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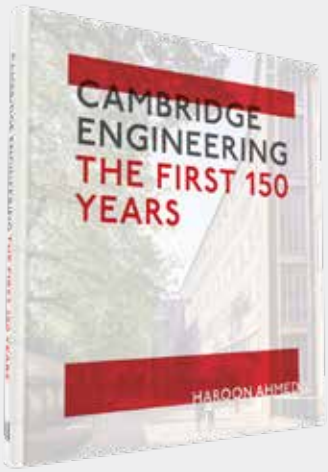
DEPARTMENT OF ENGINEERING

NEWS

UNIVERSITY OF CAMBRIDGE

In this issue



Cambridge Engineering The First 150 Years

"The history of engineering told in this book shows that Cambridge Engineering has come a long way in nearly 150 years. Its reach and impact continues to accelerate. Even my wildest predictions for the next 150 years are likely to fall short of what this unique international community of engineers will achieve."

Ann Dowling
Professor Dame Ann Dowling was Head of the Department of Engineering from 2009 to 2014.

Copies can be bought at:
profileeditions.com/cambridge-engineering-hb

Cover image: Robot hand playing the piano. Credit: Josie Hughes.

Note from the editors

In this edition, we are pleased to profile the many achievements of our female engineers who are inspiring the next generation.

At a special event held to mark International Women in Engineering Day, 30 girls from Cambridgeshire state schools were invited to the Department for a day of talks and activities. One pupil said that this had been the first time she had properly considered engineering as a career option, which just goes to show what a crucial role events such as this one can play in introducing teenagers to the world of engineering. You can read more on page 11.

We also track the progress of rising stars Dr Anna Young and Dr Jenni Sidey-Gibbons. Dr Young is a former Senior Research Associate who reflects fondly on her time at the Whittle Laboratory, a space which she says has a "sense of community" (page 16). Meanwhile, Canadian astronaut and Cambridge lecturer Dr Sidey-Gibbons has set her sights on the Moon after it was announced that she will join colleagues in the NASA-led Lunar Gateway (page 21).

One person who is impressed by the achievements of today's female engineers is alumna Ann Roberts, who shares her frank account of life as an engineering student during the 1950s (page 10). Whilst her experience wasn't all plain sailing, Ann enjoyed her time at the Department. "I'm impressed to see how today's young women have made their mark in the engineering world and continue to do so. I'm filled with admiration for them," she says.

Charlotte Hester and Jacqueline Saggers

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Head's welcome

In September, we officially opened our new Civil Engineering Building in West Cambridge. It was completed on time and on budget. We now have about half our academic divisions in West Cambridge. This is a major step towards our reintegration on the West Site. We have roughly three more academic divisions, plus our undergraduate teaching and our professional support services still to move.

The new Civil Engineering Building will house the National Research Facility for Infrastructure Sensing (NRFIS). Indeed, the building is a laboratory in itself and incorporates sensors to measure internal temperatures and strains throughout the structure. There are also environment sensors to measure a very wide range of things: from volatile organic compounds to lux levels to soil moisture content. It was designed using an innovative energy/cost metric developed through a collaboration between the mechanical and electrical consultants and the Department.

It is the second University building to be heated using ground source heat pumps which will save money and greatly reduce the carbon footprint. The one metre thick strong floor is 10m by 20m and incorporates 160 anchor points for large-scale testing. There is a microelectromechanical (MEMS) laboratory, a severe environments laboratory and a laboratory for concrete manufacture and durability. There are also laboratories for novel prototyping, sensor maintenance and vibration isolation that form the main focus of the National Research Facility.

Professor Lord Robert Mair, Head of the Centre for Smart Infrastructure and Construction (CSIC), and Professor Simon Guest, Head of the Civil Engineering Division, have been the key driving forces behind the initiative for the building and its design. Professor Giulia Viggiani has taken on the role of academic lead for the new National Research Facility.

Perhaps the greatest benefit to come from this new building is the opportunity we now have to create an integrated community centred around the discipline of civil engineering. For everyone in the field to work close enough together to share ideas informally and build a sense of intellectual identity. What is next? We are already planning to rebuild the Whittle Laboratory and install new state-of-the-art experimental facilities funded by the Aerospace Technology Institute. Through the work of Sir Frank Whittle, Sir William Hawthorne and others, the Department was key in the invention of the jet engine and the opening up of mass air travel. Our current plans will lead to the creation of a National Centre of Propulsion and Power in West Cambridge. This will enable the Whittle to play a leading role in decarbonising mass air transport and

Credit: Graham CopeKoga

power generation. The 21st century Whittle will create a sustainable future for its 20th century heritage. However, the high cost of the new facilities, including collaboration space and support for more staff in West Cambridge, means that fundraising for the project is not yet complete. If, after reading the articles on pages 8, 9 and 16 you would like to take an interest in the project, do please get in touch (rwp@eng.cam.ac.uk). We welcome all advice and engagement that will help us to make a success of this challenging, yet vitally important, initiative.

Professor Richard Prager FREng, FIET, CEng

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New Civil Engineering Building to make 'significant contribution' to UK infrastructure research

→ Robot hand playing the piano

Credit: Josie Hughes

3D-printed robot hand 'plays' the piano

Scientists have developed a 3D-printed robotic hand which can play simple musical phrases on the piano by just moving its wrist.

And while the robot is no virtuoso, it demonstrates just how challenging it is to replicate all the abilities of a human hand, and how much complex movement can still be achieved through design.

The robot hand was made by 3D-printing soft and rigid materials together to replicate of all the bones and ligaments – but not the muscles or tendons – in a human hand. Even though this limited the robot hand's range of motion compared to a human hand, the researchers found that a surprisingly wide range of movement was still possible by relying on the hand's mechanical design.

Using this 'passive' movement – in which the fingers cannot move independently – the robot was able to mimic different styles of piano playing without changing the material or mechanical properties of the hand. The results, reported in the journal *Science Robotics*, could help inform the design of robots that are capable of more natural movement with minimal energy use.

Complex movement in animals and machines results from the interplay between the brain (or controller), the environment and the mechanical body. The mechanical properties and design of systems are important for intelligent functioning, and help both animals and machines to move in complex ways without expending unnecessary amounts of energy.

"We can use passivity to achieve a wide range of movement in robots: walking, swimming or flying, for example," said PhD student Josie Hughes, the paper's first author. "Smart mechanical design enables us to achieve the maximum range of movement with minimal control costs: we wanted to see just how much movement we could get with mechanics alone."

Over the past several years, soft components have begun to be integrated into robotics design thanks to advances in 3D printing techniques, which has allowed researchers to add complexity to these passive systems.

The human hand is incredibly complex, and recreating all of its dexterity and adaptability in a robot is a massive research challenge. Most of today's advanced robots are not capable of manipulation tasks which small children can perform with ease.

"The basic motivation of this project is to understand embodied intelligence, that is, the intelligence in our mechanical body," said Dr Fumiya Iida, Reader in Robotics, who led the research. "Our bodies consist of smart mechanical designs such as bones, ligaments, and skins that help us behave intelligently even without active brain-led control. By using the state-of-the-art 3D printing technology to print human-like soft hands, we are now able to explore the importance of physical designs, in isolation from active control, which is impossible to do with human piano players as the brain cannot be 'switched off' like our robot."

"Piano playing is an ideal test for these passive systems, as it's a complex and nuanced challenge requiring a significant range of behaviours in order to achieve different playing styles," said Josie.

The robot was 'taught' to play by considering how the mechanics, material properties, environment and wrist actuation all affect the dynamic model of the hand. By actuating the wrist, it is possible to choose how the hand interacts with the piano, allowing the embodied intelligence of the hand to determine how it interacts with the environment.

The researchers programmed the robot to play a number of short musical phrases with clipped (staccato) or smooth (legato) notes, achieved through the movement of the wrist. "It's just the basics at this point, but even with this single movement, we can still get quite complex and nuanced behaviour," said Josie.

Despite the limitations of the robot hand, the researchers say their approach will drive further research into the underlying principles of skeletal dynamics to achieve complex movement tasks, as well as learning where the limitations for passive movement systems lie.

Watch the robotic hand in action:
youtu.be/XDgffOW6ZzQ

→ Dr Ioannis Brilakis, Laing O'Rourke Reader in Construction Engineering, demonstrates the Construction IT laboratory capabilities in virtual and mixed reality

New Civil Engineering Building to make 'significant contribution' to UK infrastructure research

A new multimillion pound collaborative space for the civil engineering industry to work alongside leading researchers from the University of Cambridge has officially opened.

Located on the West Cambridge campus, the new Civil Engineering Building will enable University researchers, industry and other academic institutes to work together on joint research programmes.

Sustainability and future proofing underpins the design of the building, which houses the new National Research Facility for Infrastructure Sensing (NRFIS) and has 12 world-class, state-of-the-art laboratories focusing on a wide variety of civil engineering disciplines, including sensor development, structures, geomechanics and construction.

NRFIS is part of the UK Collaboratorium for Research in Infrastructure and Cities (UKCRIC) portfolio of research and innovation facilities, funded through the Engineering and Physical Sciences Research Council (EPSRC).

"The opening of NRFIS marks a significant contribution to the UK infrastructure research community which is key to designing, building and maintaining infrastructure that is resilient, adaptable and sustainable," said Professor Lord Robert Mair, Head of the Cambridge Centre for Smart Infrastructure and Construction (CSIC), which is part of the Department of Engineering's Civil Engineering division.

"Investment in our infrastructure and infrastructure services, which are so important to citizens, is crucial for the economy and society," he added. "NRFIS is a facility where academia and industry can engage in protecting and growing the country's infrastructure base and supporting the UK to be a leader in the field of smart infrastructure."

