our profession.'

Winner - Timothy Salmon of Structure Workshop

Project title - Village Green Festival Stage

Tim graduated from the University of Cambridge with a MEng in civil and structural engineering. In his submission Tim described his work developing a demountable stage for the Village Green Festival, a free annual arts and music festival in Southend.



The judges were particularly impressed by:

- The way he met the architectural aspiration for the stage through the use of polycarbonate sheet as the web for polycarbonate/timber composite beams.
- Tim's use of engineering first principles in designing the polycarbonate and timber composite beams.
- His co-ordination of highly practical full scale load testing of a beam to validate the design approach.
- Design sketches of details that demonstrated a creative, confident and mature approach to design.

Tim says "The architectural aim of the stage design was to produce something totally different from the standard aluminium frames used at most festivals. With a timber frame and structural polycarbonate, we were able to avoid the need for any cross-bracing, which would have compromised the architectural effect. This was a challenge first in terms of analysing the structural behaviour of the composite structure, and then justifying the polycarbonate for this use. The full scale load test of part of the structure gave us clear evidence of its capabilities, which gave us further confidence in our design."

Runner up - Peter Winslow of Expedition Engineering

Project title - Stavros Niarchos Foundation Cultural Centre, Athens

Pete graduated from the University of Cambridge with a MEng in civil, structural and environmental engineering. He followed this with a PhD in structural engineering, also at Cambridge.

His submission was based on his role on the Athens Cultural Centre project for Expedition on which he was responsible for developing the design of a large 10,000m² architecturally expressed canopy with integrated photovoltaic panels.

Pete says "I have been working on a new Cultural Centre for Athens with Renzo Piano, which includes new homes for the Greek National Opera and for the Greek National Library www.snf.org/snfcc/EN/default.php. My role has been the design of a large 10,000m² architecturally expressed canopy with integrated solar photovoltaic panels. The canopy involves several novel structural engineering concepts and will be a prominent addition to the Athens skyline."

Highly Commended - Nikolaos Socratous of Arup Associates

Project title - Integrating Maths, Architecture & Structural Engineering

Nik graduated from the University of Cambridge with a MEng in civil, structural and environmental engineering in 2006. He then started his structural engineering career in Arup Associates.

Nik says, "My report "Integrating Mathematics, Architecture and Structural Engineering" is based on my involvement in the design of the new department of Engineering and Computing science of Coventry University. This work is an illustration of how structural engineers, using their strong technical backgrounds, can use Mathematics, Physics and Engineering principles as tools for generating architectural concepts. By closely collaborating with the architects, I was able to use pure Euclidean geometry and the relative sizes of the planets of our solar system to define the overall footprint of the building and the design of the break out spaces. Other innovative concepts include the translation of the Fibonacci series into a binary code which was used to define a façade pattern and also using the structural analysis force diagram to create a featured steelwork structure in the main atrium zone with conceptual references to Mondrian's art."

Yahoo! Key Scientific Challenge Winner

Congratulations go to the Department's Sébastien Bratières who is a Yahoo! Key Scientific Challenge Winner, one of 23 Students, from 16 world-class Universities.

The winners were selected based on their research proposals into the 12 different scientific challenges they believe are critical to fuelling innovation on the Web.

The Internet is 27 years old, give or take a few years and depending on who you're asking. But while the Web has changed a lot in our lives over the last couple of decades, by historical standards the science of the Internet is still relatively young.

It is a cliché to compare the Internet to Gutenberg's invention of the printing press, but it is worth pointing out that it took more than 200 years after the invention of the printing press before we experienced the rise of the novel as a popular art form. In other words, the Web we have now is not the Web we'll have in the future. There's a tremendous amount of innovation to come. The question is: "what kind of innovation can we expect?"

Yahoo! Labs believe that innovation in the Web experience of tomorrow will depend directly on the work being done behind the scenes today to create new scientific theories, models and disciplines for understanding the Internet. In fact, a core element of Yahoo! Labs' charter is to invent the new sciences that will underlie the next generation Internet. That charter is evident in their Key Scientific Challenges Program, which focuses on supporting the bright young minds at universities across the world who are thinking, researching and creating those new sciences.

Each of the winning students submitted to Yahoo! an idea and a research proposal that Yahoo!'s scientists and leaders saw as a genuine contribution to their field and to an area seen as critical to laying that scientific foundation for innovation in the future experience of the Web.

