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In this issue

Cover image: Intelligent asset cartoon drawing by Professor Duncan McFarlane. © Duncan McFarlane.

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Welcome

I recently attended the launch of the University's £2 billion fundraising campaign and I was overwhelmed by the stunning array of donors and the palpable enthusiasm for engineering. The Department's move west is one of the major projects of the campaign and in the next issue of the newsletter, we will be ready to share more of our plans for our new 100,000m² facility. This transition will be even more dramatic than the Department's original move, nearly one hundred years ago, from its cramped origins on the New Museum Site to Trumpington Street.

But do not imagine that we are sitting back basking in the glow of our historic achievements. The stories contained in the pages of this newsletter show that we are keeping very busy at the forefront of engineering doing our best in both teaching and research to crack hard problems and make a real difference.

Take, for example, the accomplishments of the Photonics Group, which is on its way to realising the dream of real-time holographic displays. The advances being uncovered by young researchers Calum Williams and Yunuen Montelongo could lead to dazzling imagery beyond anything imaginable with conventional technology. Read more about their work on page 8.

Professor Abir Al-Tabbaa heads a team in Civil and Environmental Engineering that is exploring the different ways concrete can be improved upon – some of which are being used and studied at the James Dyson Building currently being constructed outside my office as I write this letter. The 'smart' concrete innovations, including self-repairing concrete blocks, will aid in the development of more sustainable construction materials in the future. Read about how self-healing concrete works on page 10.

We are pleased to have welcomed to our ranks in the past year Professor Fumiya Iida, Lecturer in Mechatronics in the Machine Intelligence Laboratory. One product of his research is a robot that takes the principles of natural selection and builds increasingly successful 'children.' We see Iida's work as a way to bridge the gaps between biology and engineering incorporating those principles into better designs. Turn to page 24 for a link to watch this robot in action.

There are many more achievements we are proud of on every page of this newsletter including those of our alumni. Please stay in touch, give feedback on our stories, sign up for our LinkedIn group and tell us how you are using your experience at Cambridge to make the world a better place.

Professor David Cardwell FREng

To view the short film celebrating the launch of the University's 'Yours, Cambridge' campaign, visit **http://bit.ly/1Nmnkjo.**

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Credit: Phil Guest

↑ Overlooking the Thames

Improving building efficiency

An important piece of the energy puzzle

A Department of Engineering project is among those benefiting from £3 million Engineering and Physical Sciences Research Council (EPSRC) funding.

Against a world backdrop of increased concerns about energy security, price fluctuations and, of course, the need to address climate change, six research projects that aim to gain a fuller understanding of how energy is managed in the country's non-domestic buildings, have been launched.

Funded with £3 million from the Engineering and Physical Sciences Research Council (EPSRC) on behalf of the Research Councils UK Energy Programme (RCUKEP), the research will address how to use technology, data and information, mathematics, law and sociology to create better energy strategies and behaviours in the public and private non-domestic buildings stock.

Among the schemes being funded is a Cambridge project aimed at creating software that will help to reduce the uncertainty in modelling the energy management of a wide variety of buildings.

Non-domestic buildings such as offices, supermarkets, hospitals and factories account for approximately 18 per cent of UK carbon emissions and 13 per cent of final energy consumption.

By 2050, the total non-domestic floor area in the UK is expected to increase by 35 per cent, while 60 per cent of existing buildings will still be in use. This means that substantial retrofitting is likely and planning what techniques to use to save energy, as well as how to implement change with the cooperation of building occupants, is going to be essential.

Professor Philip Nelson, EPSRC's Chief Executive, said: "Improving energy efficiency is an important piece of the energy puzzle. Worldwide energy demand is rising, as are global temperatures and sea levels. We need to find smart solutions to how we use energy while improving the environment in which people have to work, rest or play. These projects will go a long way to help improve our understanding of what goes on in non-domestic buildings and add to the armoury at the disposal of those managing these facilities."

The new projects will be run at Imperial College London, University of Cambridge, University of Edinburgh, University of Oxford, University of Southampton and the University of Strathclyde.

The Cambridge project is called B-bem: The Bayesian Building Energy Management Portal.

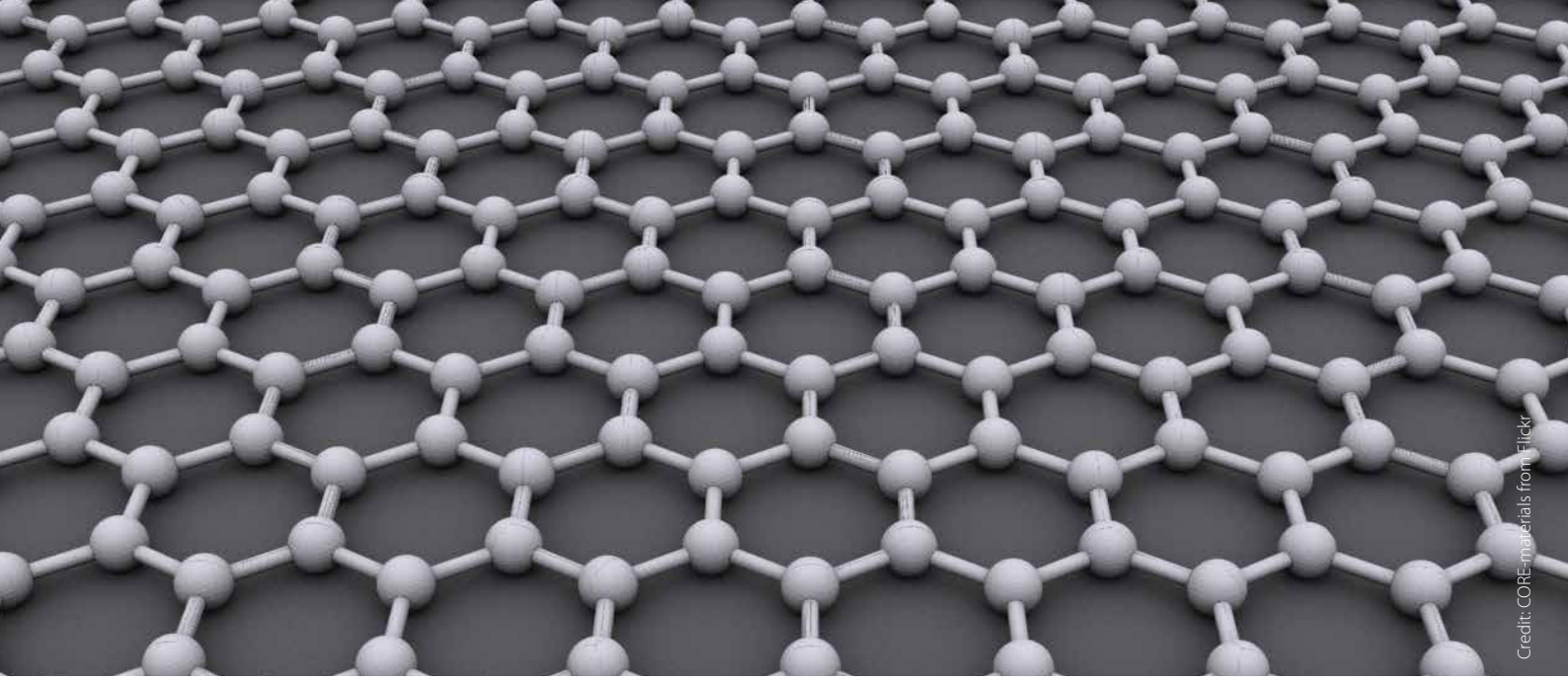
Managing energy in existing non-domestic buildings is wrought with many challenges, a number of which arguably are due to the diversity found among individual buildings and the humans who occupy them. Buildings are inherently unique systems, making it difficult to generalise technology solutions for any individual property. In 2008, the Energy Efficient Cities initiative commenced a series of projects focusing on developing retrofit analysis tools for the UK's non-domestic building sector.

> We need to find smart solutions to how we use energy while improving the environment in which people have to work, rest or play.
>
> Professor Philip Nelson

The team is led by Dr Ruchi Choudhary of the Structures Group and includes a multi-disciplinary group of researchers from Architecture, Engineering, and Judge Business School.

This article originally appeared on the University of Cambridge website

www.eeci.cam.ac.uk



Credit: CORE-materials from Flickr

↑ Model of graphene structure

Graphene's potential for energy conversion and storage

Scientists working with Europe's Graphene Flagship and the Cambridge Graphene Centre have produced a detailed and wide-ranging review of the potential of graphene and related materials in energy conversion and storage.

In a review article published recently in the journal *Science*, the researchers, led by Francesco Bonaccorso, a Royal Society Newton Fellow at the Cambridge Graphene Centre, note the substantial progress made in material preparation at the laboratory level. They also highlight the challenge of producing the materials on an industrial scale in a cost-effective manner.

Graphene – a two-dimensional material made up of sheets of carbon atoms – has many potential applications, among them energy conversion and storage. Graphene and related 2D crystals combine high electrical conductivity with physical flexibility and a huge surface-to-weight ratio. Such qualities make them suitable for storing electric charge in batteries and supercapacitors and as catalysts in solar and fuel cell electrodes.

"The huge interest in 2D crystals for energy applications comes both from their physico-chemical properties, and the possibility of producing and processing them in large quantities, in a cost-effective manner," said Francesco. "In this context, the development of functional inks based on 2D crystals is the gateway for the realisation of new generation electrodes in energy storage and conversion devices."

"Graphene and related materials have great promise in these areas, and the Graphene Flagship has identified energy applications as a key area of investment," said review co-author Professor Andrea Ferrari, who chairs the Executive Board of the Graphene Flagship, and is director of the Cambridge Graphene Centre. "We hope that our critical overview will guide researchers in academia and industry in identifying optimal pathways toward applications and implementation, with an eventual benefit for society as a whole."

Francesco added that the challenge ahead is to demonstrate a disruptive technology in which two-dimensional materials not only replace traditional electrodes, but more importantly enable whole new device concepts.

In an open-access paper published in the Royal Society of Chemistry journal *Nanoscale*, more than 60 academics and industrialists lay out a science and technology roadmap for graphene, related two-dimensional crystals, other 2D materials, and hybrid systems based on a combination of different 2D crystals and other nanomaterials. The roadmap covers the next ten years and beyond, and its objective is to guide the research community and industry toward the development of products based on graphene and related materials.

Graphene and related materials are expected to revolutionise the fields in which they are applied, and they have the potential to become the materials of the 21st century. They will supplement, and at times replace, existing substances in a range of applications. Two-dimensional materials shall in some cases be integrated into existing platforms in order to enhance them. For example, graphene could be integrated into silicon photonics, exploiting established technology for constructing integrated circuits.

The roadmap highlights three broad areas of activity. The first task is to identify new layered materials, assess their potential, and develop reliable, reproducible and safe means of producing them on an industrial scale. Identification of new device concepts enabled by 2D materials is also called for, along with the development of component technologies. The ultimate goal is to integrate components and structures based on 2D materials into systems capable of providing new functionalities and application areas.

Eleven science and technology themes are identified in the roadmap. These are: fundamental science, health and environment, production, electronic devices, spintronics, photonics and optoelectronics, sensors, flexible electronics, energy conversion and storage, composite materials and biomedical devices. The roadmap addresses each of these areas in turn, with timelines.

→ www.graphene.cam.ac.uk

→ Women from the village of Okabi taking part in Stephanie's research exercise

Credit: Stephanie Hirmer

Keeping the lights on in rural Uganda

Stephanie Hirmer, PhD student at the Department of Engineering's Centre for Sustainable Development, writes about her journey to Moyo in northern Uganda asking villagers which possessions they most value and why.

"If I have a flush toilet in my house I think I can be a king of all kings because I can't go out on those squatting latrines… also it can protect my wife from going outside alone as recently my wife was almost raped by a thug when she escorted my son to the latrine at around 10:30pm in the night."

This is Paul. His declaration of the possession he would most value is met with laughter from his fellow villagers, but it highlights a very real concern – the safety of his family.

It's also a valuable research finding for me. Too often, projects that bring electricity to villages like Paul's fail because of lack of uptake and maintenance by the rural communities. But if, for instance, the benefits of electrification could be understood in terms of the safety value of night-time lighting, this could improve the sense of community responsibility towards sustaining the technology after its implementers have gone home.

Another villager, Michael, explains that he places most value in owning a corrugated iron sheet instead of grass-thatched roofing because this would reduce the risk of indoor fires. Here too, the value of electricity can be highlighted – it would avoid the need to cook on an open fire.