NRFIS will support research in the application of advanced sensor technologies to the monitoring of the UK's existing and future infrastructure, to provide insights and data to inform the design, construction, operation and management of the UK's infrastructure and enable better decision-making.

It builds on the University's track record of delivering innovative sensor advancements through CSIC, the CamBridgeSens research network, and the Centres for Doctoral Training in Sensor Technologies for a Healthy and Sustainable Future (STHSF) and Future Infrastructure and Built Environment: Resilience in a Changing World (FIBE2). It also offers an opportunity to explore the development and application of novel sensor systems at a range of 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 asset quality, resilience of enhanced construction safety, and smarter asset management.

The new building also features:

- Construction elements that enable the building to be taken apart and re-used including the steel frame which is bolted together rather than welded and concrete 'planks' to make the floor
- Extension-friendly adaptable cladding to allow for future expansion of the building
- Thermochromatic glass slates on the facade tint in high temperatures to limit sunlight penetrating the building to maintain the best temperature
- Strategically located sensors delivering real-time feedback on the performance of the building, to include temperature, humidity and carbon dioxide levels.

www.nrfis.cam.ac.uk

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New FIBE2 CDT announced

A new information engineering course with autonomous driving at its heart

↑ Front, from left, Dr Jeffrey Hawke, guest lecturer from Wayve, Professor Roberto Cipolla and Dr Richard Turner

The Department has launched a new information engineering course for second year undergraduate students with a focus on autonomous driving.

The course aims to provide a unified view of information engineering, showing how signal processing, computer vision, machine learning and control relate to one another.

The new syllabus is a response to the need to address the global shortage of engineers who are familiar with computer vision, deep learning and reinforcement learning, at a time when the industry is growing rapidly.

As part of the course, example applications are drawn from autonomous driving, and guest lecturers from industry will introduce the students to the anatomy of a self-driving car and its autonomous driving hardware (including sensors, interfaces, actuators, and the car itself).

The course is taught by Professor Roberto Cipolla, Dr Richard Turner and Dr Glenn Vinnicombe. The guest lecturers invited to talk as part of the new course have so far included Dr Alex Kendall, alumnus and co-founder of Wayve, and his colleague Dr Jeffrey Hawke. During the Easter term, they brought along two of their self-driving cars to the Department and gave a demonstration to the students, and the Cambridge-based machine learning company also welcomed two of the students on an internship this summer.

Wayve has been testing its self-driving cars on the city's roads since January 2018. It was founded in 2017 by Dr Kendall, Research Fellow in Computer Vision and Robotics, who completed his PhD in Professor Cipolla's group, and Dr Amar Shah, who completed his PhD in Professor Zoubin Ghahramani's Machine Learning group.

Professor Cipolla said: "We're delighted to launch this new course at a time when there is a desperate shortage of engineers who are familiar with computer vision, deep learning and reinforcement learning. We use the example application of autonomous driving to provide a real-world case study of important concepts and sub-areas of information engineering. This course also aims to equip students with the ability to solve simple computer vision and machine learning problems, including object detection and segmentation, and sequential decision-making."

> We're delighted to launch this new course at a time when there is a desperate shortage of engineers who are familiar with computer vision, deep learning and reinforcement learning.
>
> Professor Roberto Cipolla

The £2 billion vegetable and the agricultural future of the East

Credit: pixabay

From crop science to robotics, supply chains to economics, researchers work collaboratively across the East of England to sustainably increase agricultural productivity and profitability.

The potato is a staple crop that we produce around five million tonnes of each year in the UK. It is an industry worth an annual £2 billion, and farmers in East Anglia harvest a third of England's entire potato crop.

At the Cambridge Global Food Security Interdisciplinary Research Centre (IRC), a University-wide network concerned with the challenges of meeting the rising food needs of a growing population, collaborative work has enabled the exploration of opportunities to improve productivity in one of the UK's key industries: agri-tech, which contributes £14.3 billion to the UK economy and employs 500,000 people.

Improved agricultural productivity would contribute to economic growth in Fenland, which accounts for about half of England's most highly productive farmland. Of all the crops grown to a significant scale, potatoes are one of the more complex.

The complexities of the potato crop are not just confined to the field, but reach all the way to the table, as Dr Mukesh Kumar, Lecturer in Operations Management at the Institute for Manufacturing (IfM), part of the Department of Engineering, has been discovering.

Dr Kumar studies the dynamics of supply chains of products ranging from cars to milk. He recently teamed up with representatives from potato industries to investigate why potatoes have one of the highest waste problems of any commodity crop.

"Our first step was to map out the potato supply chain from beginning to end," says Dr Kumar. "We were amazed to find that it involves up to 23 key actors – from seed developers, producers and growers, to farmers, processors and retailers."

He found that the main 'hotspot' for waste is at the farm, and that the processing industry was keen to address waste occurring from the farm to the factory gate.

"The difference is caused by many factors, some natural and some due to farmers having limited access to resources and technological expertise. This gap between expected production and real production is a huge waste of resources."

Dr Kumar believes the team has just scratched the surface with this pilot study; now they need to look at the wastage issue in more depth to design better solutions for farmers. "To understand our food system properly, and improve resilience and profitability, we have to continue to work closely with the growers."

One policy announced by the government in early 2018 was support for the development of high-tech innovations to make UK agri-businesses more productive and profitable, while improving resilience and protecting the environment.

Someone who recognises the complexity of this challenge is Dr Belinda Clarke, Director of Agri-Tech East, an 'innovation hub' of farmers, growers, scientists and entrepreneurs focused on improving the competitiveness of agriculture.

"Aligning the expectations of farmers with the nature of cutting-edge research is a challenge," says Dr Clarke, "and some of the frontier discovery research is quite a long way from market.

"It's all about bringing innovation to end users in a way that's immediately applicable to them," she says.

As an active member of Agri-Tech East, the University is building connections across the whole breadth of the agri-food chain. In the Department of Engineering's Machine Intelligence Laboratory, Dr Fumiya Iida, Reader in Robotics, wants to apply his expertise in robotics to the automation of agricultural processes. He's interested in the challenge of creating robots that can effectively deal with 'soft' objects, like fruit and vegetables, without damaging them.

"Robots are really terrible at manipulating soft objects," says Dr Iida. "It's so easy for us humans, but robot technology is designed for a rigid world. Assembling cars, for example, is much easier for them compared with manipulating fruit and vegetables."

Using an electrically conductive soft material, his team is making robots that are sensitive to light, chemicals and other stimuli, enabling them to deal with uncertain tasks in unstructured environments, like farmers' fields. He calls the work 'bio-inspired robotics' – looking at biology and why humans are good at certain tasks, and trying to create robots to do the same.

Dr Clarke says Dr Iida is just one example of the real willingness of researchers not just to disseminate knowledge generated within the University, but also to take on board the knowledge from within the farming community and embed it in research thinking for the future.

Written by Jacqueline Garget

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New Centre for Doctoral Training in in Agri-Food Robotics

→ From left, Professor Rob Miller, Professor John Wallwork and Sir Brian Burridge

Whittle Laboratory celebrates 50 years

The Department's Whittle Laboratory, which started its construction in 1969, is internationally recognised as the centre of excellence in aeroengine and turbomachinery research, design tools and education.

The first patent for a jet engine was filed by Frank Whittle in 1930, and his first practical engine operated in 1937, just over 80 years ago. It has taken huge, sustained effort to develop those early concepts from purely military uses into the super-efficient machines which power today's aircraft. Frank Whittle was a student in the Department of Engineering from 1934 to 1937, and the Whittle Laboratory commemorates his pioneering work through its name.

The individuals and teams who have further progressed jet engine technology in the Whittle Laboratory have now been recognised with the presentation of an Aeronautical Heritage Award by the Royal Aeronautical Society. The Aeronautical Heritage Award scheme was established to recognise significant contributions made to 'the art and science of aeronautics'.

Over the past 50 years, the Whittle Laboratory's researchers and staff have made innumerable vital contributions to the technology of jet engines, or more accurately, of turbomachinery, which includes other products such as electrical power generators, gas turbines for oil and gas pumping, and domestic items from vacuum cleaners to hair dryers.

Professor Rob Miller, Chair in Aerothermal Technology and Director of the Whittle Laboratory, gave a presentation at the Aeronautical Heritage Award plaque unveiling:

Aerospace has entered a period of disruptive market change. Rolls-Royce is developing the UltraFan family of engines with the aim of a 25% reduction in fuel burn by 2025. This is Rolls-Royce's first major architecture change since the RB211 in the 1970s. The introduction of Machine Learning and High Performance Computing has led to radical changes in their design systems. All this, in recent years, has meant unparalleled levels of technology development at the Whittle Laboratory.

The broader aerospace sector is also undergoing disruptive change. Electrification of aero-propulsion is resulting in a rapid increase in the number of new entrants in the sector. Over 70 companies globally are planning first flights of electric urban air vehicles by 2024. In the middle of the market, futuristic aircraft architectures are being seriously considered where parts of the propulsion system are embedded in the aircraft fuselage, allowing up to 15% reduction in fuel burn. In terms of very high speed propulsion, companies such as Reaction Engines are developing completely new engine architectures. The Whittle Laboratory is centrally involved in all of these areas of technology development.

The Whittle Laboratory also does a lot of research in turbomachinery for non-propulsion applications. This sector is also undergoing disruptive change. Companies such as Mitsubishi are developing new gas turbines, which can switch on and off quickly, allowing them to be used on grids which have a significant penetration of renewables. Siemens UK, which makes small land based gas turbines, believes that if we can reduce product development times by a factor of three, it can double its market share. Dyson, which develops turbomachinery for household products, face the challenge of designing turbomachinery in a completely new area of the turbomachinery design space. Its blades operate at similar Mach numbers i.e. speeds equivalent to Rolls-Royce blades, but its Reynolds numbers i.e. the viscous process in the flow, are much closer to that of insects. In addition, Dyson has a demanding product development timescale of months not years.