The practical significance of Sébastien's proposed work is as follows. Society is overwhelmed with data: this is true for individuals (eg emails, social networking sites, news); for companies (transactions, clients, employee records), for governments (census data, medical records, immigration, crime reports); and for scientists (weather and climate data, genomic data, astronomical data, pharmaceutical data). To cope with and benefit from such vast amounts of data, we need methods to be able to model the data, predict from the data, filter the relevant from the irrelevant, organise, and visualise the data. Machine learning methods provide a method for solving these important problems. Probabilistic (Bayesian) machine learning methods are necessary to handle the underlying uncertainties, noise, incompleteness, and heterogeneity of real-world data sources. Unfortunately, probabilistic machine learning methods become computationally too demanding when applied to the vast data sets of societal and scientific significance. It is therefore of critical importance to develop parallel and distributed approaches to efficient data modelling so that these computations can be distributed on large "farms" of distributed computer servers, and society can benefit from the myriad applications of machine learning methods. It is this critical research problem which Sébastien is trying to address in his PhD.

Sébastien's project brings together two strands of research that receive a lot of discussion these days:

The first is Bayesian probabilistic modelling. Abstractly speaking, this is to create mathematical models (ie representations) from observed data. These models can be used to "simulate" the process which gave rise to the data in the first place, even if very crudely. Moreover, it does so while mimicking the frequency distribution of the observed data. This in turn is operational for a range of data-related tasks: classifying, labelling, clustering, prediction, guessing missing values. Examples of such models are: representing how the part-of-speech of a word depends on the parts-of-speech of its neighbouring words in sentences, and therefore automatically labelling words with their part-of-speech (useful for further language processing); modelling how customers respond to adverts displayed on websites, according to keywords on the page, and other context information about the user and his/ her navigation; modelling viewers' tastes for movies, according to the movie's attributes, their own profile, other movies they have liked, this allows for recommendation, or catalogue analysis/construction; modelling the spatial distribution of ores in the earth crust, etc. The idea is always that some data is available, and that we want to learn from it to carry out one of the mentioned tasks.

The issue with Bayesian modelling is that it often involves summations (such as integrals) of functions over very high-dimensional spaces, with millions of dimensions. An example is that a greytone image of 100x100 pixels is determined by 100x100=10,000 pieces of data, each of which can vary along one dimension, so 10,000 dimensions. To cope with these huge summations, massive computational power is needed. So far, parallel computing has been popular: it runs several processors on one PC, which share the PC's memory and each tackle part of the task at hand before merging their results. Parallel computing goes only so far as the computation can be carried out on a single PC.

The other strand is concerned with overcoming this limitation: it involves distributed computing, where several (10 or 100 or 1000) PC's share a task and merge their results. This is very popular because of a background trend in the IT industry to sell computing services, ie



central processing units (the portion of a computer system that carries out the instructions of a computer program), power by the hour. Related IT buzzwords are cloud computing and virtualization. Sébastien's project consists of exploiting distributed (cloud) computing architectures to carry out the computation involved in applying Bayesian learning to web-scale datasets.

If you are interested in learning more about the other key challenges or are curious about why Yahoo! has chosen these specific scientific challenge areas, some researchers shared their opinions on what makes these problems important in the Key Scientific Challenge series on Yodel <http://ycorpblog.com/> the Yahoo! blog site, with posts on Green Computing, Privacy and Security, Economics and Social Systems, Advertising, Web Information Management, and Machine Learning.

The 2010 winners, in addition to receiving US\$5,000 in unrestricted seed funding, convened at Yahoo! headquarters in Sunnyvale, California for the exclusive Key Scientific Challenges Graduate Student Summit where they spent two days with the Yahoo! Labs scientists presenting their work and jointly discussing the future of these fundamental scientific challenges and ultimately how their research can have the greatest impact on the next generation of the Internet.

Sébastien has also received an extra US\$4,000 from Amazon Web Services to carry out computations on the Amazon Computing Cloud, Amazon's product for "computing as a service". This ties in with the project he received the Yahoo! award for, in that it provides him with concrete means to carry out the computations needed for this research.

UK's 'virtual water' reliance leaves international footprint

The UK's reliance on 'virtual' water, in imported food and other supplies, is exacerbating water shortages in other countries, engineering experts report. They warn the UK's future development could be threatened if we do not address the escalating global water crisis with urgency.



In a new report the *Engineering the Future* alliance* warns that with population growth, urbanisation, changing diets, pollution of water resources and climate change, global water resources are set to become even more stressed. Two thirds of the UK's water footprint is now effectively imported in the form of food, energy and other goods that require water for production and transportation from countries that are themselves under water stress.