Understanding the locals' real needs and desires can be a key element in overcoming the lack of technology uptake. Finding out what these are is the aim of my PhD research, working with Dr Heather Cruickshank at the Centre for Sustainable Development. While the technology itself has been extensively studied, social attributes in project design have received little attention.

To provide better infrastructure services to rural communities, it is fundamentally important to relate to the beneficiaries' needs and aspirations, and I need to travel to the areas to learn this at first hand. Infrastructure failure after the projects are handed over to the communities is common across the basic utility provisions such as water and electrification, and I am keen to discover if there is a way of improving project longevity by 'selling' a service that is valued.

Today is the first day of fieldwork and we have arrived at the village of Moyo for the day's focus group discussions. The village is still very familiar to me; not much has changed since my last visit three years ago when I was working with the German Development Agency, GIZ, on the installation of the community-operated pico-hydropower scheme. These schemes are perfect for small communities with about 50 homes that require only enough electricity to power a few light bulbs and a small number of electrical items. In Moyo, however, the scheme no longer works, and the villagers are once more plunged into darkness while a more effective solution is being explored.

We meet one of the women to mobilise the six chosen villagers. We decide to start with the men, as by late morning some of the men in the village will be drunk.

Identifying what is important to rural villagers when implementing basic infrastructure projects is far more complex than simply asking "what is important to you?" I have made a 'value game' and explain to the locals that they must choose, initially individually, 20 items from a list of approximately 50 items that include cow, hoe, fridge, water pot, bed and utensils. Following prioritisation, they will be asked to give reasons as to why these items are important to them.

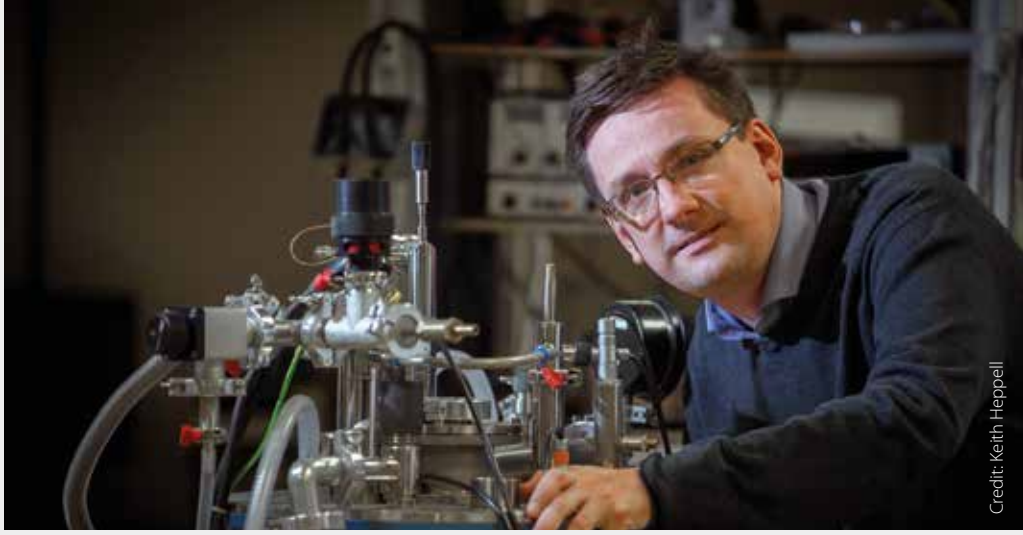
> "To provide better infrastructure services to rural communities, it is fundamentally important to relate to the beneficiaries' needs and aspirations.
>
> Stephanie Hirmer

Another example arises during the discussion. The villagers use kerosene lamps to light their homes. Simply offering a solution that replaces light from one source with another is not enough. Modern technologies can offer benefits that are indirectly linked to aspects perceived as 'very important' in rural communities – in this case, avoiding the use of fume-producing kerosene would resonate with the mothers' hopes of keeping their children healthy.

The findings from my research will be fed back to project implementers. My hope is that only small adjustments in the project design will be required in order to communicate these 'additional' benefits to the target users, and that the lights will be turned on and kept on in rural villages like Moyo.

A version of this article originally appeared in the University of Cambridge's *Research Horizons* magazine.

→ www.eng.cam.ac.uk/profiles/sah93



Credit: Keith Heppell

Superconductivity
The turning point from niche to mass markets

An interview with Dr John Durrell, newly appointed Lecturer in Superconductivity, by Philip Guildford, Director of Research

Philip: The discovery of high-temperature superconductivity in 1987 created a tremendous amount of scientific and media interest, but then faded from public view. What happened?

John: Superconductivity intrigues experts and lay people alike. Zero resistance to electricity, huge magnetic fields, and magnetic levitation are all the stuff of science fiction. Before 1987, it had been seen in materials at –255°C. In 1987, it was seen in new materials at –183°C. Still very cold, but can be achieved with liquid nitrogen, rather than hydrogen, and much cheaper cooling systems. Everyone got very excited, possibly too excited, with the idea of using these materials in everyday applications. It was impossible for the scientists and engineers to deliver results immediately to match the media hype and inevitably the media's focus moved on to the next big thing.

Philip: So what progress has been made since the discovery?

John: Lots of hard work away from the media spotlight has delivered superconducting wires and materials that are used in all sorts of niche applications such as MRI scanners in hospitals, very high field magnets for research and in very sensitive devices for measuring magnetic fields. But now everything is set to move up a gear.

Philip: Why is this the moment of transition?

John: In our group in the Department of Engineering, we have got to the point where we can make big pieces of bulk superconductor with superb properties. We recently broke the world record for the magnetic field trapped in a lump of superconductor (J H Durrell et al 2014 Supercond. Sci. Technol. 27 082001). We have an industrial process for producing this material. This opens the door to using much higher magnetic fields in more everyday applications such as motors and generators. For instance, we can now imagine ordinary commercial ships running with superconducting in the engine room. Mark Ainslie in our group is working on prototypes right now which we expect to be only 25% of the bulk of a conventional motor. In addition, Suchitra Sebastian and colleagues in the Cavendish Lab in Cambridge have revealed a theoretical basis for explaining why the materials we use superconduct that could accelerate our hunt for even better materials. The combination of practical industrial processes for making the materials, practical prototypes and a strong theoretical foundation creates this moment of transition in our field.

Philip: What lies ahead?

John: The hard graft of building greater understanding, improving materials, scaling up production and making it all robust enough for industrial use. As we work closely with companies, progress to market will leap forward and probably in unexpected directions, as the interface between academia and industry often generates the exciting unforeseen opportunities.

> Superconductivity intrigues experts and lay people alike. Zero resistance to electricity, huge magnetic fields, and magnetic levitation are all the stuff of science fiction.
>
> Dr John Durrell, Lecturer in Superconductivity, Department of Engineering

Philip: And for you personally?

John: I feel privileged to be looking after Professor David Cardwell's group for five years while he is Head of the Department of Engineering. I want to do much more than just be the caretaker. I want to maintain the momentum that David has built over the years, keep the team spirit, develop our industrial connections and really make the most of this turning point for superconductivity. After five years, I want David and the team to be really proud of our results: new scientific and engineering discoveries, demonstrations of superconducting machines and companies working with us to take superconductors into new practical applications.

bulk-sucon.eng.cam.ac.uk

Credit: Jim Nix (Flickr)

↑ St Pancras International Station

Cambridge awarded £18 million in funding to support UK infrastructure research

Funding announced by the Chancellor in the last budget is part of a wider £138 million programme to support the UK's infrastructure and cities.

The University of Cambridge will receive £18 million in funding to ensure that the UK's infrastructure is resilient and responsive to environmental and economic impacts, as announced by the Chancellor in the budget earlier this year. The Cambridge funding will be used to support research in the application of advanced sensor technologies to the monitoring of the UK's existing and future infrastructure, in order to protect and maintain it.

The funding is part of the wider UK Collaboration for Research in Infrastructure & Cities (UKCRIC), which is a £138 million capital investment that will be centred around the Olympic Park in Stratford and will include 13 university partners from across the UK.

The proposed research stems from a need for UK national and local infrastructure (such as transport, water, waste, energy and information technology systems) to be fit for purpose for supporting societal development in a changing world.

UKCRIC will integrate knowledge, tools and methods from a wide range of disciplines. Its initial case proposes four strands:

A: Investment in capital equipment and facilities (national 'Laboratories') that underpin transformative research for all partners and stakeholders

B: A national 'Observatory' and living laboratories that will establish a network of linked infrastructure 'observatories' to test current and proposed urban infrastructure systems, and to enable rapid trialling of solutions

C: A multi-level modelling and simulation environment that allows 'what if' experiments to be carried out in a high performance computing environment

D: Creation of a Coordination Node (CN) to integrate activities and industry collaboration across UKCRIC

Once the business case for UKCRIC has been agreed, the collaboration will receive further details on funding allocation and capital investments.

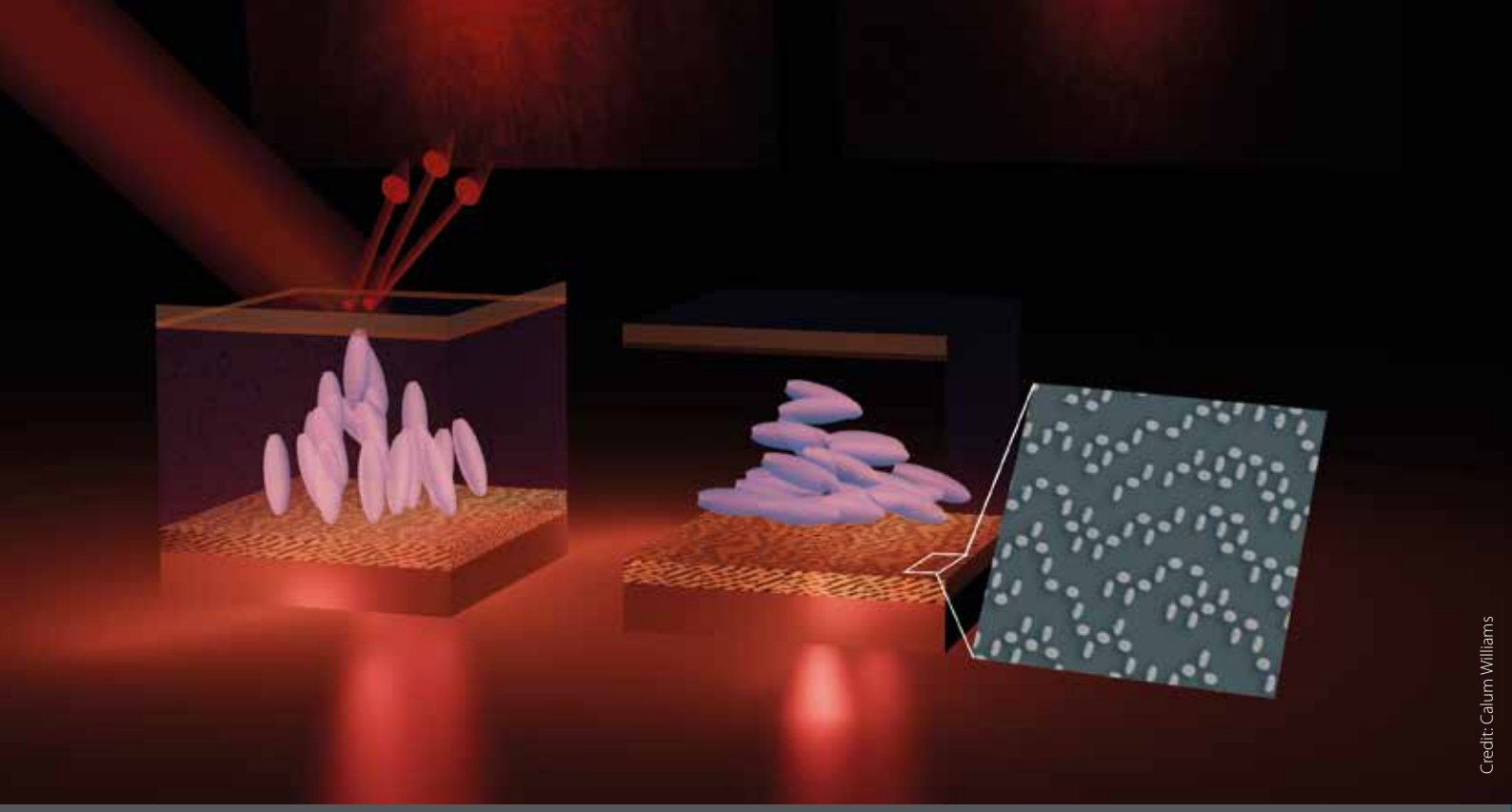
The Cambridge funding will be used to build a National Research Facility for Infrastructure Sensing on the West Cambridge site, which will build upon the expertise of the University's Centre for Smart Infrastructure and Construction (CSIC). The new building will be an interdisciplinary centre for sensors and instrumentation for infrastructure monitoring and assessment, spanning scales from an individual asset, such as a tunnel, building or bridge, to a complex system such as a railway or a city district. More advanced sensors and appropriate data analysis will ensure better product quality, enhanced construction safety, and smarter asset management.