We believe that the winners in this new world will be companies who can adapt to new technologies more quickly and at lower

cost than the competition. Over the last five years, one of the core aims of the Whittle Laboratory has been to radically transform the way we develop aero-propulsion in the UK, making it at least 10 times faster and 10 times cheaper.

Like Whittle in the early days of the jet engine, we believe that 'injecting pace and simplicity' into the way we develop new propulsion systems is key to meeting this future challenge. The solution, we believe, is to merge the digital and physical systems involved in technology development. This allows us to 'tighten the circle' between design, manufacture and testing.

We have found that when the technology development timescale approaches the human timescale, of around a week, innovation explodes. This concept is based on recent pioneering trials undertaken at the Whittle Laboratory (funded by the Aerospace Technology Institute and Rolls-Royce).

To reduce the technology development time scale from years to a week has meant that the time taken to design, manufacture and test technologies has all had to be massively reduced.

- *We have reduced design times by two orders of magnitude by the use of Computational Fluid Dynamics (CFD) developed to run on Graphics Cards by Dr Graham Pullan (graphics cards that were originally designed for computer gaming). This reduces the CFD runtime for a typical blade to just minutes, allowing us to implement new augmented design systems based on Machine Learning*

- *We have reduced manufacturing times by two orders of magnitude by using rapid prototyping and rapid machining. The key, developed by Dr James Taylor, has been to directly link the design system with in-house machine tools, allowing designers to realise physical blades in around a day, direct from the design system*

- *We have reduced the time required to test a compressor by at least two orders of magnitude. The key, developed by Dr James Taylor and Dr Tony Dickens, has been to carefully analyse the testing process using value stream analysis. This has allowed around 95% of operations to be removed from the testing process, cutting testing time from months to hours.*

In order to take full advantage of agile technology development, a different way of working is required. Traditional technology development is inhibited by inter-organisational barriers and by top-down inflexible management structures. To overcome this small Formula 1 style, autonomous co-located teams were formed, made up of both industry and academia. This was only possible because of our long-term partnerships with industry.

The work culminated in September 2017 in a trial. An academic/industry team were embedded in the Whittle Laboratory and given four Rolls-Royce compressor technologies to develop (two from Rolls-Royce Derby, one from Rolls-Royce North America and one from the Whittle). The results were astonishing. In 2005, a similar trial had taken place and took the Whittle Laboratory team two years. And we weren't bad at it! In 2017, using the new methods, it took the team a week. This demonstrated cutting the time and cost of testing a technology, by a factor of 100.

Over the next five years, a team led by Dr Nick Atkins, have developed a plan to expand this 'rapid technology development process' to around 80% of the UK's future propulsion testing needs. With the support of our industry partners, the University of Cambridge and the UK government, we are planning to significantly expand the Whittle Laboratory building and its new rapid test capability. Watch this space.

You may think that I'm biased when I say that I honestly believe that the quality of research and education currently available in the Whittle Laboratory is as high, if not higher, than at any time over the last 50 years. In terms of research excellence, Whittle Laboratory publications have been awarded The Gas Turbine Award – the American Society of Mechanical Engineers highest honour in the field – an incredible nine years out of the last 13. In terms of educational excellence, five years ago, we set up the Centre of Doctoral Training in Gas Turbine Aerodynamics. This is a collaboration between three Universities (Cambridge, Oxford and Loughborough) and four companies (Rolls-Royce, Mitsubishi, Siemens and Dyson) sponsored by EPSRC, with the aim of training the next generation of leaders in the field. The training offers an unparalleled experience with students being lectured by experts from all over the world and undertaking practical training such as stripping a gas turbine at Siemens. This has made the UK the most attractive country in the world for students seeking a graduate education in this field.

Just at its opening 50 years ago, the Whittle Laboratory faced the challenge of developing technologies which would make low cost air travel available to the masses, I believe that today, the Whittle Laboratory is perfectly placed to ensure that the UK meets the aerospace challenges of the next 50 years.

↑ Professor Rob Miller

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New Centre for Doctoral Training in Future Propulsion and Power

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Meet Whittle Laboratory alumna Dr Anna Young

whittle.eng.cam.ac.uk

→ LEFT: Ann graduated in 1959. RIGHT: Ann goes punting down the Cambridge Backs with her mother

Credit: Ann Roberts

ALUMNI UPDATE

Carving a career in engineering in the 1950s

Alumna Ann Roberts (née Wilkinson) shares her memories of being an engineering student at Cambridge during the 1950s.

"I'm sure it will entertain, amuse, and/or horrify some of your present students," she says, "So here it goes…"

I matriculated at Newnham College in 1956. Originally reading Natural Sciences, I switched to Aeronautical Engineering for the last year. As preparation for the year's course, I was required to complete a basic practical course in either welding or milling; I chose the latter as I could burn myself simply by boiling an egg!

I joined the Apprentice Training School at the nearby company of A. V. Roe. At the time, it was a flourishing local aircraft manufacturer. I was regarded with some suspicion as the company had never had a female apprentice before, but once I was accepted, all the tutors and fellow apprentices were so helpful that I had no trouble completing the course successfully.

All the qualifying students on the course were treated to a flight on an AVRO plane – except me. But, as so often encountered back then, the apologetic disclaimer was that the flights were 'not insured for women'. I did, however, get a large box of chocolates and the good wishes of the entire class.

My presence at the Engineering Lab came as quite a shock to both staff and students. By the end of my first day in the lab (located at the time on Lensfield Road), I must have been asked over 100 times whether or not I was a student. I had to be extra careful to uphold the future reputation of all female students, such as dressing neatly and femininely! We had all known of a female student in the past who had ridden a 1000cc motorbike, been a demon-fast bowler on the Newnham cricket team, and had terrified all lesser females who met her!

Several staff members asked what I was doing there, and all without exception expressed their pleasure at having a female student. One student, however, was heard to say, "Damn, we shall have to start shaving now", but after the initial shock wore off, I was met with nothing but encouragement and support from staff and fellow students.

My father was an engineer and was full of encouragement for me. He was delighted when I continued to pursue the same career. After Cambridge Finals in 1959, I went straight into my first job with Bristol Aircraft at the princely sum of £600 per year (we did not have to search for jobs, they came to us in those days).

I was lucky enough to have a very successful career with Bristol Aircraft. I spent nearly five years working for the company in their research department. I worked on the destructive phenomenon of Flutter which, at the time, was causing much concern. I then moved on to studying airflow in general. I actually published a paper for the Aeronautical Research Council with my immediate boss J. G. Wright, titled *Airflow over Ogival Wings*.

My pay rapidly increased. This was after it was discovered that the male assistant I soon employed was being paid considerably more than I was. It was a great time however, and I enjoyed working with such clever people, as well as the chance to work at other famous laboratories across the UK. Soon after I got married, I became pregnant, and my job was terminated because of the then 'company policy' – 'working mothers' were a bad risk.

I tried to return to work, but virtually the entire aeronautical industry in the UK had either died or moved to America. My career took a change of direction. I got involved in the possibilities of 'centre pivot' irrigation agriculture. I ended my working life in the research labs of a Finnish company that was developing the use of enzymes in the growing of food crops. I relocated to the USA in 2001.

I loved my time at the Department of Engineering. Even the occasional disapproval from my days there armoured me for the prejudice and resentment I would later encounter in the real world. Every time I open my copy of the *Department of Engineering News*, I'm comforted and impressed to see how today's young women have made their mark in the engineering world and continue to do so. I'm filled with admiration for them.

Credit: Charlotte Hester

Inspiring future engineers

↑ Dr Christelle Abadie, Lecturer in Civil Engineering, helps pupils build an origami arch

As part of International Women in Engineering Day 2019, the Department hosted a special event for 30 girls from Cambridgeshire state schools and encouraged them to build an origami arch.

Dr Christelle Abadie, Lecturer in Civil Engineering, led a workshop on an introduction to origami engineering, with help from Dr Megan Davies Wykes, Liz Acton Lecturer in Engineering, PhD students Alessandra Luna Navarro and Sakthy Selvakumaran, and Outreach Officer Maria Kettle.

Following the workshop, the Year 8 and 9 pupils were challenged to each build sections of a 1.8 metre-long origami arch, a structure that can also be used as an emergency shelter. The hands-on activity took place in the Department's Dyson Centre for Engineering Design – a space primarily for undergraduates to learn, create and innovate.

The Department also hosted a networking lunch, introduced by the Head of the Department Professor Richard Prager, that included two poster displays: one of inspirational female engineers nominated by students and staff, and another showcasing women's engineering-related research in the Department. In his welcome speech, Professor Prager said: "I hope that you will see how rewarding, satisfying and worthwhile it is to be an engineer. And, if you follow engineering as a career, I hope that you will inspire others to follow in your footsteps."

A tour of Queens' College followed, where a high tea was served and aspects of civil engineering were discussed. PhD student Sakthy Selvakumaran gave an inspiring talk on her research which involves monitoring bridges from space using satellites.

Dr Abadie said: "I wish that *every* pupil had the opportunity to learn and do something they are passionate about after leaving school. I am passionate about what I do, and I was delighted to be able to share with the girls how rewarding and exciting engineering can be."

One of the pupil's said: "This is the first time I've properly considered engineering as an option."

International Women in Engineering Day is a global awareness campaign, coordinated by the Women's Engineering Society (WES), and this year (June 23) participants were encouraged to show the world how they are 'transforming the future' in pursuit of more diversity in engineering.