Water is one of the most undervalued natural commodities in the world, directly affecting national security through its impact on economic growth, energy security, food supply and healthcare. This domino effect has been described by the Government's Chief Scientific Advisor Professor Sir John Beddington as a 'perfect storm', which could lead to global instability if each of the inter-dependent elements are not addressed.

Chairman of the working group Peter Guthrie, Professor of Engineering for Sustainable Development here at the Department, says:

"If the water crisis becomes critical it will pose a serious threat to the UK's future development because of the impact it would have on our access to vital resources. Food prices would sky-rocket and economic growth would suffer.

"To prevent this we must recognise how the UK's water footprint is impacting on global water scarcity. We should ask whether it is right to import green beans – or even roses – from a water-stressed region like Kenya, for example. The burgeoning demand from developed countries is putting severe pressure on areas that are already short of water. Our virtual water footprint is critical and we need to give it far more attention."

Global Water Security: an engineering perspective says that the UK must take the lead by tackling its own water footprint, managing its own water resources sustainably but also by managing the virtual water embedded in its imports. Because the UK uses so much water internationally through its imported goods and services, it has a duty to provide leadership on the development and implementation of global responses. *Engineering the Future* identified several areas where action will aid the global response to water security:

1. Water management solutions should be considered in the context of the entire water system, from "cloud to coast" as well as the implications immediately upstream and downstream. In this systems approach, all types of water must be considered together, and in this context, the flows and uses of water in a catchment area feeding the soil (green water), free water in rivers and reservoirs (blue water) and used or waste water (grey water) all need to be included. This approach can lead to significant efficiencies in managing water systems.
2. New and better technologies and practices. Technologies and techniques already exist but they need to be refined, developed and in some cases re-assessed in relation to the energy-food-water nexus and to take into account the impact on the eco-system. Key will be finding ways to improve water efficiency in agriculture, which makes up 70% of current water usage and is vital for food supply. As our diets are changing to include more meat than grains, this is expected to increase significantly. One kilogram of beef requires ten times the amount of water that grain does to produce and transport.
3. Developing new, *sustainable* sources of water through technology. Current methods include desalination, water recycling, reuse and harvesting; however these do not take the energy-food-water nexus into account. Global Water Intelligence recently reported that an extra 9.5 cubic metres of freshwater is being produced per day, mainly due to a marked increase in water desalination. *Engineering the Future* warns that desalination is currently extremely energy intensive and unless low carbon energy sources can be used it is not a sustainable solution. Further research is required to find sustainable solutions.
4. Governance and regulation. Water security transcends geographical boundaries and requires international regulation to ensure localised responses do not adversely impact elsewhere in the water system. Local responses can be tailored to meet specific requirements within this global framework.

Professor Guthrie concludes: "There is no single silver bullet for water security. Water management must be looked at in a holistic way, from 'cloud to coast' including all forms of water – in the soil as well as in rivers and reservoirs. Reducing demand will be important but so will developing engineering solutions to create new, sustainable sources of water and promote efficiency in current practices.

"This is a complex issue that transcends geographical and cultural boundaries and cuts across many other crucial sectors such as energy and food supply. To avoid the perfect storm requires a global response, with global policies and governance – backed up by forward-thinking action at a national level to meet individual countries' requirements."

* An alliance including the Institution of Civil Engineers (ICE), Royal Academy of Engineering (RAEng), and the Chartered Institution of Water and Environmental Management

Download the report at www.raeng.org.uk/gws



Courtesy of Jonathan Mullin

Intelligent Search

The Department's Professor Zoubin Ghahramani (right) and Katherine Heller, along with Dinesh Vadhia, CEO and founder of the spin-off startup Xyggy, wrote the article below about their work on new ways of searching the internet, as a guest post on the thenoisychannel.com website.

People are very good at learning new concepts after observing just a few examples. For instance, a child will confidently point out which animals are “dogs” after having seen only a couple of examples of dogs before in their lives. This ability to learn concepts from examples and to generalize to new items is one of the cornerstones of intelligence. By contrast, search services currently on the internet exhibit little or no learning and generalization.

Bayesian Sets is a new framework for information retrieval based on how humans learn new concepts and generalize. In this framework a query consists of a set of items which are examples of a concept. Bayesian Sets automatically infers which other items belong to that concept and retrieves them. As an example, for the query with the two animated movies, “Lilo & Stitch” and “Up”, Bayesian Sets would return other similar animated movies, like “Toy Story”.