"Building a UK infrastructure research community like UKCRIC is important to help us design, build and maintain infrastructure which is resilient, adaptable and sustainable," said Professor Robert Mair, Head of Civil Engineering and of the Centre for Smart Infrastructure and Construction (CSIC) at the University of Cambridge. "The UK needs to do more to invest in its infrastructure and infrastructure services, which are so important to its citizens. This is an issue which cannot be ignored, so we welcome this new investment as a positive way to engage academia and industry in protecting and growing the UK's infrastructure base."

Cambridge is one of 13 universities receiving funding from UKCRIC. The consortium is being co-ordinated by University College London.

This article originally appeared on the University of Cambridge website.

www-smartinfrastructure.eng.cam.ac.uk



Credit: Calum Williams

↑ Rendered schematic of holographic pixels in operation showing switching states

Real-time holographic displays one step closer to reality

Researchers from the Department of Engineering have designed a new type of pixel element which could make three-dimensional holographic displays possible.

Real-time dynamic holographic displays, long the realm of science fiction, could be one step closer to reality, after researchers from the Department developed a new type of pixel element that enables far greater control over displays at the level of individual pixels. The results are published in the journal Physica Status Solidi.

As opposed to a photograph, a hologram is created when light bounces off a sheet of material with grooves in just the right places to project an image away from the surface. When looking at a hologram from within this artificially-generated light field, the viewer gets the same visual impression as if the object was directly in front of them.

Currently, the development of holographic displays is limited by technology that can allow control of all the properties of light at the level of individual pixels. A hologram encodes a large amount of optical information, and a dynamic representation of a holographic image requires vast amounts of information to be modulated on a display device.

A relatively large area exists in which additional functionality can be added through the patterning of nanostructures (optical antennas) to increase the capacity of pixels in order to make them suitable for holographic displays.

"In a typical liquid crystal on silicon display, the pixels' electronics, or backplane, provides little optical functionality other than reflecting light," said Calum Williams, a PhD student in the Photonics Group and the paper's lead author. "This means that a large amount of surface area is being underutilised, which could be used to store information."

Calum and his colleagues have achieved a much greater level of control over holograms through plasmonics: the study of how light interacts with metals on the nanoscale, which allows the researchers to go beyond the capability of conventional optical technologies.

Normally, devices which use plasmonic optical antennas are passive, meaning that their optical properties cannot be switched post-fabrication, which is essential for real-world applications.

Through integration with liquid crystals, in the form of typical pixel architecture, the researchers were able to actively switch which hologram is excited and therefore which output image is selected.

> "A large amount of surface area is being underutilised, which could be used to store information."
>
> Calum Williams

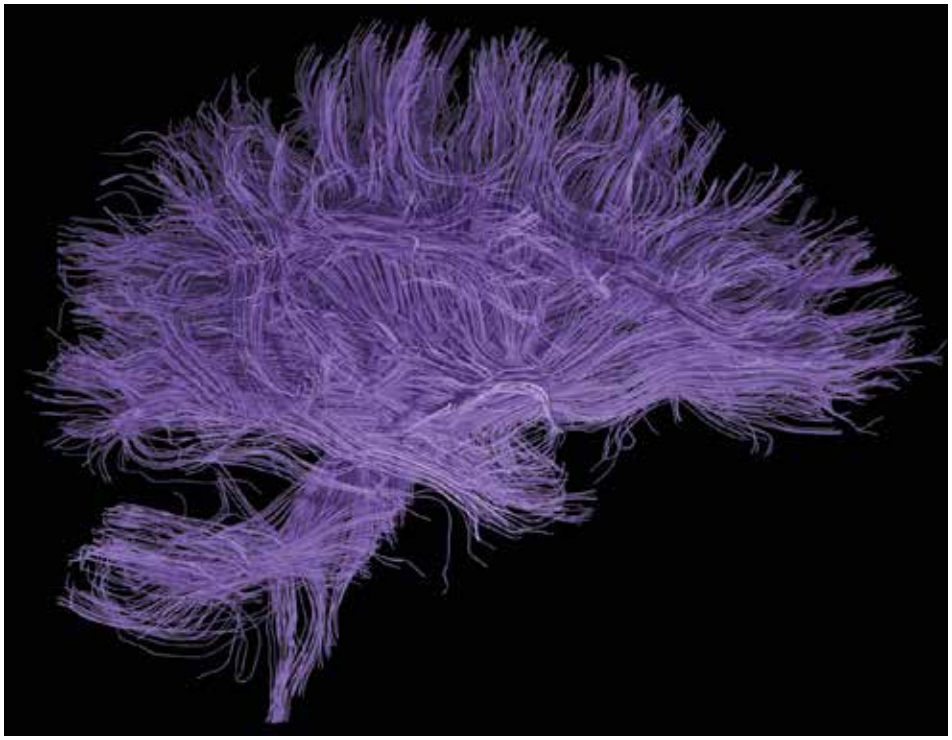
"Optical nanoantennas produce a strong interaction with light according to their geometry. Furthermore, it is possible to modulate this interaction with the aid of liquid crystals," said co-author Yunuen Montelongo, a PhD student in the Photonics Group.

The work highlights the opportunity for utilising the plasmonic properties of optical antennas to enable multi-functional pixel elements for next generation holographic display technologies.

Scaling up these pixels would mean a display would have the ability to encode switchable amplitude, wavelength and polarisation information, a stark contrast to conventional pixel technology.

This article originally appeared on the University of Cambridge website.

www.eng.cam.ac.uk/profiles/cw507



Credit: Ars Electronica

Thinking inside the box

New research into the phenomenon of design fixation may help in the development of new tools and strategies that help to stimulate the creative process without inadvertently limiting it.

It's a common occurrence: when faced with a problem which is similar to one which has been faced before, most people will default to what worked in the past. As the saying goes, if it ain't broke, don't fix it. But while this approach often works, it can also limit thinking and prevent alternate, and possibly better, solutions from being considered. In psychology, this phenomenon of being 'stuck in a rut' or failing to 'think outside the box' is known as the 'Einstellung' effect, 'mental set' or 'fixation'.

Fixation occurs in all sorts of settings, such as with the interpretations that scientists make of their data, the decisions that managers make in organisations, and in the diagnoses that physicians make. It's also an issue in design and engineering, where knowledge of earlier solutions can inadvertently narrow the range of answers that designers explore when responding to new problems.

"Whether designing a new toy, a new bridge, or a new piece of software, fixation can stop the creative process cold, severely limiting the way in which we see a problem and the variety of solutions we explore," said Dr Nathan Crilly of the Department of Engineering. "However, there is still a lack of in-depth research on fixation in the real-world settings that experimental research is meant to simulate. In particular, we have little knowledge of how fixation occurs in professional design projects that have conflicting objectives, long timescales and experienced team members." To address this gap in knowledge, Nathan conducted a qualitative study, which found that although various formal methods are used to promote creative thinking, reflecting on prior episodes of fixation is the most effective way of guarding against such episodes in the future. The results are published in the journal *Design Studies*.

What causes fixation varies from person to person, and from project to project, but common factors include a commitment to initial ideas, project constraints that prevent exploration, and organisational cultures that give people ownership of their ideas, which gives them the incentive to defend them.

Common factors that prevent fixation include diverse teams, making and testing models and facilitation of the creative process by people who are familiar with fixation risks. However, experience can be a both a blessing and a curse when it comes to preventing fixation. As designers gain more experience, they learn how certain approaches succeed or fail, with the experience of failure particularly prominent in their minds. This accumulated knowledge can cause designers to become increasingly conservative, with experienced designers sticking to a restricted set of solutions.

While experience of failure can lead to fixation, other forms of experience can help to prevent it. For example, by working on a variety of different projects, designers are exposed to the many ways in which any given problem can be solved. This experience of variety acts to remind designers that the current problem they are addressing must have multiple possible solutions.

Finally, and perhaps most interestingly, as designers accumulate design experience, they also accumulate experience of fixation, either in themselves or in those they interact with. These episodes of blindness might only be recognised in retrospect, but by reflecting on them, designers can learn to recognise their biases and learn to resist them.

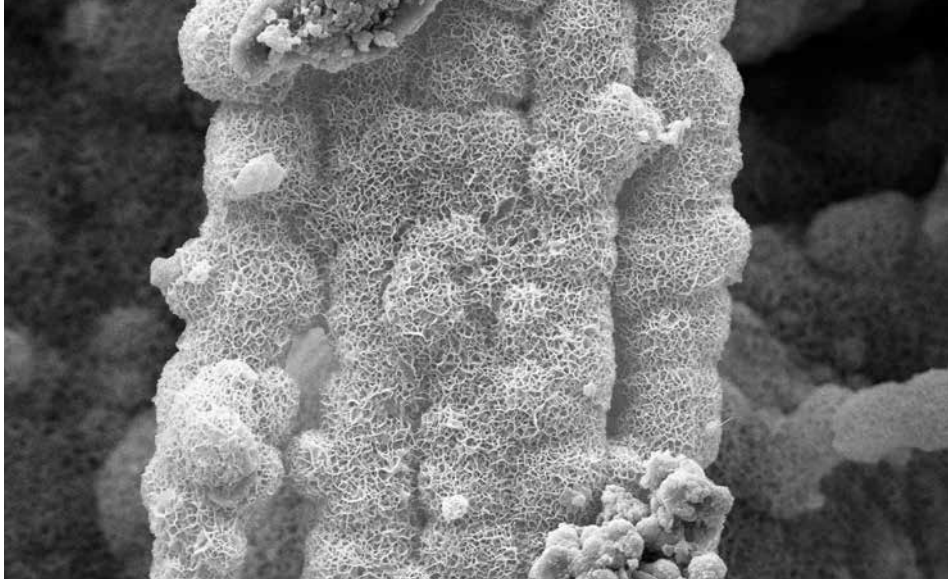
> "Fixation can stop the creative process cold, severely limiting the way in which we see a problem and the variety of solutions we explore."
>
> Dr Nathan Crilly

Despite their awareness of the risks of fixation and the steps they take to guard against it, designers also recognise that fixation is a difficult problem to control. According to Nathan, it is important to gain a better understanding of the various creative behaviours that people exhibit and the barriers that block that behaviour.

"By understanding the nature of fixation, we'll be able to develop the tools and techniques that effectively address it in the contexts where it occurs and understand how these tools should be presented to the people who will use them," said Nathan. The research has been funded by the UK Physical Sciences & Research Council (EPSRC).

Nathan Crilly

www-edc.eng.cam.ac.uk/people/nc266.html



Health-conscious concrete

Roads that self-repair, bridges filled with first-aid bubbles, buildings with arteries… not some futuristic fantasy but a very real possibility with 'smart' concrete.

Skin is renewable and self-repairing – our first line of defence against the wear and tear of everyday life. If damaged, a myriad of repair processes spring into action to protect and heal the body. Clotting factors seal the break, a scab forms to protect the wound from infection and healing agents begin to generate new tissue.

Taking inspiration from this remarkable living healthcare package, researchers are asking whether damage sensing and repair can be engineered into a quite different material: concrete.

Self-healing materials were voted one of the top ten emerging technologies in 2013 by the World Economic Forum, and are being actively explored in the aerospace industry, where they provide benefits in safety and longevity. But perhaps one area where self-healing might have the most widespread effect is in the concrete-based construction industry.

Concrete is everywhere you look: in buildings, bridges, motorways, and reservoir dams. It's also in the places you can't see: foundations, tunnels, underground nuclear waste facilities, and oil and gas wells. After water, concrete is the second most consumed product on earth.

But, like most things, concrete has a finite lifespan. "Traditionally, civil engineering has built-in redundancy of design to make sure the structure is safe despite a variety of adverse events. But, over the long term, repair and eventual replacement is inevitable," said Professor Abir Al-Tabbaa, from the Department of Engineering and the lead of the Cambridge component of the research project.