> I wish that every pupil had the opportunity to learn and do something they are passionate about after leaving school. I am passionate about what I do, and I was delighted to be able to share with the girls how rewarding and exciting engineering can be.
>
> Dr Christelle Abadie

www-engineeringdiversity.eng.cam.ac.uk
www.inwed.org.uk

New Centres for Doctoral Training announced

Five new Centres for Doctoral Training (CDTs) involving the University of Cambridge have been announced by UK Research and Innovation (UKRI) to develop the skills needed for UK prosperity.

A **CDT in Future Propulsion and Power** will be led by Dr Graham Pullan, Reader in Aerothermal Engineering, and will train at least 90 PhD students over the next eight years, with the first cohort due to arrive in October 2019.

Dr Pullan said: "We're excited about the launch of the new EPSRC CDT in Future Propulsion and Power. The Centre will provide at least 90 graduate students with the skills and knowledge they need to address the aero-propulsion and power generation challenges of the next decade. Our research will cover topics such as low emission engines, hybrid-electric propulsion, urban air mobility, high performance computing for high performance engines, and AI-driven design."

The Centre has been developed with the support of four industry partners: Rolls-Royce, Mitsubishi Heavy Industries, Siemens and Dyson. It builds on the success of the EPSRC CDT in Gas Turbine Aerodynamics. The two new themes are 'Data, learning and design' and 'Systems integration'.

Credit: pixabay

www.turbocdt.org

The world's first **CDT in Agri-Food Robotics** will create the largest ever cohort of Robotics and Autonomous Systems (RAS) specialists for the global food and farming sectors.

The CDT will provide funding and training for at least 50 doctoral students, who will be supported by major industry partners and who will specialise in areas such as autonomous mobility in challenging environments, the harvesting of agricultural crops, soft robotics for handling delicate food products, and 'co-bots' for maintaining safe human-robot collaboration and interaction in farms and factories.

The CDT brings together a unique collaboration of leading researchers from the Universities of Lincoln, Cambridge and East Anglia, located at the heart of UK agri-food business, together with the Manufacturing Technology Centre, supported by leading industrial partners and stakeholders from across the food, farming and robotics industries. These include John Deere, Syngenta, G's Growers, Beeswax Dyson, ABB and the Agricultural and Horticultural Development Board.

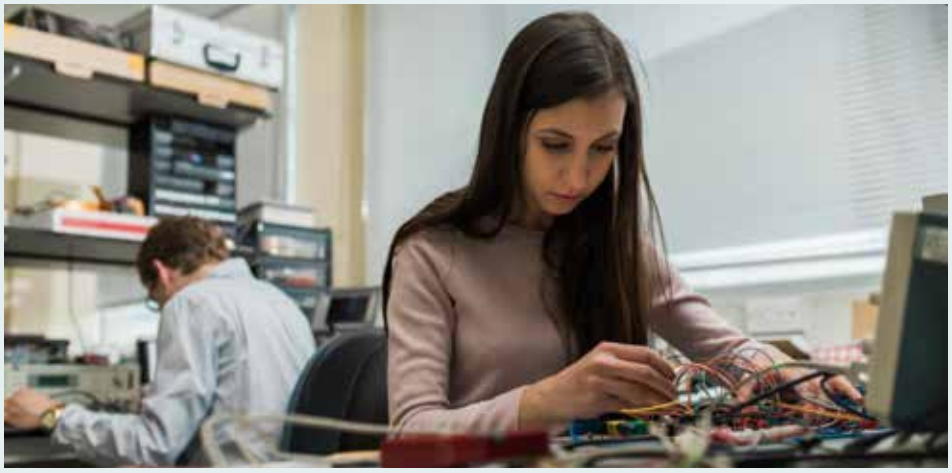
Funded by the EPSRC, the new CDT will see all 50 students follow a common foundational year, studying on the new MSc Robotics and Autonomous Systems at the University of Lincoln. Then 20 of the students will carry out their PhD studies at Lincoln, 20 at Cambridge, and 10 at UEA. The wide-scale engagement with industry will enable the students' research to be pushed rapidly towards real-world applications in the agri-food industry.

Dr Fumiya Iida, Reader in Robotics at the University of Cambridge's Department of Engineering, is the Centre's Deputy Director. He said: "Agri-Food Robotics is an ideal research area where high-impact scientific challenges and industrial needs meet. On the one hand, many real-world problems in the industry such as manual handling of crops and reliable recognition of food are still regarded as considerable scientific challenges that the world-leading experts are intensively investigating today. On the other, the solutions to these problems will impact the competitiveness of UK Agri-Food businesses."

Credit: Bio-Inspired Robotics Lab

↑ Field tests of 'Vegebot' the automated Lettuce Harvesting Robot developed by the Bio-Inspired Robotics Lab at the University of Cambridge

lcas.lincoln.ac.uk/wp/cdt



A **CDT in Connected Electronic and Photonic Systems (CEPS)** will build on the success of the EPSRC-funded collaboration between UCL and the University of Cambridge, which saw the setting up of joint CDTs for Photonic Systems Development in 2009 and Integrated Photonic and Electronic Systems in 2013.

Five cohorts of PhD students will be trained in the new CDT over the next eight years.

The aim is to train researchers to lead a new generation of industries providing products and systems, connecting electronics with photonics. It brings together multi-disciplinary, cutting-edge research activities from groups in electronic engineering, communications, photonics, nanotechnology, physics, materials, computer science, manufacturing, biomedical engineering, biotechnology, civil engineering and chemical engineering – with contributions from more than 35 collaborating companies – to provide an outstanding training environment for its students.

Cambridge Professor Richard Penty, Director of Research for the new CDT, said: "The vision of this CDT is to create a new generation of researchers who are able to carry out world-leading research in integrated circuits and systems which incorporate electronic, photonic and wireless components, thus providing future leaders in the creation of the connected electronic and photonic systems upon which society will depend. The change in systems that this will enable is as profound as the development of the personal computer from a simple stand-alone device, to the fully networked information appliance that we have today. The benefits to the UK economy will be correspondingly large."

www.ipes-cdt.org

The **EPSRC CDT in Integrated Functional Nano (i4nano**), based in the Maxwell Centre on the West Cambridge site, will encourage interdisciplinary research and training in nano across the Departments of Engineering, Physics, Chemistry, Materials Science, Chemical Engineering and others.

The Centre will build on the world-leading work of the current NanoDTC programme. A total of 40 new studentships have been created and will be enhanced by pledges of more than 20 studentships from industry and other partners, making this a total of 60 studentships in the new i4nano Centre.

Professor Stephan Hofmann, Co-Director of the i4nano CDT from the Department of Engineering, said: "A distinctly ambitious goal in this next phase of the CDT will focus on heterogeneous materials integration, exploiting new in-operando probing to capture materials behaviour at actual industrially relevant process/operation conditions, underpinning up-scaling and system integration strategies."

Senior Teaching Associate Dr Karishma Jain said innovation training will be at the heart of the i4nano CDT, giving high-calibre postgraduate engineers, physicists, chemists and materials scientists a broader experience than currently possible in graduate research. Dr Jain added that it will also provide them with the knowledge and tools to turn inventions into robust and economically productive innovations that will help build the next generation of successful technology businesses in the Cambridge Ecosystem and beyond.

www.nanodtc.cam.ac.uk

A **CDT in Future Infrastructure and Built Environment: Resilience in a Changing World (FIBE2)** expands and builds on the strength of the current CDT in Future Infrastructure and Built Environment (FIBE CDT) to address the wider remit of resilient infrastructure.

The FIBE2 CDT will provide more than 60 fully funded PhD students over the next five years. The £6.5m funding from EPSRC is supported by £12.5m funding from 27 industry partners and involves collaboration with nine international academic centres around the world.

The FIBE2 CDT will lead the transformation in the resilience of our infrastructure through the creation of an inspirational doctoral training programme for talented cohorts from diverse academic and social backgrounds to conduct world-class, cutting-edge industry-relevant research. The goal is to develop the infrastructure professionals of the future, equipped with a versatile and cross-disciplinary skill set to meet the most complex emerging challenges and contribute effectively to better infrastructure decision-making in the UK.

The new CDT will tackle the strategically important area of infrastructure resilience in the context of five categories of threats and associated opportunities:

1. Infrastructure resilience against technological uncertainty
2. Infrastructure resilience against environmental causes
3. Infrastructure resilience in a world of economic and political change
4. Infrastructure resilience to support urbanisation and demographic change
5. Infrastructure resilience in a changing society and culture.

www.fibe-cdt.eng.cam.ac.uk

→ PuriFlow Team (from left): James Lee, Darius Danaei and Sian Evans

Institute for Manufacturing Design Show 2019

In the first year of the two-year Manufacturing Engineering Tripos (MET) course, teams of three or four students complete a major design project to develop a new product with real business potential.

Having first identified a customer need, the students research the market, develop original design concepts and create a full business plan. Projects from past years have generated some exciting new ideas and innovative technology, with a number of prototypes going into commercial production and winning national prizes.

Students put together displays to explain the technical ideas and business potential behind their design work. The projects are always diverse and normally include conceptual solutions, technical and experimental designs. Students are encouraged to produce and show working prototypes wherever possible.

Some of the 2019 projects are outlined below, summarised by the students in their own words:

PuriFlow

PuriFlow is an electrostatic precipitator (ESP) designed to remove particulates from the air. Mounted on lamp posts, and completely self-cleaning, this technology can be rolled out in cities. It is an affordable and effective solution to the urban air pollution problem.

In our proposed design, the ESP will be deployed in batches of tens of thousands, strapped to lamp posts across busy metropolitan areas. We aim to reduce the operating cost and preserve the effectiveness of the ESP by innovating a self-cleaning system. The self-cleaning will be achieved by periodic vibrations to loosen the collected matter, which will then be collected in a container that only requires cleaning once every few years.