How does this work? Human generalization has been intensely studied in cognitive science and various models have been proposed based on some measure of similarity and feature relevance. Recently, Bayesian methods have emerged as models of both human cognition and as the basis of machine learning systems.

Bayesian Sets – a novel framework for information retrieval

Consider a universe of items, where the items could be web pages, documents, images, adverts, social network profiles, audio, video, investments, patents, resumes, medical records, or any other class of items we may want to query.

An individual item is represented by a vector of features of that item. For example, for text documents, the features could be counts of word occurrences, while for images the features could be the amounts of different colour and texture elements.

Given a query consisting of a small set of items (eg a few images of buildings) the task is to retrieve other items (e.g. other images) that belong to the concept exemplified by the query. To achieve the task, we need a measure, or score, of how well an available item fits in with the query items.

A concept can be characterized by using a statistical model, which defines the generative process for the features of items belonging to the concept. Parameters control specific statistical properties of the features of items. For example, a Gaussian distribution has parameters which control the mean and variance of each feature. Generally these parameters are not known, but a prior distribution can represent our beliefs about plausible parameter values.

The score

The score used for ranking the relevance of each item x given the set of query items Q compares the probabilities of two hypotheses. The first hypothesis is that the item x came from the same concept as the query items Q . For this hypothesis, compute the probability that the feature vectors representing all the items in Q and the item x were generated from the same model with the same, though unknown, model parameters. The alternative hypothesis is that the item x does not belong to the same concept as the query examples Q . Under this alternative hypothesis, compute the probability that the features in item x were generated from different model parameters than those that generated the query examples Q . The ratio of the probabilities of these two hypotheses is the Bayesian score at the heart of Bayesian Sets, and can be computed efficiently for any item x to see how well it “fits into” the set Q .

Automatically learns

An important aspect of Bayesian Sets is that it automatically learns which features are relevant from queries consisting of two or more items. For example, a movie query consisting of “The Terminator” and “Titanic” suggests that the concept of interest is movies directed by James Cameron, and therefore Bayesian Sets is likely to return other movies by Cameron. The power of queries consisting of multiple example items is unexploited in most search engines. Searching using examples is natural and intuitive for many situations in which the standard text search box is too limited to express the user’s information need, or infeasible for the type of data being queried.

Uses

The Bayesian Sets method has been applied to diverse problem domains including: unlabelled image search using low-level features such as colour, texture and visual bag-of-words; movie suggestions using the MovieLens and Netflix ratings data; music suggestions using last.fm play count and user tag data; finding researchers working on similar topics using a conference paper database; searching the UniProt protein database with features that include annotations, sequence and structure information; searching scientific literature for similar papers; and finding similar legal cases, New York Times articles and patents.

Apart from web and document search, Bayesian Sets can also be used for advert retrieval



through content matching, building suggestion systems (“if you liked this you will also like these” which is about understanding the user’s mindset instead of the traditional “people who liked your choice also liked these”) and finding similar people based on profiles (eg for social networks, online dating, recruitment and security). All these applications illustrate the countless range of problems for which the patent-pending Bayesian Sets provides a powerful new approach to finding relevant information.

Interactive search box

An important aspect of the approach is that the search box accepts text queries as well as items, by dragging them in and out of the search box. Drag an item of interest from the results into the search box and the relevance changes. When two or more items are added into the search box, the system discovers what they have in common and returns better results. Items can be toggled in/out of the search and completely removed by dragging them out of the search box. Each change to an item in the search box automatically retrieves new relevant results.

Summary

Bayesian Sets demonstrates that intelligent information retrieval is possible, using a Bayesian statistical model of human learning and generalization. This approach, based on sets of items, encapsulates several novel principles. First, retrieving items based on a query can be seen as a cognitive learning problem; where we have used our understanding of human generalization to design the probabilistic framework. Second, retrieving items from large corpora requires fast algorithms and the exact computations for the Bayesian scoring function are extremely fast. Finally, the example-based paradigm for finding coherent sets of items is a powerful new alternative and complement to traditional query-based searches.

Finding relevant information from vast repositories of data has become ubiquitous in modern life. Professor Ghahramani’s research team believes that this approach, based on cognitive principles and sound Bayesian statistics, will find many uses in business, science and society.