The UK spends around £40 billion per year on the repair and maintenance of existing, mainly concrete, structures. However, repairing and replacing concrete structures cause disruptions and contribute to the already high level of carbon dioxide emissions that result from cement manufacturing.

In 2013, researchers in Cambridge joined forces with colleagues at the Universities of Cardiff (who lead the project) and Bath to create a new generation of 'smart' concrete and other cement-based construction materials.

"Previous attempts in this field have focused on individual technologies that provide only a partial solution to the multi-scale, spatial and temporal nature of damage," explained Professor Al-Tabbaa. By contrast, this study, funded by the Engineering and Physical Sciences Research Council (EPSRC), provides an exciting opportunity to look at the benefits of combining several 'healthcare packages' in the same piece of concrete. "

Mechanical damage can cause cracks, allowing water to seep in; freezing and thawing can then force the cracks wider. Loss of calcium in the concrete into the water can leave decalcified areas brittle. And, if fractures are deep enough to allow water to reach the reinforcing steel bars, then corrosion and disintegration spell the end for the structure.

The team in Cambridge is addressing damage at the nano/microscale by developing innovative microcapsules containing a cargo of mineral-based healing agent. It's like having a first-aid kit in a bubble: the idea is that physical and chemical triggers will cause the capsules to break open, releasing their healing and sealing agents to repair the lesion. "While various cargo and shell materials have been developed for other applications ... they are not generally applicable to cement-based matrices and are far too expensive for use in concrete, which is why we have needed to develop our own," explained Professor Al-Tabbaa.

As the Cambridge researchers move closer to the best formulations for the microcapsules, they have begun collaborating with companies who can scale up the production to the levels required to seed tonnes of cement. Meanwhile, the three research groups are also beginning to test combinations of each of their techniques, to find the best recipe for maximum self-healing capability. With the help of industrial partners, field trials are testing and refining the most promising combined systems in a range of real environments and real damage scenarios. This will include testing them in non-structural elements in the Department of Engineering's new James Dyson Building which is currently under construction.

> "We want concrete to be a material for life that can heal itself again and again when wounded."
>
> Professor Abir Al-Tabbaa

"This is when it will become really exciting," said Professor Al-Tabbaa. "To be truly self-healing, the concrete needs to be responsive to the inherently multidimensional nature of damage, over long time scales. We want concrete to be a material for life that can heal itself again and again when wounded."

Abir Al-Tabbaa

This article originally appeared in the University of Cambridge's *Research Horizons* magazine.

www-geo.eng.cam.ac.uk

Credit: Tmarliyy via Flick

↑ Paddington Station

Air quality concerns inside London's Paddington Station

A risk assessment produced by Department of Engineering researchers has found troubling levels of pollution inside London's Paddington Station.

The team found that during one week in September 2012, the air quality was at least as bad as air by a busy roadway nearby. And in many cases it was worse. Dr Adam Boies, Energy Efficient Cities University Lecturer in the Energy Group, along with Dr Jacob Swanson and PhD student Uven Chong of the Energy Efficient Cities Initiative, published their findings in the journal *Environmental Research Letters*.

"There is an obvious risk associated with exhausting diesel emissions into a semi-enclosed environment, yet it has not received much study," Dr Boies said. "These results show that regulators should consider setting standards for train station air quality in the same way we regulate outdoor air quality. It is too soon to state what the health impacts for workers or patrons of the station are, but further study could provide those answers."

Paddington Station is a terminus, with trains only entering from one side and the rest of the building largely enclosed. The station delivers 38 million passengers to their destinations each year, acting as a hub for train services to the west and southwest. Around 70 percent of trains at Paddington are powered by diesel engines; trains manufactured before 2006 are not subject to European regulations on their emissions. Additionally, there are currently no air quality regulations for rail stations in the UK, but the pollution could be harmful to health – particularly for station staff and workers at food outlets, who are inside the station all day.

"If the same standards that apply for outdoor air applied to indoor air, we found that pollution levels within Paddington Station exceeded such levels multiple times throughout the week we analysed," Boies said. "And it is likely that if a longer study was permitted by station operators, significantly more exceedances would have been recorded."

The team installed kits at five locations inside the station to measure the mass of particulate matter on two platforms, near food outlets that cook with gas, on the ramp of the main station exit and on the roadside outside. They also monitored nitrogen oxides, sulphur dioxide, and particulate matter size and number at two locations. The measurement campaign ran from 17 to 21 September 2012, with measurements beginning at around 4a.m. and lasting until battery ran out roughly 8 hours later.

Paddington Station's hourly mean particulate mass concentrations averaged 16 µg/cubic metre whilst the hourly mean NO_2 concentrations averaged 73 parts per billion and SO_2 concentrations averaged 25 parts per billion. There were five instances when the hourly mean NO_2 concentrations exceeded the 106 ppb hourly mean limit set by the European Union for outdoor air quality. These standards allow 18 such hourly exceedances per year. At times the hourly averages exceeded the annual average EU standard for ambient air quality of 25 µg per cubic metre.

The team compared the station results with those from Marylebone Road, a busy street about 1.5 km away. Particulate mass from at least one measurement site within the station was higher than at Marylebone Road on three out of four days, whilst NO_2 was higher within Paddington on four-out-of-five days and SO_2 was higher within the station on all three days it was measured.

"While the long-term solution for reduced pollution levels is likely electrification, we need not wait until electrification comes to take action," Boies said. The studies were part of the Energy Efficient Cities Initiative (EECi), which aims to determine the impacts on UK cities of energy use for transportation and in buildings. "We found that very little was known about the air quality of stations housing diesel trains, thus we set out to conduct the first known study to determine whether air quality concerns existed with such stations" Boies said.

"There are many solutions to air quality problems, so long as we understand the root cause," Boies continued. "I am hopeful that with further work, air quality in one of the UK's most important transportation modes can be drastically improved."

> "Regulators should consider setting standards for train station air quality in the same way we regulate outdoor air quality.
>
> Dr Adam Boies

www.eng.cam.ac.uk/profiles/amb233
www.eeci.cam.ac.uk

Institute for Manufacturing
Design Show 2015

Teams of third-year Manufacturing Engineering Tripos (MET) students in the Department of Engineering have completed a major design project to develop a new product with real business potential, which they then presented at the Institute for Manufacturing (IfM) Design Show 2015.

The MET is a programme for third and fourth-year engineering students who have successfully completed the first two years of an engineering degree. MET takes the best engineers and provides them with the management competence, business acumen and interpersonal and organisational skills they need to become world-class leaders.

The following are the 2015 projects.

The Dot.Motion

The Dot.Motion is a laser music visualisation system. When music is played through it, a series of laser patterns are created which 'dance' on the wall in time to the music.

A laser beam is reflected off a pair of mirrors, which are attached to two speakers. As music is played through the speakers the mirrors vibrate, creating dynamic and exciting patterns which appear to 'dance' in time to the music.

The focus on the aesthetic design of both the product itself and the effects produced offers a refreshing change from the low-quality and unimaginative options currently available. Additional key features include a strobing effect, filters to improve visual output and multiple laser colours to enhance the user experience.

Team: Robert Alner, Louise Ashenden, Jørn Emborg and Daniel Yanev

Ice Ice Maybe

A compact and stylish on-demand ice-maker that frees up freezer space used by traditional ice makers. Innovative cooling technology forms cubes from any liquid, or cools your drink directly.

Our on-demand ice-maker is compact, easy to use, and attractive enough to be stored or kept on the counter, like a coffee machine. It can be developed to produce a number of ice cubes from fresh, filtered water, or from your drink in seconds – so melting ice doesn't dilute it.

The team looked at a variety of ways to cool water to form ice rapidly, and form it into cubes – a difficult technical challenge. They exploited the thermoelectric effect, where passing electricity through a junction between two dissimilar metals produces a temperature difference. Various ways of making the thin layers that are produced into cubes were explored, drawing inspiration from industrial processes such as injection and dip moulding.

Team: Jack Fellows, Martha Geiger, Archie Lodge and Kaimei Zhang

↑ Reelcycle

Beacon ACE

Our project is an automated variable candle-maker for the luxury gadget market, aimed at arts and technology enthusiasts. The machine can be programmed to print many different candle types.

Unlike current commercial 3D printers which use plastics, we decided to extrude wax and use that process to form candles. The overall vision for our product is a candle-maker where the candle produced is influenced by external inputs from the surrounding environment (such as motion, manual control, noise, light etc.)

Our aim for the project was to produce a functional prototype that would be able to print a simple candle design from wax pellets. This prototype would need to store wax, feed into a heating element at a steady rate, have movement on three axes (radial movement of extruder, vertical movement of bed, rotation of bed), and control all these actions.

Team: Ellie Griffiths, Melissa Leonard, Titas Sokolovas and Edmond Wang

ReelCycle

3D printing is exploding in popularity, but generates considerable scrap plastic. The product recycles this back into a cartridge for the printers, saving £30/kg for the operators. Unlike existing machines, it is fully integrated, making it the most consumer-friendly on the market.

Despite 3D printing's innate appeal and potential, it is currently expensive, unreliable and complicated to use. Many businesses already use 3D printers for prototyping during the design process, but many are now increasingly harnessing it in more conventional manufacturing, particularly in niche industries such as motor sports and personalised medicine.

The ReelCycle makes 3D printing cheaper and greener to use. It allows businesses and individuals to produce new reels of plastic, which are used in 3D printers as cartridges. These

↑ ProSort

↑ Inclusion Chair

reels are produced using scrap printed parts, or inexpensive pellets, thereby reducing material waste and saving money on printing materials.

Team: Jack Agass, Will Harborne, Nirali Patel and Theo Snudden

ProSort CC-60

The ProSort CC-60 is a mechanical device to collect, sort and stack shuttlecocks dispersed over badminton courts after training drills. For club and professional players: tedious, manual sorting is history!

Although crucial to player development, drills lead to hundreds of shuttlecocks being dispersed around the badminton court. Players must manually gather and stack shuttlecocks back into long columns, typically 20 each, ready for the next set of drills. This is a time-consuming, tedious and tiring task for players, especially straight after intense training drills. Doing this task by hand was the only viable option, until now.

The CC-60 collects, sorts and stacks up to 60 shuttlecocks. Players no longer have to waste time and energy gathering and sorting shuttlecocks by hand.

Team: Sarah Barrington, Tianyi Li, Thomas Louth and Milan Patel

Strings 'n' Things

Strings 'n' Things is a new and innovative recycling process. Plastic bottles are cut into long continuous strings which can then be wound or woven into lampshades, vases, ropes or mats.

Strings 'n' Things enables low-volume recycling to be economically feasible and provides a low-energy method of transforming waste bottles into new products. With further development, the project could contribute to a reduction in the proportion of plastic bottles sent to landfill.

At the heart of the project is a simple and effective machine that cuts waste bottles into strings. The strings are then wound around a mould in a unique pattern and heated in an oven. The heating causes fusion of the crossing strings, resulting in beautiful hollow forms when the assembly is cooled and the mould is removed. This process takes advantage of the properties of the string to produce aesthetically pleasing products.

Team: Benjamin Evans, Susannah Evans, Michael Lin and Naythran Thayakaran

Fabricate

This project is the development of a process for recycling fabric into a composite suitable for diverse applications. Cotton sourced from old clothing acts as the fibre in a matrix of silicone rubber.

250,000 tonnes of recyclable fabric is wasted in the UK each year. Various binding agents can transform this fabric into a product of the desired characteristics and shape. Multiple experiments revealed that silicone rubber was superior in dimensional accuracy, as well as producing a detailed surface finish and a rubbery texture. The project direction then became optimising the process to create a useful composite. The kit targets the growing craft market, which is currently worth £745 million. It can be used either with the included moulds or personalised moulds produced by the customer for their specific application.

Team: Amy Spruce, Dan Jones, Rabbiya Naveed and Will McDermott

The Inclusion Chair

The Inclusion Chair is a revolutionary mobility device that tackles the social exclusion of locomotor-disabled individuals in India from their culture of interacting and living at floor level.

One cohort of 2.13% of India's 1.3 billion population is often neglected and hidden behind closed doors: the disabled population of India. Where social interactions and living occur at floor level, locomotor disabled individuals are unable to participate when using the only medical device on the market: a conventional wheelchair.