RAD TouchCut Pro

An educational tabletop CNC router, where the cutting paths are drawn directly onto an image of the workpiece via a touchscreen. Much safer. Much faster. Much more inspiring.

RAD TouchCut Pro aims to bridge this gap between the secondary school Design and Technology curriculum and machining industry processes, while providing a practical classroom tool for student projects.

A student can clamp any piece of wood (within A2 size) onto the machine bed. They use the built-in camera to capture an image of the material which is displayed on the touchscreen. Next, they draw shapes to be cut out, directly onto the image, then watch as the machine follows an identical cutting path to the one drawn on the touchscreen. In order to allow the student to gain a greater understanding of the machining process, our product is partially transparent so the mechanical system inside can be viewed.

↑ RAD TouchCut Pro Team (from left): Rory Dyer, Dylan Bogod and Akhil Sonthi

CoCoal

CoCoal's open-source technology aids communities in rural Kenya. This low-cost method produces high quality cooking briquettes from coconut charcoal. This simultaneously reduces waste, deforestation and household energy expenditure.

Our multi-stage process first crushes the charcoal down to an optimal particle size, before it is mixed with water and Cassava starch, a locally available binder material. The mixture is then pressed in batches and allowed to dry to form solid briquettes.

By open-sourcing our technology to rural communities, we will enable them to produce energy-dense cooking charcoal from their food waste. This will provide Kenyans with a viable business opportunity, will limit deforestation and will decrease household spending on cooking.

View all the Design Show photos:
www.eng.cam.ac.uk/Flickr
www.ifm.eng.cam.ac.uk


Credit: pixabay

New research set to boost construction sector sustainability and productivity

A new collaborative research project involving Cambridge engineers aims to improve the sustainability and productivity of the construction sector.

Funded by UK Research and Innovation (UKRI), under the Industrial Strategy Challenge Fund 'Transforming Construction', the three-year project – Automating Concrete Construction (ACORN) – will develop a holistic approach to the manufacture, assembly, reuse, and deconstruction of concrete buildings, leading to a healthier, safer, built environment.

The research involves Dr John Orr, Lecturer in Concrete Structures, who is working alongside colleagues at the University of Bath and the University of Dundee. ACORN will capitalise on the computational and robotics expertise of the research team, to create an end-to-end digital process to automate the manufacture of concrete buildings, capitalising on the recent proliferation of affordable robotics and bringing them into an industry ripe for a step-change in sustainability and productivity.

The construction sector is responsible for nearly half of the UK's carbon emissions and concrete alone for 5% of global CO2 emissions. The widespread use of flat panel formwork for concrete leads to materially inefficient prismatic shapes for the beams, columns, and floor slabs in our buildings. This practice, which has been around since Roman times, is a key driver behind the high embodied carbon emissions associated with concrete structures. As much as half of the concrete in a building could be saved, if only we approached our use of the material in a different way.

The ACORN team are working towards creating a culture that is built on the concept of using enough material, and no more. The team believe that by using innovative digital tools and techniques to optimise the shape and reinforcement at the design phase, as well as using robotics to create bespoke formwork and reinforcement during construction, a new generation of buildings will begin to dominate – buildings that use material only where it is needed, and that are manufactured in safe, quality-controlled and highly productive off-site facilities.

"Something as simple as allowing beams, columns and floor slabs to have the shape they need to take load, rather than the shape they need to be easily formed, allows a complete rethink of the way material is used in our buildings," said Dr Orr. "We can begin to ask exciting questions about their shape, what material they should be made from, how we can take into account whole-life value and how we should organise our design processes to take advantage. ACORN will answer all of these questions."

Dr Paul Shepherd, Principal Investigator and Senior Lecturer in the University of Bath's Department of Architecture and Civil Engineering, said: "ACORN is tackling the UK government's construction 2025 targets head-on. By automating construction, moving it off-site, and developing a culture of using just enough material, and no more, the project will lower costs, reduce delivery times and dramatically reduce carbon emissions."

ACORN is supported by 12 project partners: AECOM Ltd (UK); AKT II; Arup Group Ltd; Building Research Establishment Ltd; Buro Happold; Byrne Bros; Cambridge CSIC; Foster and Partners; Laing O'Rourke Ltd; McKinsey and Company UK; OPS Structural Engineering and Tonkin Liu.

To ensure the ideas of ACORN are taken up by industry, the partners will share their practical knowledge of the latest industry trends and will provide case studies on which to benchmark the research.

> Something as simple as allowing beams, columns and floor slabs to have the shape they need to take load, rather than the shape they need to be easily formed, allows a complete rethink of the way material is used in our buildings.
>
> Dr John Orr

http://automated.construction

ALUMNI UPDATE

Dr Anna Young

Dr Anna Young studied Engineering at Cambridge and stayed on to do her PhD. She then received the Maudslay-Butler Research Fellowship, moving on to a Senior Research Associate role in the Centre for Doctoral Training in Gas Turbine Aerodynamics at the Whittle Laboratory. She is now a Lecturer in Mechanical Engineering at the University of Bath.

Tell us about your journey to Cambridge

I did A-Levels in Maths, Further Maths, Physics and History. Between my AS-Levels and A-Levels I did the EDT's Headstart, which is a week-long taster course for people considering studying Engineering at university. After leaving school, I did the RAEng's Year in Industry Scheme at Southeastern Trains in London. I studied Engineering at Cambridge from 2004-2008.

What was life like in the Whittle Laboratory?

I ended up doing my final year research project in the Whittle Laboratory, studying aero-engine compressor stall. I enjoyed my final year project more than the industrial placements I'd done, because of the opportunity to look more deeply at a problem, and so I stayed on to study the same thing for my PhD, which I finished in 2012.

What I enjoyed most about the Whittle Laboratory was the sense of community. While the academics all run their own research groups, there is a lot of collaboration and sharing of ideas. The Laboratory runs on tea/coffee, and teatime officially happens at 11am and 4pm every day. This is a good chance for staff and students to talk informally about research (when you've been banging your head against a brick wall all morning, it's often the case that you come to tea and find someone else has a piece of kit or a bit of code that will solve your problem. It's also a good chance to fill up on cake to celebrate/commiserate with someone on their latest prize or broken piece of equipment).

After my PhD, I got the Maudslay-Butler Research Fellowship, which enabled me to stay on at the Whittle Laboratory for a further three years. I also got some funding to run a large project on improving the reliability of tidal turbines. This might sound like a strange move from aero engines, but the physics involved is the same – aerofoils spinning through a fluid and adding/removing power to a flow.

I moved from the Research Fellowship to a Senior Research Associate role in the Centre for Doctoral Training (CDT) in Gas Turbine Aerodynamics at the Whittle Laboratory, which was a mix of research and teaching. Through hosting the CDT, the lab has grown a lot and the students really benefit from getting to see research in Oxford, Cambridge and Loughborough during their MRes year, as well as interacting with all four of the industrial sponsors (Rolls-Royce, Mitsubishi Heavy Industries, Siemens and Dyson). They have a far more holistic view of the power and propulsion research landscape than previous generations of PhD students and they have grown their own network of future leaders in the field. For me, the CDT job was a great opportunity to develop my own research group and to expand my network too.

What contribution to your field are you most proud of and why?

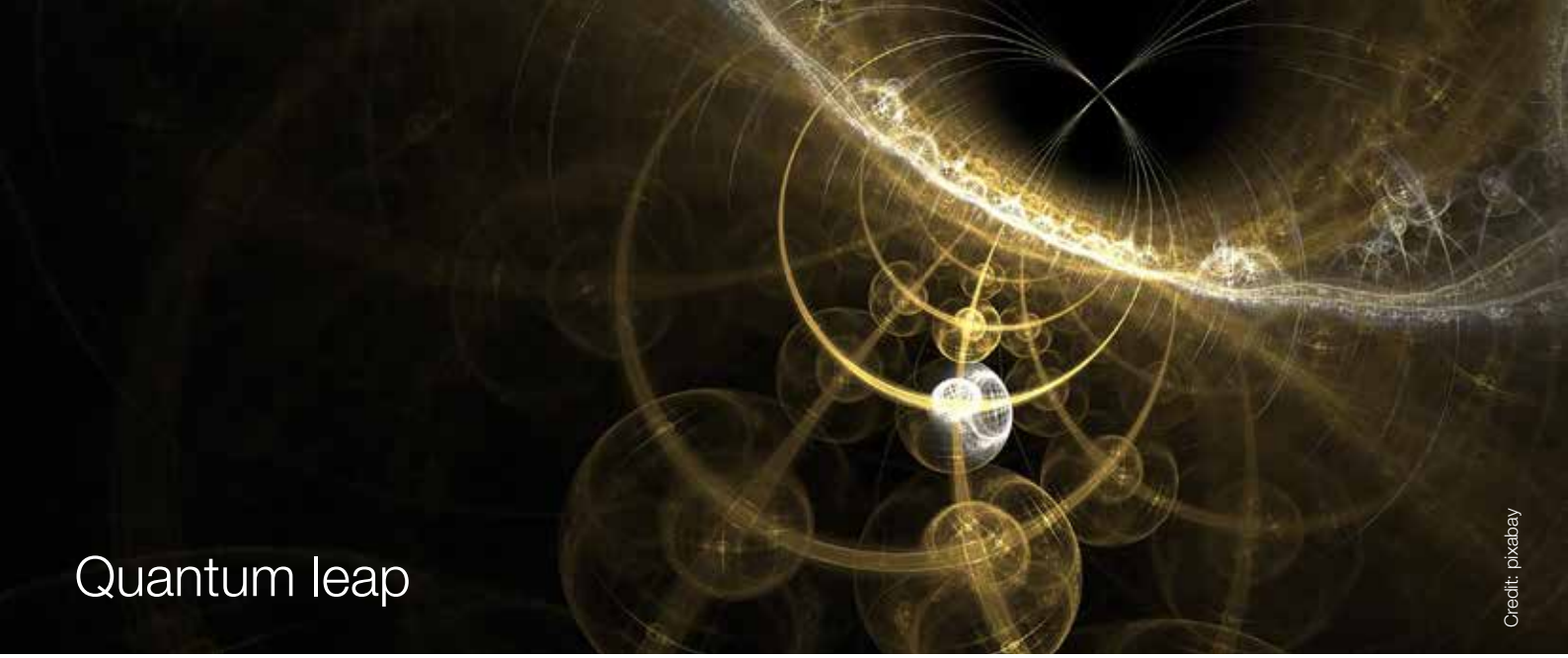
Over the past six years, I have been using my expertise from aerospace to solve problems faced by the tidal power industry. This different perspective has enabled my team and I to come up with novel solutions. For example, we've used aerospace techniques to develop a new probe for measuring the turbulence at tidal sites that is cheaper and more accurate than the state-of-the-art marine device. We've also shown that the fatigue loading on a turbine can be reduced by using flaps like those found on aircraft wings.