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In conversation with Stephen Morris

Stephen Morris is a researcher in the Department's Centre of Molecular Materials for Photonics and Electronics. He undertakes and manages research within the liquid crystal materials and devices area. His work has led to several world class publications on flexoelectric and lasing liquid crystals for novel applications in the *Journal of Applied Physics*, *Journal of Physics D* and recent invited papers for *The Journal for the Society of Information Display*. This work demonstrates how successfully Steve has bridged the gap between materials physics, characterisation and device engineering / applications.

Since completing his PhD Steve has been employed by the EPSRC basic technology grant, COSMOS, and has taken on the role of research co-ordinator for the project. This includes fostering collaboration between Engineering, Physics and Chemistry, in which he has done an excellent job with collaborative publications as evidence of his success. Steve has also embraced the teaching role and was awarded a Fellowship at St Catharine's College, where he is now Director of Studies for Physics.

Steve was recently interviewed about his career. The article below by Virginia Gewin was originally published in the journal *Nature* as a 'Nature-jobs' feature and has been reproduced here with the editor's permission.

What is the best career decision you've made?

Agreeing to be project manager on a large four-year grant funded by the UK Engineering and Physical Sciences Research Council. We sought to develop a new generation of micrometre-sized, tunable light sources. Combining two roles – as a postdoc and a project manager – has been difficult, but it has been made easier by the team ethos of this group. The biggest hurdle was definitely being able to juggle my own research at the same time as doing managerial tasks – reporting, planning, and meeting targets for deliverables and milestones for the project as a whole.

Was the 2010 Young Scientist award a surprise?

Yes. I checked my email one Friday evening and found out I had won the award. I didn't even know I had been nominated. It is so nice to get recognition from your peers, who understand the intricacies of what you are doing – especially because this is such a small, specialized community. I don't know how much impact it will have on my career over the long term.

When did it become clear to you that you wanted to pursue a career in research?

As a third-year undergraduate, I had the opportunity to produce a thesis that described in detail why there was a discrepancy between the predicted and observed behaviour of solar neutrinos. Scientists had measured fewer neutrinos flowing from the Sun to Earth than was predicted by the standard model of physics. As I tried to make sense of this discrepancy, I realized that I wanted to do a PhD and pursue a research-based career in science.

How did you get interested in the new field of liquid-crystal lasers?

It was basically the result of meeting someone who offered me an opportunity I probably wouldn't have

found on my own. When I was applying for PhD positions, I focused on experimental and nuclear particle physics. Then I met Harry Coles, Director of the Centre of Molecular Materials for Photonics and Electronics. He opened my eyes to the alternatives offered by working with liquid-crystal lasers, which I hadn't considered. This burgeoning field really appealed to me because the physics was interesting, cross-disciplinary and had the potential for exciting applications.

What are the potential applications?

Liquid-crystal materials can be made into organic laser devices – which may be useful for medical diagnostic techniques because they are so small. These lasers are the thickness of a human hair and tunable in terms of wavelength, so they can be adapted easily to a host of situations. It may some day be possible to combine them with infrared medical diagnostic tools to create devices that are able, for example, to detect retinal glucose levels associated with the onset of diabetes.

What motivates your work more – the experiments or the applications?

I'm motivated by the day-to-day aspects of doing experiments in the lab. The applications really interest me, but ultimately small breakthroughs in fundamental research drive any progress towards new applications.

How has working in a small field affected your career decisions?

I've been very lucky to work with some of the leading groups in this new field, so there isn't much reason to move – something one is typically supposed to do as a postdoc. I would be hard-pressed to find another position where I would have both the top facilities and a world-class range of colleagues to work with.

Have you had a career-defining moment?

Being elected as a fellow of St Catharine's College, Cambridge, in 2007 was an important moment for me. It is quite rare for people to be elected as fellows of colleges, the decision being based in part on teaching and research accomplishments, unless they have a full academic position at the university. I was a postdoc and a project manager at the time. As I was only on contract, I felt it was some vindication that I was, at least, going in the right direction.

Are you trying to carve out a niche at Cambridge?

Yes. My ultimate goal is to secure a position at Cambridge – and that is certainly no easy feat. It is fiercely competitive here. I'm realistic that, although it is something I'm striving for, it is a long shot. The next few years are my opportunity to prove myself. There is also an element of luck because lectureships usually come up only now and again.



Stephen Morris, the 2010 British Liquid Crystal Society Young Scientist, is interviewed about his career.

This article can be found on the Nature website at:
www.nature.com/naturejobs/2010/100909/full/nj7312-239a.html
Dr Steve Morris details at: www-g.eng.cam.ac.uk/CMMPE/people.html