Our mechanical system allows a user to lower themselves to floor level for social interactions whilst maintaining the functionality of a conventional wheelchair at sitting level. We have created a modular design that allows for a vast amount of customisation to accommodate different body shapes as well as variances in disability types. The design not only uses sustainable materials such as a bamboo frame, it also incorporates low-cost and easily accessible materials to enable simple manufacture.

Team: Tian Xi Lim, Mateus Pniewski, Georgia Ware and Stephanie Wen

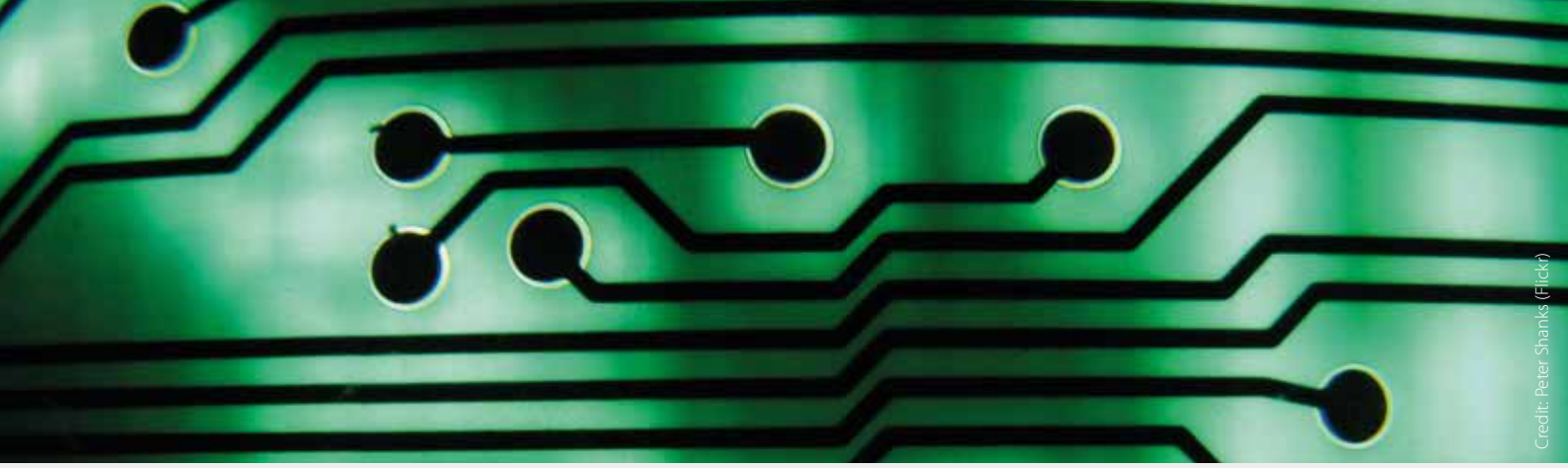
L.E.D. Zeppelin

L.E.D. Zeppelin is an interactive toy aimed at the children's, young persons' and office executives' toy markets.

A pair of helium airships do aerial battle under the remote control of two (or more) players, firing infrared beams at each other in order to score 'hits' and disable the opponents' control systems. Our product is built around the Arduino micro-controller using a custom-coded radio control system and game logic. Two-way communication is possible between the airship and the controller allowing in-game feedback and score tracking displayed to the player via the controller. We plan to continuously improve the product while increasing market share with the eventual aim of approaching a national toy retailer.

Team: Freddie Ashford, Ben Brebner, Mudit Dubey and Elizabeth Fletcher

To watch videos about each of these products visit http://bit.ly/1NpBljb



Credit: Peter Shanks (Flickr)

↑ Circuit board

New understanding of electromagnetism could enable 'antennas on a chip'

New understanding of the nature of electromagnetism could lead to antennas small enough to fit on computer chips – the 'last frontier' of semiconductor design – and could help identify the points where theories of classical electromagnetism and quantum mechanics overlap.

A team of researchers from the University of Cambridge have unravelled one of the mysteries of electromagnetism, which could enable the design of antennas small enough to be integrated into an electronic chip. These ultra-small antennas – the so-called 'last frontier' of semiconductor design – would be a massive leap forward for wireless communications.

In new results published in the journal Physical Review Letters, the researchers have proposed that electromagnetic waves are generated not only from the acceleration of electrons, but also from a phenomenon known as symmetry breaking. In addition to the implications for wireless communications, the discovery could help identify the points where theories of classical electromagnetism and quantum mechanics overlap.

The phenomenon of radiation due to electron acceleration, first identified more than a century ago, has no counterpart in quantum mechanics, where electrons are assumed to jump from higher to lower energy states. These new observations of radiation resulting from broken symmetry of the electric field may provide some link between the two fields.

The purpose of any antenna, whether in a communications tower or a mobile phone, is to launch energy into free space in the form of electromagnetic or radio waves, and to collect energy from free space to feed into the device. One of the biggest problems in modern electronics, however, is that antennas are still quite big and incompatible with electronic circuits – which are ultra-small and getting smaller all the time.

"Antennas, or aerials, are one of the limiting factors when trying to make smaller and smaller systems, since below a certain size, the losses become too great," said Professor Gehan Amaratunga of the Department of Engineering, who led the research. "An aerial's size is determined by the wavelength associated with the transmission frequency of the application, and in most cases it's a matter of finding a compromise between aerial size and the characteristics required for that application."

Working with researchers from the National Physical Laboratory and Cambridge-based dielectric antenna company Antenova Ltd, the Cambridge team used thin films of piezoelectric materials, a type of insulator which is deformed or vibrated when voltage is applied. They found that at a certain frequency, these materials become not only efficient resonators, but efficient radiators as well, meaning that they can be used as aerials. The researchers determined that the reason for this phenomenon is due to symmetry breaking of the electric field associated with the electron acceleration. In physics, symmetry is an indication of a constant feature of a particular aspect in a given system. When electronic charges are not in motion, there is symmetry of the electric field.

Symmetry breaking can also apply in cases such as a pair of parallel wires in which electrons can be accelerated by applying an oscillating electric field. "In aerials, the symmetry of the electric field is broken 'explicitly' which leads to a pattern of electric field lines radiating out from a transmitter, such as a two wire system in which the parallel geometry is 'broken'," said Dr Dhiraj Sinha, the paper's lead author.

> "If you want to use these materials to transmit energy, you have to break the symmetry … this is the missing piece of the puzzle of electromagnetic theory.
>
> Professor Gehan Amaratunga

The researchers found that by subjecting the piezoelectric thin films to an asymmetric excitation, the symmetry of the system is similarly broken, resulting in a corresponding symmetry breaking of the electric field, and the generation of electromagnetic radiation.

The electromagnetic radiation emitted from dielectric materials is due to accelerating electrons on the metallic electrodes attached to them coupled with explicit symmetry breaking of the electric field.

"If you want to use these materials to transmit energy, you have to break the symmetry as well as have accelerating electrons – this is the missing piece of the puzzle of electromagnetic theory," said Amaratunga.

The future applications for this discovery are important, not just for the mobile technology we use every day, but will also aid in the development and implementation of the Internet of Things: ubiquitous computing where almost everything in our homes and offices is connected to the internet. For these applications, billions of devices are required, and the ability to fit an ultra-small aerial on an electronic chip would be a massive leap forward.

"It's actually a very simple thing, when you boil it down," said Sinha. "We've achieved a real application breakthrough, having gained an understanding of how these devices work."

www.eng.cam.ac.uk/profiles/gaja1

From Tripos to TripAdvisor

Since leaving the Department of Engineering, Alumna Lily Cheng has had a whirlwind career that now boasts President, Asia-Pacific, at TripAdvisor.

TripAdvisor is one of the world's largest travel websites. Lily leads the company's growth in the Asia-Pacific region with a focus on China, India and Japan. Since joining the corporation in 2010 as senior director of strategy and business development in the APAC region, Lily has been instrumental in establishing TripAdvisor's offices in Singapore and Beijing.

Raised in Hong Kong, Lily became interested in computers and technology at a young age. She found herself in the back streets of the city, collecting various electronic components and assembling them into small gadgets. "It was like an entire street with all the parts you would find in an RS or Farnell catalog laid out in little plastic bins," she said. "It was my version of a candy store."

Becoming an engineering student was a natural progression for Lily. "I really love the feeling of being able to make something. I wanted to be an inventor." She considered industrial design but in the end decided on a more technical track. "It was considered a 'safe bet' in Chinese society, which was an influencing factor."

During her time at Cambridge, Lily was exposed to a wide variety of disciplines, including mechanics, electronics, thermodynamics and structures. In the end, she pursued the Manufacturing Engineering Tripos (MET). "I was particularly interested in the intersection of engineering and business," Lily said. "The program exposed us not only to engineering skills but skills that are very important in the business world, like accounting and public speaking."

Studying under Department of Engineering lecturers such as Dr Hugh Hunt, Professor Sir Mike Gregory and Professor Cam Middleton, Lily honed skills that are highly sought in the internet economy. "An engineering mindset, combined with analytical and data manipulation ability, combined with outward-facing skills to pitch ideas in a business context and secure resources are all very key," Lily said. "Graduates from the MET program develop a unique combination of these skills and the ability to traverse the intersection of these disciplines in a way that's very valuable to business."

"Regardless of whether you are in a start-up or in a global internet company like TripAdvisor, being able to bridge comfortably between technology and business is important when you are trying to secure financial resources for your ideas," Lily said. "Graduates from Cambridge Engineering are often able to pull things out of the bag that breaks conventional stereotypes of what engineers can do.

"In my current role at TripAdvisor, I am very fortunate to have the opportunity to be involved in many different disciplines of the organisation. One day, I might have a conversation with our engineering leaders about how we can optimise the architecture of our code base. The next day, I might meet with political leaders in different countries to explore how TripAdvisor can be a platform to grow their economies through the promotion of tourism. The next day, I might sit in a

usability study watching users from different countries trying to search for information on our app to understand the areas of friction."

TripAdvisor's founder and CEO Stephen Kaufer, Lily noted, is an engineer and approaches work through a hypothesis and data-driven approach. "The logic and analytical skills that an engineering foundation develops is critical to our everyday work."

What makes an intelligent infrastructure asset?

What would it take to enable a piece of infrastructure to take care of itself, asks Duncan McFarlane of the Cambridge Centre for Smart Infrastructure?

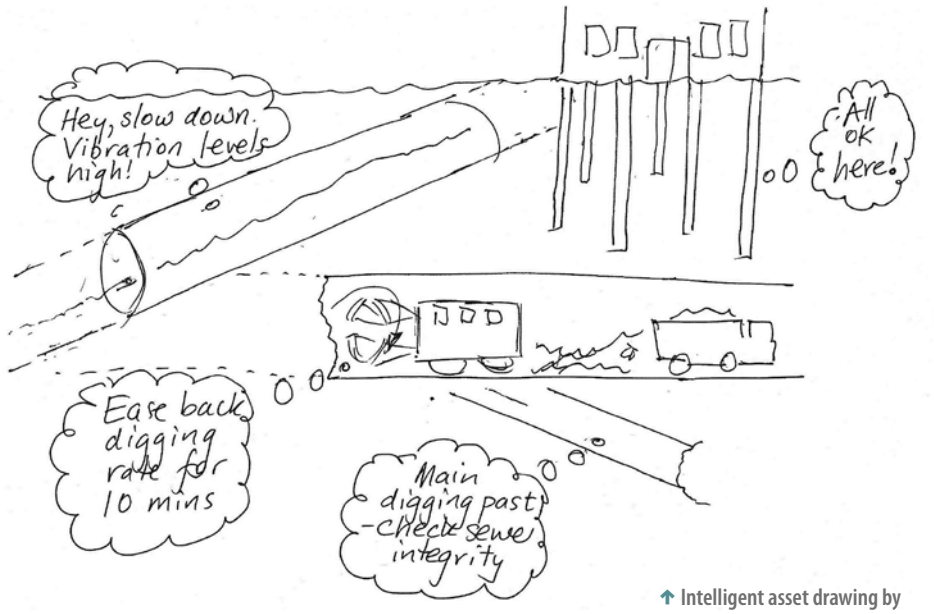
What might asset intelligence mean in an infrastructure context? That was the question I was recently asked to provide a view on at a meeting on Infrastructure Asset Management at the Institution of Civil Engineering. Particular regard was to be given to the increasing numbers of sensors under development and the reduced budgets available for maintaining key assets.