What do you see as being the next big thing in your field?

In aerospace, there's going to be a lot of disruption from urban air vehicles and new propulsion technologies to meet emissions and noise targets. Tidal power is a very new industry and I'm excited to see the MeyGen project in Scotland going ahead. This will be the first large-scale commercial tidal power farm and should be built over the next five to 10 years.

What advice would you give to someone who wanted to follow in your footsteps?

Do it! Engineering is a great career and there are lots of different options. Try things out, get some work experience, go on some taster courses, get a Raspberry Pi and see what you can make it do. That way, you'll see what you enjoy (and what you don't), and you can set the direction of your career towards things you most enjoy.



Credit: pixabay

Quantum leap

Cambridge researchers are devising new methods to keep sensitive information out of the hands of hackers. They launched the UK's first 'unhackable' network – made safe by the "laws of physics" – in 2018.

When buying an item online, we voluntarily hand over our credit card information. But how do we know that it's safe? Most sensitive information sent over the internet is secured through encryption, a process that converts information into a code that can only be unlocked by those with the encryption key. Currently, encryption keys are essentially impossible to break with conventional computing equipment – it would simply take too long and too much computing power to do the mathematical calculations that could reveal the key.

But in the coming decades, all that could change. Google, IBM and many other companies are all working to build a quantum computer that would outperform contemporary computers by taking advantage of the ability of subatomic particles to exist in more than one state at a time. A quantum computer could enable us to make calculations and solve problems that are well out of reach of even the most powerful supercomputers, but in the wrong hands, they could also crack encryption keys with relative ease.

So how can individuals, corporations and governments keep information safe in the face of this potential threat?

Our researchers are working to defend against the security threats posed by quantum computers by developing 'unhackable' encryption keys hidden inside particles of light, or photons, and sent over optical fibres.

Quantum keys are generated randomly through quantum mechanics, taking advantage of a property of photons that prevents them being cloned. The real strength of quantum links, however, is that if an attacker attempts to intercept the key, the quantum state of the photons changes and they cannot be used as part of the key, rendering the information carried by the stolen photons worthless.

"This means that we can send single photons over our networks and end up with keys at each end which are fundamentally secure," says Professor Ian White, Head of the Photonics group in the Department of Engineering.

In June 2018, Professor White and his colleagues Professor Richard Penty and Dr Adrian Wonfor started putting these ideas into practice with the launch of the UK's first quantum network. The 'metro' network provides secure quantum communications between the University's Electrical Engineering Division in West Cambridge, the city centre and Toshiba Research Europe Ltd (TREL) on the Cambridge Science Park. It was built with corporate partners including ADVA and Toshiba.

The network has since been extended and connected to other sites around the country, including BT's research and development centre in Ipswich, and is currently being extended to the National Physical Laboratory in London and the University of Bristol, creating the first UK quantum network – a project of the Quantum Communications Hub, a consortium of eight UK universities led by the University of York, as well as private sector companies and public sector stakeholders.

"This network provides us with a UK facility where we can test ideas that until now have been research-based, and to get users used to the concepts behind quantum communications so they can translate this technology into practice," says Professor Penty. "There's a world of difference between transmitting quantum keys over a coil of fibre in the lab and actually putting it in the ground."

The network has the highest quantum key rate in the world. This secures a data network in Cambridge that runs at roughly five times the capacity of the entire University network, and the link to BT in Ipswich operates at five times that again. The link to BT is comparable with the highest data capacity links in the UK, and has the possibility for scale-up in future.

"For us, it's really important to get this right as it's our first chance to start doing very detailed studies and see how these systems really work in the field," says Professor White. "This is only the start, however."

In addition to the continued growth and development of the quantum network, the researchers are also investigating other ways that quantum technology could be used to secure information.

The Cambridge group, along with several other academic and industrial collaborators, have recently secured several parallel funding bids from Innovate UK to develop both lower cost terrestrial and space-based quantum communications.

"The main thrust of all of this work has been to develop technologies that can be commercialised and put into regular use," says Professor White. "Cybersecurity is such an important issue, and we think that the laws of physics can be used to make our data transmission as secure as possible."

Predicting fruit harvest with drones and artificial intelligence

Outfield Technologies is a Cambridge-based agri-tech start-up company which uses drones and artificial intelligence, to help fruit growers maximise their harvest from orchard crops.

Outfield Technologies' founders Jim McDougall and Oli Hilbourne have been working with PhD student Tom Roddick from the Department's Machine Intelligence Laboratory to develop their technology capabilities to be able to count the blossoms and apples on a tree via drones surveying enormous apple orchards.

"An accurate assessment of the blossom or estimation of the harvest allows growers to be more productive, sustainable and environmentally friendly", explains Outfield's commercial director Jim McDougall.

"Our aerial imagery analysis focuses on yield estimation and is really sought after internationally. One of the biggest problems we're facing in the fruit sector is accurate yield forecasting. This system has been developed with growers to plan labour, logistics and storage. It's needed throughout the industry, to plan marketing and distribution, and to ensure that there are always apples on the shelves. Estimates are currently made by growers, and they do an amazing job, but orchards are incredibly variable and estimates are often wrong by up to 20%. This results in lost income, inefficient operations and can result in substantial amount of wastage in unsold crop."

Outfield's identification methods are an excellent application of the research that PhD student Tom Roddick, supervised by Professor Roberto Cipolla, is working on. Tom is part of the Computer Vision and Robotics Group which focuses on solving computer vision problems by recovering 3D geometry, modelling uncertainty and exploiting machine learning. Much of the recent research within the group concentrates on the development and use of modern deep learning methods, and in particular convolutional neural networks (CNNs).

CNNs are computational algorithms designed to recognise visual patterns in data. They consist of millions of artificial 'neurons' which process visual data in a manner very loosely inspired by real neurons in the brain. Such systems 'learn' to identify patterns by being shown huge numbers of labelled examples, rather than being programmed with task-specific rules.

During his PhD, Tom has been working on autonomous driving, looking at street scenes captured on camera, annotating and labelling each element. He pinpoints where the cars are, the pedestrians, the kerb etc. To do this he uses a deep learning technique called semantic segmentation, based on the pioneering SegNet algorithm developed in the group, to label each individual pixel to give a high-level understanding of what is going on in the scene. Outfield need to identify apples and blossom in their orchard photographs and one way to do that is to use this semantic segmentation method.

Another aspect of Outfield's data collection method is to pinpoint where their drones are at all times and there is another strand of computer vision that concentrates on localisation, working out where you are in the world and what you are looking at. Alumnus Kesar Breen, independent machine learning and computer vision consultant, has taken time out of his busy schedule to advise Jim and Oli. Kesar has helped them with an overview of the technologies that they could be using for the orchard modelling and analysis to find out where the crops are, and drafted a potential algorithm to do this, with time frames and requirements. Kesar says, "Outfield is doing some very cool stuff working with some interesting but proven technologies, on an important business problem. I think it is very likely to be commercially viable."

Talking about his work with Outfield, Tom says, "Outfield's semantic segmentation needs have some very specific subtleties that are very interesting from a research point of view for example. I am used to looking at images to identify large objects such as cars, which are easy to spot, but what Outfield has are these huge aerial view images of orchards that are millions and millions of pixels and it wants to detect each blossom flower or each piece of fruit to calculate how many of them there are. I have been looking at how to do that efficiently and robustly to be able to distinguish between things like; is this an apple on a tree? Or is this an apple on the ground?"

Jim says, "The UK has some of the best technology and the best technology scientists in the world. We are currently beta testing, which includes using the model with crops other than apples.

"We have a robust plan for the next two to three years, and we are opening an investment round in October 2019 to close in Q1 2020. This will allow us to bring onboard more of the team full time and test the products out at scale in New Zealand and the UK over the next year."

https://outfield.xyz

Credit: Simon Connellan on Unsplash

→ Ed Clancy, Geraint Thomas, Steven Burke and Peter Kennaugh take off in the Team Pursuit at London 2012

Cambridge engineers are going for gold at Tokyo 2020

Professor Tony Purnell discusses Cambridge's contribution to Olympic success and the wider potential of their findings from the track.

Professor Purnell, Visiting Professor in the Department of Engineering, is also a Fellow-Commoner in Engineering at Trinity Hall, former Team Principal of the Jaguar Formula One motor racing team and has been Head of Technical Development at British Cycling since 2013.