With ever-greater numbers of infrastructure assets, the uncertainty about their lifespan and the conditions they might face, and the declining availability of funds for maintenance and upkeep, future asset management will need to:

- Involve low-cost, easy-to-maintain sensing, data gathering and management
- Prioritise all assets within a single integrated portfolio
- Examine value of the use of the asset in conjunction with cost of maintenance
- Be robust to future ownership and usage changes

Today's centralised co-ordination of assets by asset owners or third party facility managers makes future asset management particularly challenging. What would it take to empower an asset to 'take care of itself'? Work with Boeing in the 2000s, developing software environments to enable aircraft parts to schedule their own repair and replacement, extended the notion of a self-aware asset to propose a definition and set of characteristics for an intelligent infrastructure asset: a self-contained infrastructure element linked to its own monitoring, diagnostic and maintenance strategy and with the ability to guide, influence or direct its own use, maintenance and support. In order to do this, the intelligent infrastructure asset needs:

1. Constructed/fabricated properties and unique identity
2. State awareness – an awareness through sensing or inspection of its own state (location, degradation, strain)
3. Communication – an ability to communicate information relating to identity and state when integrated into larger systems
4. Data management – an ability to collect/store/retrieve data associated with the elements' identity, properties and state as required
5. Language – an ability to interpret and communicate information relating to rules
6. Decision (support) – an ability to influence decisions that are made with regard to the assets or collection of the assets
7. Value system – a means of evaluating cost and benefit in terms of service provided by the asset and services received



↑ Intelligent asset drawing by Professor Duncan McFarlane

In simple terms this means that any information associated with an asset is tightly 'bound' to the asset it represents and not to the owner/user/operator.

Directly – and automatically – associating the actions with the asset itself reduces the risk that facilities management operators might miss key indicators or that maintenance tasks might be neglected due to altered priorities or reduced budgets.

Within the Centre for Smart Infrastructure and Construction (CSIC) at the University of Cambridge, a significant amount of groundwork for developing more intelligent infrastructure assets is underway. CSIC, which collaborates with 41 industry partners from construction and infrastructure organisations, addresses infrastructure challenges on three levels: city level, asset level and sensor level.

Research focussed on assets ranges from development of new distributed, low-energy, low-maintenance sensing systems, to better ways of managing and visualising asset data, to methods for computing asset value over its life to future-proofing strategies for ensuring forthcoming needs and environment changes are accounted for in the asset management plan.

More to the point, these research initiatives directly underpin the development of a smarter, more self-sustaining infrastructure environment both in the construction phase and during the asset's operating life. This might just make the theory of infrastructure asset management become one that can be practically deployed.

Duncan McFarlane is a Co-Investigator at CSIC at the University of Cambridge where he is Professor of Industrial Information Engineering. This article was produced in conjunction with CSIC colleagues Professor Kenichi Soga and Dr Ajith Parlikad and originally appeared in *Infrastructure Intelligence*.

Duncan McFarlane

www.eng.cam.ac.uk/profiles/dm114
www-smartinfrastructure.eng.cam.ac.uk

Professor Steve Young's pioneering speech technology work recognised

Professor Steve Young is the 2015 recipient of the IEEE James L. Flanagan Speech and Audio Processing Award.

The annual prize is given to an individual or teams of up to three for "an outstanding contribution to the advancement of speech and/or audio signal processing."

Professor Young is Professor of Information Engineering in the Information Engineering Division.

The award citation reads: "For pioneering contributions to the theory and practice of automatic speech recognition and statistical spoken dialogue systems."

Professor Young works in speech technology, focussing in particular on developing systems which allow a human to interact with a machine using voice.

This involves machines like mobile phones recognising the user's words, understanding what the words mean, deciding what to do and how to respond and then converting the response in textual form back into speech.

David Stevenson at National Health Executive (NHE) magazine, interviewed Professor Young. The following extracts are taken from this interview article which originally appeared in the NHE magazine.

Steve Young, Professor of Information Engineering at the University of Cambridge, and a global expert in speech recognition technologies, gives his thoughts on the advances and challenges facing this 'growing' research area. He told NHE that research in this area made steady but not spectacular progress from the mid-1980s to the mid-2000s. "But over the last five to 10 years we've seen really quite significant acceleration in progress," he said. "And that is why we are now seeing speech recognition coming into the mainstream with services like Apple Siri and Google Now, and the new smart watches that do speech recognition.

Professor Young added that modern systems are built on the notion of building statistical models that represent the data.

"So the way you build a speech recogniser, essentially, is that you get some data, which is people speaking, you transcribe the data and then you try to model the data and find a way to automatically generate the transcriptions yourself – and then you have a speech recogniser," he said. "The key to all of that is some quite sophisticated statistical modelling algorithms and the availability of the data."

The expert told us that it is the nature of data, and its wide availability nowadays, that has changed the speech recognition landscape. "When you speak into your phone, the signal is being routed to a server farm somewhere in North Carolina if you're Apple or South Carolina if you're Google, and it is being processed there and the result is being fed-back to your phone," said Professor Young.

This allows two things to happen. Firstly, it unleashes the possibility of using some very powerful computing to recognise people's voices. Then secondly, and more importantly, the companies are capturing the data.

"When Siri was first launched, for example, it wasn't that great," said Professor Young, "but as more people started using it the company was capturing huge amounts of data. And then by using and collecting the data and upgrading the models, people found the recognition improved so they used the system more, so they gave more data. That has happened over a wide range of fields, and it is the 'big data' paradigm that we are hearing a lot about."

> "For pioneering contributions to the theory and practice of automatic speech recognition and statistical spoken dialogue systems.
>
> The award citation

Dictation in the medical area has been one of the mainstays, certainly for commercial dictation applications, he added.

Despite dedicating 35 years to research in the field of speech recognition, and with his research helping to set global standards for benchmarking systems and being the basis of many commercial systems, Professor Young remains modest about his award, joking that organisations sometimes feel they have to give them out "just because someone has been around long enough".

Nevertheless, he said he is "humbled" to become the 2015 recipient of the IEEE James L Flanagan Speech and Audio Processing Award.

www.eng.cam.ac.uk/profiles/sjy11

Tony Gee, designer of the Gladesville Bridge

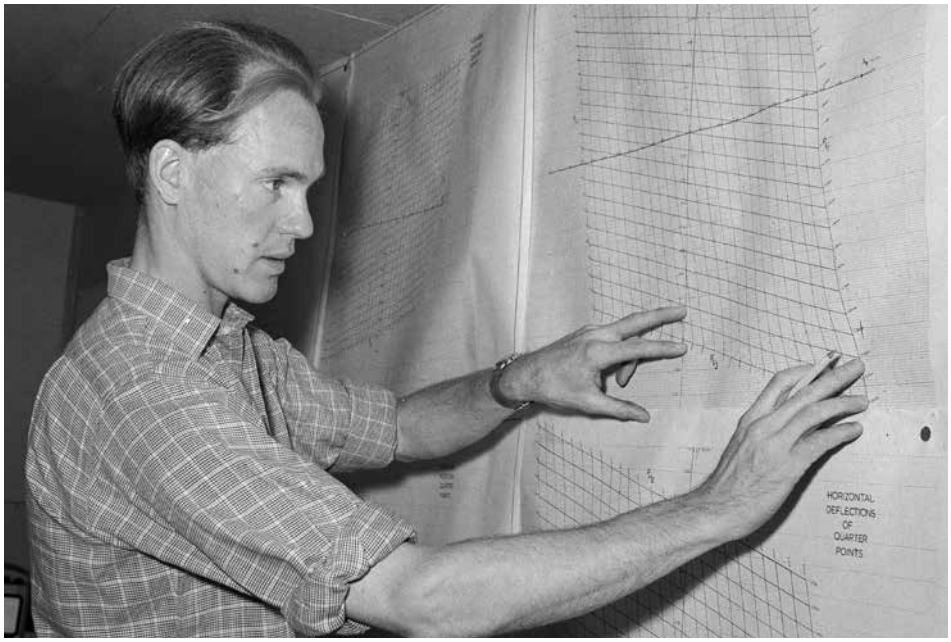
Alumnus Tony Gee had his 15 minutes of fame towards the end of 2014 when the 50th Anniversary of the opening of the Gladesville Bridge was celebrated in Sydney, Australia. Tony tells the story of how he came to be the designer of the Gladesville Bridge below.

Although not particularly well known in the UK, Gladesville Bridge was the longest concrete span in the world at the time it was built, a distinction it held for a further 7 years. The New South Wales personnel who were organising the 50th Anniversary celebrations asked Structurae, the largest database for civil and structural engineers, whether they could find any record of the designer of any other major bridge being around to celebrate its 50th Anniversary: the nearest they could come up with was Othmar Ammann, the designer of the Verrazano Narrows Bridge in New York, who lived for 33 years after its opening.

Needless to say, Gladesville Bridge holds a very special place in my life. The circumstances which led to a raw graduate being responsible for the detailed design of a record breaking bridge seemed unexceptional at the time and it didn't really sink in until later just how fortunate I had been. My boss Guy Maunsell had returned from Australia with his concept for a big concrete arch and needed someone to work with him on the realisation of his dream. It had to be done as inexpensively as possible because it was viewed as somewhat of a long shot and the recent graduate recruit was the obvious choice! It was only after the design was finished that I realised what an incredible opportunity it had been.

I am sometimes asked how bridge design then differed from now. Two words - codes and computers. Design specifications were very basic; from memory, the Department of Main Roads bridge code ran to about 40 pages and the UK one was only slightly longer. The current version of the US bridge design specification contains 1,638 pages. We had to design almost everything from first principles and since several aspects of the design were not addressed in any of the specifications, this allowed us a latitude not available today.

Although a limited number of main frame computers existed, there were no commercially available engineering programmes so we had to write our own. The potential benefits of computerisation outweighed the effort of learning basic programming and ultimately all aspects of the analysis and detailing of the arch were executed using application programmes specially written for the purpose.



The people of Sydney should be extremely proud that they live in the only city in the world where a bridge like Gladesville could be overshadowed by – or at least have to share the limelight with – two other iconic structures. It was and still is by any standards a great bridge, not only because of its record-breaking span – and there have only been six larger concrete arches built in the intervening 50 years – but because it featured a number of design innovations which have since been widely adopted. It is greatly to the credit of the former Department of Main Roads that they had the courage, open-mindedness and generosity to accept an alternative design which stretched the boundaries to such an extent that it gave them plenty of cause to reject it had they been so inclined.

It is extremely gratifying to see this 50 year anniversary receiving well-merited attention. It is also a sobering reminder of the passage of time! However, Gladesville is so soundly constructed and in such good condition that I see no reason why it should not remain functional for another 50 years and I look forward to gazing down in 2064 on our descendants celebrating the centenary of one of the world's great bridges. The bridge has recently been recognised as an "International Historic Engineering Landmark".

Tony founded the consulting engineering firm of Tony Gee and Partners in 1974. He retired from the practice in 1988 to live and work in the United States but the firm continues to thrive: it is now over 400 strong and was named "Medium Size Practice of the Year" by New Civil Engineer in 2013.

At the time of his later 'retirement' in 1995, Tony believes he was the only – and probably the last – person to be FICE, FIStructE and FIMechE.

He was a two-term Member of Council of the IStructE and a Founding Member of Council of the Steel Construction Institute.

He won an Oscar Faber Medal at the IStructE, a Telford Premium at the ICE and finally, in 1992, the Telford Gold Medal, the highest award of the Institution at the ICE.

Although he refers to his 'retirement,' he is still doing some consulting and is currently working on the design of the first commercially viable maglev transportation project, having been involved in the development of the system for the past 20 years.

PhD student Camille Bilger receives Airbus Group UK TechMaster Award

Camille Bilger, a PhD student in the Department of Engineering's Energy and Fluids group, has received the Airbus Group UK TechMaster Award.

Camille's research involves simulating jet fuel injection inside engine combustion chambers. She then studies the impact of these findings for Rolls-Royce civil aircraft engines. In particular, her group is interested in simulating the liquid fuel-film atomisation in fuel injector devices. Improving combustion is critical for the next generation of aircraft in order to lower the fuel consumption and reduce pollutant emissions. A detailed understanding of the atomisation process in two-phase flows is still a missing link in effectively controlling the process of fuel atomisation as well as fuel ignitability and combustion under all possible operating conditions.

The complexity of the physics involved has curbed the research growth in the field. Her research goal is to continue gaining valuable knowledge and experience within the fields of hydrodynamics, fluid instabilities and turbulence with the ultimate goal of addressing significant scientific issues of notable challenge.

Camille grew up in Strasbourg, France, and moved to St Andrews, UK, in 2008 to study Astrophysics at the University of St Andrews. After graduating from St Andrews in June 2012 with a MSci. degree in Astrophysics (First Class Honours; SELEX Galileo 2012 prize for the best Astrophysics Masters thesis), she moved to Cambridge in September 2012 to undertake a comprehensive programme of graduate teaching and research (M.Phil. in Energy Technologies, Distinction), for which she was funded by an Airbus Group TechMasters Award scholarship. In this broad programme, students have the opportunity to learn and integrate multiple engineering disciplines. The curriculum emphasised renewable energies, combustion, computational fluid dynamics, turbulence and management in technology.

↑ Camille Bilger

The Airbus Group UK TechMasters Awards consist of six scholarships of £5,000 each per year, dedicated to supporting UK students reading for a Masters degree in aerospace-related areas. In addition, the programme provides opportunities to connect with senior management and employees across the group, and gain in-depth understanding of the group and the wider aerospace industry.

www.eng.cam.ac.uk/profiles/cb757

3D printing has left the station

On his industrial experience summer placement, a Department of Engineering student experienced the real-world applications of a 3D printer in a bustling rail manufacturing centre.

During the summer break, Aiden Chan, a second-year engineering student, had the chance to work at Progress Rail Services – one of the largest suppliers of railroad and transit products including switches, crossings, buffer stops and transition rails – at its Sandiacre site.

Aiden was assigned to help integrate a 3D printer into the company's operations. He participated in the device's testing and calibration and ensured the printer was capable of producing templates that met Progress Rail's demanding specifications.

After familiarising himself with the printer's machine code, optimising the setup process and customising the printer's web interface in HTML, Aiden wrote up a comprehensive user guide to assist future employees and others unfamiliar with the system. He also looked into how the printer's applications could be expanded through the company.

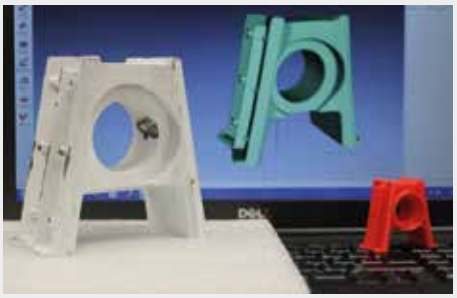
One immediate use for the 3D printer was to create scale models of products to be shown to clients and employees alike. To construct these, several separate pieces were printed and later assembled.

In addition to the printer, a 3D scanner was introduced at Progress Rail to facilitate on-site rail inspections. Aiden likewise learned this system and also produced a user guide that documented the entire process from scanning an object to 3D printing a scale model.

"I have learned a lot in my time at Progress Rail," Aiden says. "My confidence in [computer-assisted drawing] has seen a large boost, and the range of transferable skills offered by the 3D printer has been enormous."

Aiden is no stranger to working with 3D models – in his spare time, he constructs intricate LEGO sculptures in the form of dinosaurs, swordfish and robots.

All the Department's students are encouraged to seek opportunities to broaden their engineering experience and to build their skills. At the same time, the students provide companies with an enthusiastic and motivated group of extremely bright young engineers, interested in doing practical projects that deliver real value. Student placements provide a win-win opportunity for students and companies alike. **If you are a large or small company, and you think you can find some useful work or a project for one of our undergraduate students, please contact our Industrial Placements Team: details at the link below.**



Credit: Aiden Chan

↑ Stretcher bar casing alongside a 3D printed scale model

www.eng.cam.ac.uk/collaboration/student-placements

Blindingly fast computers within reach

Alumni of the Department of Engineering have gone on to found Optalysys, a company with the goal of making computer processors that use light instead of electricity.

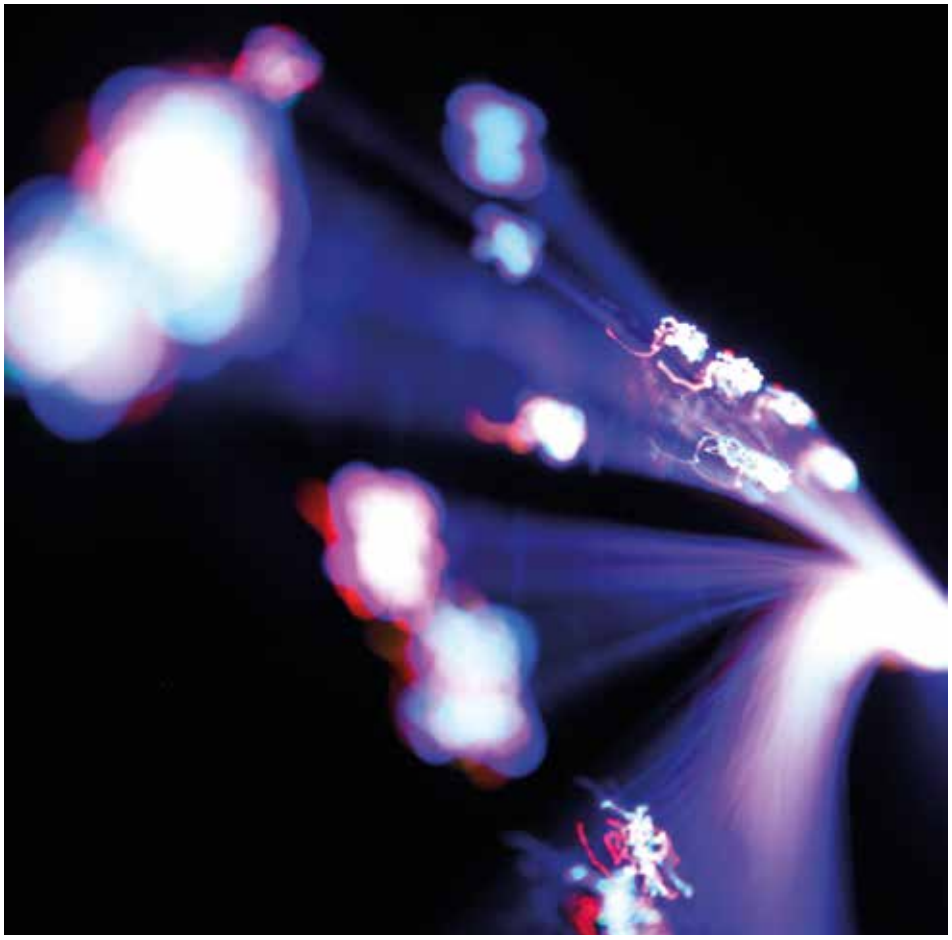
The company's latest achievement is a functioning prototype of a scaleable, lens-less optical processor able to perform mathematical calculations. The design, codenamed Project GALILEO, represents a breakthrough in scaleable, practical optical processing that calculates at the speed of light and in parallel. Applications for this research are in weather forecasting, vehicle aerodynamics and big data analysis for genomics and financial analysis.

Two new projects are on the horizon. One is in gene sequencing and analysis with the establishment of the Genome Analysis Centre. "We are also a partner in a major European project led by the European Centre for Mid Range Weather Forecasting," said Dr Nicholas New, Optalysys founder and Cambridge alumnus. "This is laying the foundations for exascale computing in weather forecasting." Also, Optalysys is talking with a major Formula 1 team as well as financial institutions about future projects.

Nicholas, who earned his PhD at Cambridge in Optical Pattern Recognition, founded the company on the back of research he performed for his degree. "It was clear from the start that optical electronics held huge potential to be applied to big data processing tasks," he said. "The challenge to work on something truly groundbreaking was very attractive." Nicholas studied under Professor Tim Wilkinson of the Photonics Group (who holds an advisory role at Optalysys).

Also on the team are Drs Andy Lowe and Ananta Palani. Andy's role on the team is to examine how large computational tasks are undertaken and how optical computing can reduce the energy computation uses. He came to Cambridge to study Computational Fluid Mechanics under Professor Peter Davidson and was attracted to the diverse range of high-quality research. His education here created "a solid foundation for the challenges we face building state-of-the-art technology," Andy said. "If you want to push the boundaries of what we are doing as engineers and scientists, you need to trust your education. Cambridge did that."

Hailing from the United States, Ananta chose Cambridge for the research taking place at the Centre of Molecular Materials for Photonics and Electronics (CMMPE). There he examined photonics in the area of Fourier optics and helped advance optical microscope technology that can observe extremely small objects such as viruses. The self-directed style of the PhD prepared him immensely for his career and at Optalysys. "I learned through hard-work how to iteratively research a given area and how to collaborate with others," Ananta said. He hopes the technologies he works on today will "increase the currently achievable speed and capability of researchers and hopefully improve life for humanity."



Credit: Jeff Ferzoco via Flickr

Nicholas New

Andy Lowe

Ananta Palani

www.optalysys.com

Credit: Bob Mical (Flickr)

↑ Data center

Let's get statted

With more information than ever at our fingertips, statisticians are vital to innumerable fields and industries. Welcome to the world of the datarati, where humans and machines team up to crunch the numbers.

"I keep saying that the sexy job in the next 10 years will be statisticians, and I'm not kidding," Hal Varian, Chief Economist at Google famously observed in 2009. It seems a difficult assertion to take seriously, but six years on, there is little question that their skills are at a premium.

Indeed, we may need statisticians now more than at any time in our history. Even compared with a decade ago, we can now gather, produce and consume unimaginably large quantities of information. As Varian predicted, statisticians who can crunch these numbers are all the rage. A new discipline, 'Data Science', which fuses statistics and computational work, has emerged.

"People are awash in data," reflects Zoubin Ghahramani, Professor of Information Engineering in the Computational and Biological Learning Laboratory. "This is occurring across industry, it's changing society as we become more digitally connected, and it's true of the sciences as well, where fields like biology and astronomy generate vast amounts of data."

Over the past few years, Richard Samworth, Professor of Statistics at Cambridge, has watched the datarati step out from the shadows. "It's probably fair to say that statistics didn't have the world's best PR for quite a long time," he says. "Since this explosion in the amount of data that we can collect and store, opportunities have arisen to answer questions we previously had no hope of being able to address. These demand an awful lot of new statistical techniques."

'Big data' is most obviously relevant to the sciences, where large volumes of information are gathered to answer questions in fields such as genetics, astronomy and particle physics, but it also has more familiar applications, such as transport data from Oyster cards, supermarket transactions, social media posts and 'lifelogging' through fitness apps.

This information, as Professor Ghahramani points out, is no use on its own: "It fills hard drives, but to extract value from it, we need methods that learn patterns in the data and allow us to make predictions and intelligent decisions." This is what statisticians, computer scientists and machine learning specialists bring to the party – they build algorithms, which are coded as computer software, to see patterns. At root, the datarati are interpreters.

Despite their 'sexy' new image, however, not enough data scientists exist to meet this rocketing demand. Could some aspects of the interpretation be automated using artificial intelligence instead, Professor Ghahramani wondered? And so, in 2014 and with funding from Google, the first incarnation of The Automatic Statistician was launched online. Despite minimal publicity, 3,000 users uploaded datasets to it within a few months.

Once fed a dataset, the Automatic Statistician assesses it against various statistical models, interprets the data and – uniquely – translates this interpretation into a short report of readable English. It does this without human intervention, drawing on an open-ended 'grammar' of statistical models. It is also deliberately conservative, only basing its assessments on sound statistical methodology, and even critiquing its own approach.