"I use technology in any way possible to make the Olympic team quicker, that's basically my role," he said. For some of his students, their fourth-year engineering project can quite literally help Team GB go for gold. "The work the students do really does translate into Olympic success, so I think the projects have a glamorous end game."

"There were significant contributions to the Rio performance from Cambridge academics and students," said Professor Purnell. Team GB's cycling performance in 2016 was enormous. "I think every time trial in the velodrome was an Olympic record, every rider from the British team that went to the velodrome won a medal – it was outstanding. But now I'd argue we probably overdid it, because the rest of the world has woken up to the fact that an engineering approach works in cycling. We're going to have to do something pretty special in Tokyo to keep that technical lead."

The road to Tokyo

With the success of Rio at the back of everyone's minds, the road to Tokyo has been scattered with obstacles. Last year's press coverage impacted sponsorship, which has affected Professor Purnell's role. "We had a massive delay in some of the financials and new regulations means we've had to halve our development period," he said. "To balance that compared to Rio we're working much more as a team for Tokyo. A lot of the stuff we're doing this cycle won't work without the coaches and riders getting involved."

"Engineering is difficult and when you're doing something for the first time it's especially difficult, because stuff goes wrong," he said. "This time around we are doing some genuinely new approaches and of course things are going wrong left, right and centre – it's hard, but it's definitely fun because we're really trying to break new ground. I'm utterly blessed to have the team we've got and I'm fanatical about delivering what we've invented.

"The University is like a vortex. Professor Keith Glover from the Department of Engineering called me up and asked if I could do a lecture, then another, then a position came up and you say yes and then you get sucked in, but I really enjoy it. I've met people who know nothing about cycling but are experts in dynamics or structures. That's one of the joys of being here – you meet people who have real expertise in all kinds of areas. More often than not they'll give you a different way of thinking that you'd never previously entertained."

Professor Purnell's work with the students has earned him the reputation of building his own 'mafia' within cycling. "One student who did a PhD in cycling is now at British Cycling as our analyst, another PhD student is doing jaw-dropping work, we've got ex-Cambridge people involved in the consultancy companies we use. There's a strong and healthy follow-up rather than just being a project that's done and forgotten."

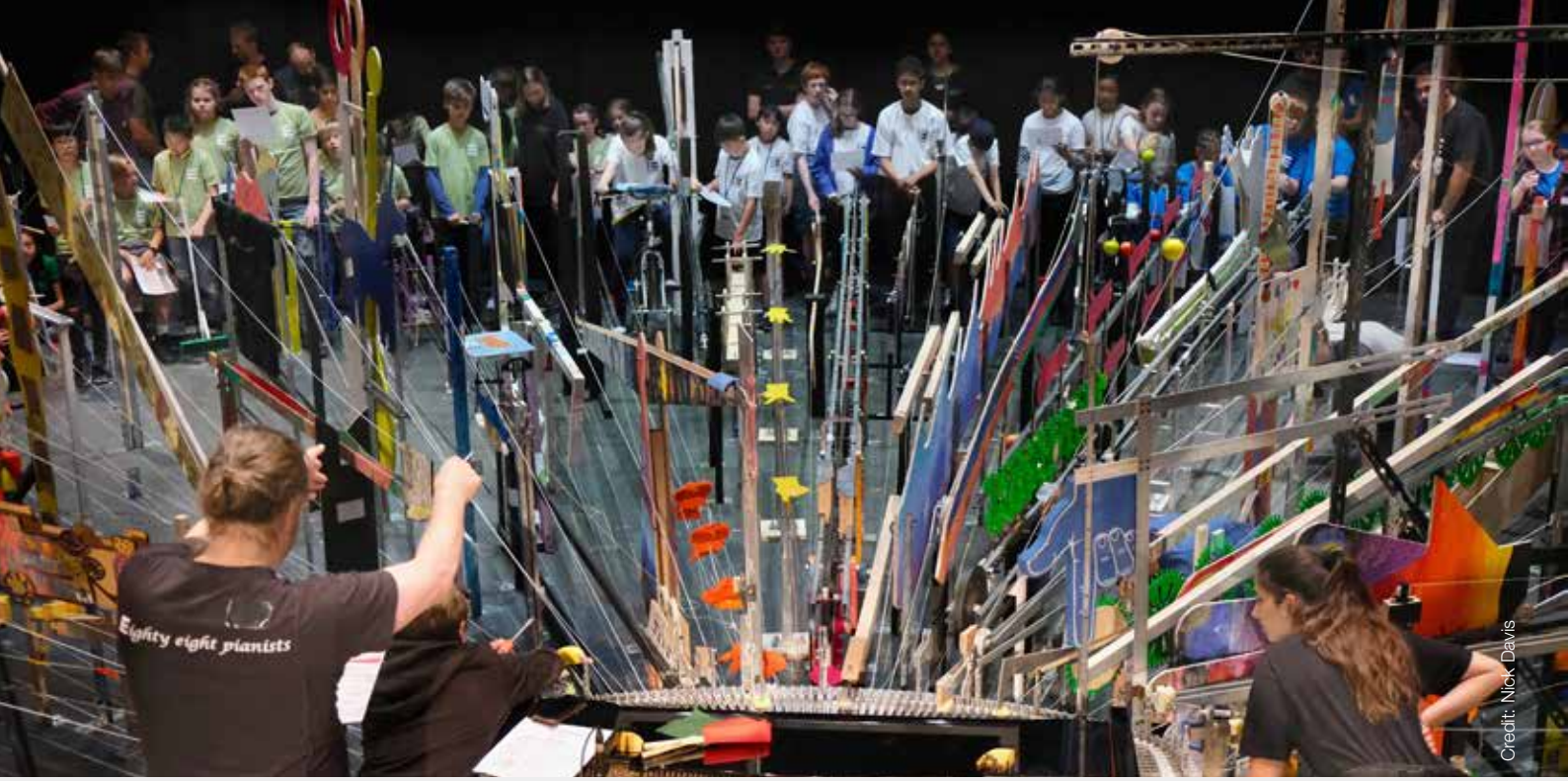
Engineers change the world

The cycling industry has pushed engineering to its limits in recent years, moving constantly towards efficiency. "We could disseminate everything we've learned from cycling to low-speed vehicles, wind turbines, systems design and road traffic controls," said Professor Purnell. "I believe it's engineers who change the world, not politicians."

Despite leading the engineering charge in cycling, he hasn't always been a believer in its power on the track. "When I was a boy, I used to dream of beating one hour for a 25 mile time trial. Then I got this job and knew it was time to take aerodynamics seriously. I started racing again in my early 50s and went from struggling to do it in an hour, to doing it seven minutes under, all with the same power. That was when the penny dropped that aerodynamics is important. Members of the University Cycling Club are doing 25 mile time trials regularly in under 50 minutes. They're not genetically superior to 10 years ago – it's a change in the mentality, the kit and our understanding of the sport."

With Rio's success behind him and Tokyo lying ahead, Professor Purnell is aware they're reaching a tipping point in just how much more they can do. So what's the next big thing? "I think there's masses still to do with training methods to get the most out of each human. The future will be that people keep emerging who are outliers, and they'll be really good. Couple this with engineering and we'll see records tumble for some while yet."

Written by Annabel Nicholson



Credit: Nick Davis

Universities and school children combine art and engineering to smash world record

↑ View from the piano

The world record for the number of people playing the same piano at the same time has been broken by 88 primary school children, as part of a project thought up by Cambridge engineers.

On August 19, the University of Cambridge, along with nine other UK universities, assisted the children, aged between six and 14, in smashing the world record during a performance called 88 Pianists held at the ICC in Birmingham. As there are 88 keys on a piano, it was decided that there would be 88 individual players – one for each key – to ensure that the record they set would never be broken. The previous world record stood at 21 people. Set up by the University of Cambridge to commemorate the 500th anniversary of Leonardo da Vinci, the record-breaking performance – judged by Professor Julian Lloyd Webber – required 88 inventions that would allow each player to reach their individual piano key from seven metres away.

Credit: Nick Davis

↑ Mathilde, age six, from Leeds, performing

Engineers from each of the 10 universities worked with primary schools from across the UK to design and build the mechanisms.

What began as a project to inspire future engineers, quickly developed into leading engineers being inspired by the imaginations of 2,500 children. From flying rabbits, to ballerinas, giraffes and trains, the children's inventions were used to play a specially-composed piece of music written by Martin Riley, which used the DNA of da Vinci himself. The performance was supported by the Royal Birmingham Conservatoire, part of Birmingham City University, and in the audience were more than 500 leading engineers from around the world, who had gathered together for their annual meeting.

Professor Julian Allwood, Project Creator from the University of Cambridge, said: "I'm so proud of the collaboration that led to this world record. Watching 88 children performing on stage, with one of the key engineering team behind each group of four to support them, and knowing the stories behind each of the amazing mechanisms, the performance was, for me, a summary of a year's joyful teamwork.

"I'm really captivated by the opportunity that this project has revealed to explore the space for expansive imagination between the creative arts and technology. The reaction from the audience was overwhelming. To my surprise, the statement I heard most often, from what I thought were my hard-headed academic colleagues, was that they were moved to tears. The children's achievement in designing and delivering 88 Pianists was always joyful, but it seems also to have sounded a profoundly emotional chord."

Professor Julian Lloyd Webber, Principal of the Royal Birmingham Conservatoire, said: "This was a truly fantastic collaboration between engineering and music. The imagination of the children involved was astonishing and has to be seen to be believed. Royal Birmingham Conservatoire is so proud to have collaborated with the University of Cambridge on this world record-breaking project, which has yet again proved that music empowers children."

www.88pianists.com

Credit: Canadian Space Agency

Cambridge engineer supports next steps in lunar exploration

Cambridge engineer and Canadian astronaut Dr Jenni Sidey-Gibbons will join colleagues at the Canadian Space Agency (CSA) in a project that will see humans return to the Moon.

Earlier this year, it was announced that Canada had formed a new partnership in the NASA-led Lunar Gateway – an international collaboration in human space exploration. About one-fifth the size of the International Space Station (ISS), it will orbit the Moon and will provide living space for astronauts, a docking station for visiting aircraft, and laboratories for research. Canada's contribution to the Gateway will be a smart robotic system – Canadarm3 – that will repair, maintain and inspect the Gateway. It will move equipment, support spacewalks, assemble and deploy scientific instruments, and handle scientific samples collected on the Moon's surface.

Dr Sidey-Gibbons was recruited to the CSA as a member of the 2017 NASA astronaut class. A Lecturer in Internal Combustion Engines at the University of Cambridge, she is one of the Department of Engineering's ambassadors for Engineering Diversity and helped form Cambridge Robogals in 2014, an international, not-for-profit, student-run organisation that aims to increase female participation in STEM.

"With the announcement that Canada will be a part of NASA's Lunar Gateway project, I feel excited and hopeful for our space programme," said Dr Sidey-Gibbons. "Not only will we have the opportunity to take Canadian concepts to the Moon, but we will benefit from the science and technology we develop to help get us there. Personally, I feel ecstatic at the opportunities in front of us. Going to the Moon in the Apollo era changed what we thought was possible. Returning to the Moon in a sustainable capacity will do the same."

A CSA spokeswoman added: "Canada's anticipated benefits in participating in the Gateway and Lunar programme will ensure a bright future for Canada's astronaut programme by securing flight opportunities for our current and future astronauts. It will also allow the Canadian science community to perform scientific investigations around and on the surface of the Moon, and to test cutting-edge technologies in the harsh environment of deep space and radiation."

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>
> Dr Jenni Sidey-Gibbons

www-engineeringdiversity.eng.cam.ac.uk

Credit: Jaq Saggers

Design Project Office computer upgrade underway thanks to generous donation

↑ Students at the new dual monitor work stations

Thanks to the generous support of alumna Helen Morton, the Department has been able to upgrade the facilities in the Design Project Office (DPO), and work is in progress to add an extra computer monitor and stand to all 84 workstations.

The DPO is one of the Department's largest and most heavily used learning spaces. It is used to teach classes of around 80 undergraduates drawing, design and computing in the first two years of their course. Smaller classes also use the space, particularly for outreach work.

The DPO is also a popular place for students to work on group projects, both as part of their course, and for external activities, for example the student-led societies such as the Cambridge University Eco Racing (CUER) team. Organisers of events, such as Hackathons, are also keen to make use of the facilities.

Mark Thompson, DPO Manager, is tremendously enthusiastic, and is constantly striving to make the DPO a pleasant and functional working environment.

All workstations in the DPO were initially equipped with a single computer monitor and stand, but it was noticed that students were gravitating towards computer facilities in the Department which provided dual monitors, allowing them to access help pages, data sources or other applications, whilst simultaneously working on the task in hand.

The dual monitor facilities installed so far are proving enormously popular with staff and students alike. Students are using the upgraded workstations for extracurricular individual team and project work, alongside their academic work.

As the Department's teaching methods evolve towards more self-directed learning supported by online resources and forums, the additional monitors will enable this, allowing students to work at their own pace, and with flexible timeframes.

Professor Richard Prager, Head of Department, said: "This upgrade directly benefits the students every time that they work on computers in the DPO. We always encourage our students to draw large, clear diagrams and, among many other benefits, this upgrade will make it easier for them to do so when they are using CAD software. We are very grateful indeed to Helen Morton for the thoughtful and generous way that she supports our students and the undergraduate engineering course more broadly."

↑ Helen Morton

If you are interested in supporting research, teaching and the next generation of engineers, please contact Georgina Cannon, Director of Development, by emailing georgina.cannon@admin.cam.ac.uk

Honours, awards and prizes

Future Leaders Fellowship

Dr John Biggins, Lecturer in Applied Mechanics, has been announced a recipient of the UK Research and Innovation's (UKRI) first Future Leaders Fellowship.

Dr Biggins is among 41 new fellows who will each benefit from a share of £40 million towards cutting-edge research over the next four years. He is designing soft, stretchy machines powered by artificial muscles rather than electric motors; technology that could benefit miniaturisation.

Young Engineer of the Year

Dr Giorgia Longobardi has been named RAEng Engineers Trust Young Engineer of the Year.

Dr Longobardi, co-founder and CEO of Cambridge GaN Devices Ltd (CGD), a spin-out from the Department, was picked as one of five young female engineers by the Royal Academy of Engineering (RAEng) who have been outstandingly successful in their respective fields at an early stage of their careers. She received a £3,000 prize.

New professorship

Professor Mark Girolami has been elected to the Sir Kirby Laing Professorship of Civil Engineering.

He will provide academic leadership for the Centre for Digital Built Britain (CDBB) across the University and more broadly throughout the national and international research communities. The CDBB is a partnership between the Department of Business, Energy & Industrial Strategy and the University of Cambridge to understand how the construction and infrastructure sectors could use a digital approach to better design, build, operate, and integrate the built environment.

Entrepreneurial competition winner

Congenita, a start-up tackling heart defects in newborn babies, has won the Medical Technology (MedTech) Venture Competition developed by the Cambridge Judge Entrepreneurship Centre.

Engineering PhD student Dante McGrath (pictured) is co-founder of the start-up which has designed software to create personalised 3D models for surgeons to correct congenital heart defects in newborn babies. The company was awarded first prize of £10,000.

Pilkington Prize winner

Dr Cesare Hall has been announced as one of the winners of the 2019 Pilkington Prize.

He was voted best Part 1A lecturer in the Department for two years running, and is known for his fun and accessible thermodynamics lectures featuring live experimental demonstrations. His research, on new propulsion technology to reduce emissions from aircraft, features heavily in his teaching. He is also committed to access and outreach and regularly delivers engineering masterclasses and admissions talks.

Fellowship announced

Dr Ruizhi Wang from the Centre for Advanced Photonics and Electronics (CAPE), has been awarded a Royal Academy of Engineering Enterprise Fellowship.

The Fellowship will enable him to further establish and grow his spin-out company HexagonFab, which is using 2D materials to develop next-generation biosensors for industrial and medical applications.

Speech recognition expert honoured

Professor of Information Engineering, Mark Gales, has been elected a Fellow of the International Speech Communication Association (ISCA).

This is in recognition of his "*wide-ranging, fundamental contributions to research and leadership in the fields of speech recognition, synthesis and statistical modelling algorithms*".

Award-winning tech

Fibre optic sensing systems designed by Cambridge Centre for Smart Infrastructure and Construction (CSIC) have won the Best Use of Technology Award at the Rail Partnership Awards.

Designed and trialled for the 30m-deep cutting slopes at Hooley, near Croydon, the systems use the rate of strain change produced by rockfall in the debris-collecting mesh to help identify and predict problematic areas before they lead to mesh failure.

Credit: pixabay

↑ Demonstrating a virtual reality headset

Engineers' printed transistor unlocks potential for portable real-time sensing

Cambridge engineers have developed a high performance printed transistor with flexibility for use in wearable and implantable electronics.

A transistor is a semiconductor component used to work as an electrical switch and/or to amplify current, allowing the current flowing through it to be controlled by an electrical signal.

The researchers' inkjet-printed transistor is sensitive enough to accurately detect electrophysiological signals from the skin when used in conjunction with a wearable device.

In the virtual environment, for example, the tracking of subtle eye movements by electro-oculography is needed for a better, more realistic depiction which relies on, for example, depth of field rendering. Compared to other thin film technologies such as silicon or metal oxides, the transistor's power consumption is one thousand times less and the signal-to-noise ratio one hundred times better.

The results, reported in the journal *Science*, demonstrate the potential of using low-cost inkjet-printing technology to directly integrate biomaterials with electronics, in order to create new applications at the forefront of the electronics-biology interface, such as the tracking of eye movements in virtual and augmented reality.

"This is the first time such a high performance printed transistor has been achieved that demonstrates good reliability over several months, without changing characteristics," said Dr Chen Jiang, the paper's first author, formerly from the Electrical Engineering Division of the Department of Engineering. "This transistor improves upon typical organic transistors that have a lower level of reliability of just a few days or even a few hours." In 2018, Dr Jiang was awarded the IEEE Electron Devices Society PhD Student Fellowship to promote and support electron devices research.

Dr David Hasko, the paper's co-author from the Department of Engineering, said: "This application demonstrates a further example of how it is possible to fabricate a whole circuit using just a single, highly affordable, inkjet printing tool that puts a fabrication plant within reach of most university departments. It would be an excellent way of introducing, for example, design rules and micro-fabrication in a practical way."

Professor Arokia Nathan, the former Chair of Photonic Systems and Displays in the Department of Engineering, who led the research, added: "The outcome of this research is very exciting. A close-to-ideal performance of largely design-rule independent transistors and circuits is the quintessential demonstration of how to achieve a low power, high signal resolution analogue sensor interface using low-cost, simplistic printing technologies." Professor Nathan is now an entrepreneur managing his own high tech start-ups.

Professor Manohar Bance, Chair of Otology and Skull Base Surgery, University of Cambridge and Honorary Consultant, Cambridge Universities Hospitals Foundation Trust, said: "This technology represents a major step forwards in efficiently and accurately measuring biological signals. The future will include real-time measurement of signals from many biological systems and their incorporation into monitoring real-time motor assistance and diagnostics. The interface between biology and electronics is a fundamental area to develop to realise this future."

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