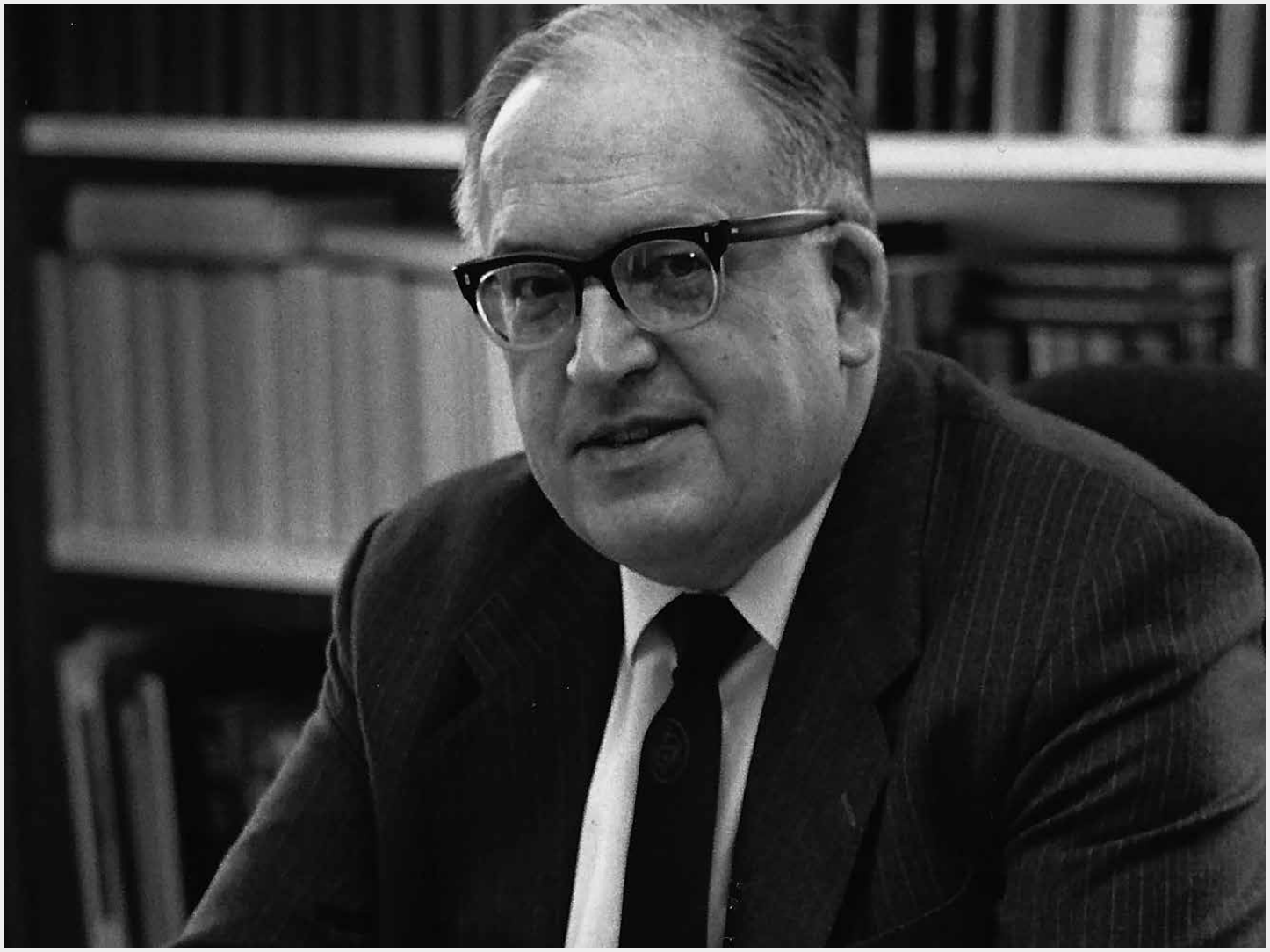
Professor Ghahramani and his team are now refining the system to cope with the messy, incomplete nature of real-world data, and also plan to develop its base of knowledge and to offer interactive reports. In the longer term, they hope that the Automatic Statistician will learn from its own work: "The idea is that it will look at a new dataset and say, 'Ah, I've seen this kind of thing before, so maybe I should check the model I used last time'," he explains.

> "It fills hard drives, but to extract value from it, we need methods that learn patterns in the data and allow us to make predictions and intelligent decisions.
>
> Professor Zoubin Ghahramani

Professor Zoubin Ghahramani, left, and Professor Richard Samworth

This article originally appeared on the University of Cambridge website.

www.eng.cam.ac.uk/profiles/zg201



Professor Sir John Horlock 1928–2015

Professor Sir John Horlock, highly influential figure in turbomachinery aerodynamics and power generation, former Professor in the Department of Engineering and founder of the Whittle Laboratory, has died, aged 87.

Professor Horlock first studied engineering at Cambridge at St John's College and earned his PhD in 1958. As the *Independent* writes, "He went to St John's to read for the Mechanical Sciences Tripos. His supervision partner was Neville Kirby, who had worked on gas turbines – and Horlock, too, became interested in these new power plants. Having won the Rex Moir Prize, he obtained a summer scholarship at MIT. During a recess, he was shown around Princeton University by a professor of aeronautics; in the common room of the Institute of Advanced Studies was the quiet figure of Albert Einstein, a member of the institute. The thrill of meeting and talking to Einstein was to remain an inspiration to Horlock."

After a time working at Rolls Royce and Liverpool University, he returned to the Department in the 1960s as Professor, serving as Deputy Head of Department under Sir William Hawthorne.

While conducting research on compressor aerodynamics, Professor Horlock wrote two highly influential books, *Axial Flow Compressors* and *Axial Flow Turbines*. He was also interested in promoting turbomachinery research in a wider context. Having obtained the necessary funding, Professor Horlock then founded the Whittle Laboratory in 1973, where today ground-breaking research on fluid dynamics and thermodynamics is conducted by top Engineering minds. He was elected to the Royal Society in 1976.

Professor Horlock went on to become vice-chancellor of Salford University and then the Open University. However, he soon found himself returning to Cambridge and the Whittle Laboratory to continue his research work. In this time he published numerous papers and wrote several more books. He also became treasurer and later Vice President of the Royal Society. He was knighted in 1996 for services to science, education and engineering.

"Professor Horlock maintained a strong interest in the personal welfare of students, young academics and not-so-young academics," recalled Professor John Young of the Energy Group. "Many have cause to be grateful for his kindness, generosity and support, myself included. He once told me that he had been personally involved in the appointment of over 200 professors! In his life he mixed with the eminent, the great and the good, but he always retained a sympathetic understanding for the difficulties of others, whoever they were."

Professor Sir John Harold Horlock, born 19 April 1928, died 22 May 2015.

Honours, awards and prizes

Undergraduate Alexander Grafton
Undergraduate Alexander Grafton (centre) has been recognised for "engineering excellence." The UK's top engineering undergraduates were presented with the prestigious Sir William Siemens Medal at the Museum of Science and Industry in Manchester.

Andy Zhang and Anthony To were also nominated and were shortlisted for the award.

Professor David Cardwell has been awarded an Honorary Doctor of Science (D.Sc) by the University of Warwick for producing ground-breaking research, of making a global impact and of sustaining a real-world relevance.

Professor Sir Mark Welland has been awarded an Honorary Doctor of Science (D.Sc) by the University of Bristol. Sir Mark has demonstrated exceptional scientific leadership, not only in Britain, but throughout the world.

Professor Gopal Madabhushi of the Geotechnical and Environmental Group has received the Indian Geotechnical Society (IGS) and Oil and Natural Gas Corporation (ONGC) biennial award for his research on the structural integrity of offshore wind turbines. Also cited were PhD student Aliasger Haiderali and Department of Engineering alumnus Dr Ulas Cilingir.

Professor John Robertson and Professor Zoubin Ghahramani have been elected as fellows of the Royal Society.

Professor John Robertson FRS (left) is Professor of Electronic Engineering. The Royal Society has recognised Professor Robertson for his sustained contribution to the production and development of electronic devices.

Professor Ghahramani (right) is Professor of Information Engineering in the Computational and Biological Learning Laboratory. The Royal Society has recognised Professor Ghahramani as one of the pioneers of semi-supervised learning methods, active learning algorithms and sparse Gaussian processes.

The Qualcomm Innovation Fellowship (QInF) program has recognised **Yarin Gal** and **Mark van der Wilk**, graduate students in the Machine Learning Group. They have been selected for their research proposals and awarded £10,000 fellowships as well as receiving mentoring from Qualcomm researchers.

Alumnus **Robert K. Perrons** has been appointed a member of the Australian Government's Expert Network to accelerate the commercialisation of promising new energy technologies. He also serves as Associate Professor at the Queensland University of Technology in Australia.

Professor Andy Neely has been appointed as the new head of the University of Cambridge Institute for Manufacturing (IfM), part of the Department of Engineering, as well as Professor of Manufacturing on the retirement of Professor Sir Mike Gregory on 30 September.

Professor Gregory, who has been a driving force behind the IfM since its inception, added: "I am pleased to welcome Andy Neely to his new role. He knows IfM well and is highly regarded in the wider manufacturing community. He is ideally placed to lead the next stage of development at the IfM."

Professor Neely is the founding director of the Cambridge Service Alliance and is currently Royal Academy of Engineering Professor of Complex Services. He is internationally recognised for his work on the servitization of manufacturing, organisational performance measurement and management.

Dr Hugh Hunt, Reader in the Department of Engineering, has been awarded the 2015 Royal Academy of Engineering Rooke Award for outstanding contributions to the public promotion of engineering.

The Rooke Award is given to an individual, small team or organisation who has contributed to the Royal Academy of Engineering's aims and work through promoting engineering to the public. Hugh was recognised for his efforts over the past 25 years through direct education, television and radio, inspiring thousands to engage with engineering and science.

Professor Jim Woodhouse is one of thirteen inspirational academics who have been honoured for the outstanding quality and approach to their teaching.

The annual Pilkington Prizes, which honour excellence in teaching across the collegiate University are awarded annually to academic staff, with candidates nominated by Schools within the University.

On the origin of (robot) species

Researchers have observed the process of evolution by natural selection at work in robots, by constructing a 'mother' robot that can design, build and test its own 'children', and then use the results to improve the performance of the next generation, without relying on computer simulation or human intervention.

Researchers led by the Department of Engineering have built a mother robot that can independently build its own children and test which one does best; and then use the results to inform the design of the next generation, so that preferential traits are passed down from one generation to the next.

Without any human intervention or computer simulation beyond the initial command to build a robot capable of movement, the mother created children constructed of between one and five plastic cubes with a small motor inside.

In each of five separate experiments, the mother designed, built and tested generations of ten children, using the information gathered from one generation to inform the design of the next. The results, reported in the open access journal PLOS One, found that preferential traits were passed down through generations, so that the 'fittest' individuals in the last generation performed a set task twice as quickly as the fittest individuals in the first generation.

"Natural selection is basically reproduction, assessment, reproduction, assessment and so on," said lead researcher Dr Fumiya Iida, Lecturer in Mechatronics at the Machine Intelligence Laboratory, who worked in collaboration with researchers at ETH Zurich. "That's essentially what this robot is doing – we can actually watch the improvement and diversification of the species."

For each robot child, there is a unique 'genome' made up of a combination of between one and five different genes. As in nature, evolution in robots takes place through 'mutation', where components of one gene are modified or single genes are added or deleted, and 'crossover', where a new genome is formed by merging genes from two individuals.

In order for the mother to determine which children were the fittest, each child was tested on how far it travelled from its starting position in a given amount of time. The most successful individuals in each generation remained unchanged in the next generation in order to preserve their abilities, while mutation and crossover were introduced in the less successful children.

The researchers found that design variations emerged and performance improved over time: the fastest individuals in the last generation moved at an average speed that was more than twice the average speed of the fastest individuals in the first generation. This increase in performance was not only due to the fine-tuning of design parameters, but also because the mother was able to invent new shapes and gait patterns for the children over time, including some designs that a human designer would not have been able to build.

"One of the big questions in biology is how intelligence came about – we're using robotics to explore this mystery," said Iida. "We think of robots as performing repetitive tasks, and they're typically designed for mass production instead of mass customisation, but we want to see robots that are capable of innovation and creativity."

Evolutionary robotics is a growing field which allows for the creation of autonomous robots without human intervention. Most work in this field is done using computer simulation. Although computer simulations allow researchers to test thousands or even millions of possible solutions, this often results in a 'reality gap' – a mismatch between simulated and real-world behaviour.

While using a computer simulation to study artificial evolution generates thousands, or even millions, of possibilities in a short amount of time, the researchers found that having the robot generate its own possibilities, without any computer simulation, resulted in more successful children. The disadvantage is that it takes time: each child took the robot about 10 minutes to design, build and test. According to Iida, in future they might use a computer simulation to pre-select the most promising candidates, and use real-world models for actual testing.

Iida's research looks at how robotics can be improved by taking inspiration from nature, whether that's learning about intelligence, or finding ways to improve robotic locomotion. A robot requires between ten and 100 times more energy than an animal to do the same thing. Iida's lab is filled with a wide array of hopping robots, which may take their inspiration from grasshoppers, humans or even dinosaurs.

"It's still a long way to go before we'll have robots that look, act and think like us," said Iida. "But what we do have are a lot of enabling technologies that will help us import some aspects of biology to the engineering world."

This article originally appeared on the University of Cambridge website.

See the robots in action at: http://bit.ly/1NcByDF
www.eng.cam.ac.uk/profiles/fi224

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