InspiredResearch Winter 2014 Issue 5

News from the Department of Computer Science, University of Oxford

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University of Oxford

Department of Computer Science

InSpired Research…

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NEWS

GCHQ certifies MSc in Software and Systems Security

The certification of six Master's degrees in Cyber Security, including the one from Oxford, was announced by Rt. Hon Francis Maude MP, Minister for the Cabinet Office, in August. The certification process forms part of the National Cyber Security Programme, and the assessment was based on the expert views of industry, academia, professional bodies, GCHQ and other government departments.

Certification represents GCHQ's acknowledgement that the MSc 'provides well-defined and appropriate content, delivered to the highest standard'. Students completing the MSc who satisfy the GCHQ requirements in terms of module choice will receive an additional certificate confirming that they have completed a 'GCHQ-certified Master's degree in Cyber Security'. Certification will assist employers to differentiate between candidates when employing cyber security staff.

The other universities fully certified by GCHQ for Cyber Security Master's degrees are Edinburgh Napier University, Lancaster University, and Royal Holloway, University of London. Provisional certified status was awarded to Cranfield University and the University of Surrey.

Sir Nigel Shadbolt to become Principal at Jesus College

Sir Nigel Shadbolt will become the first computer scientist to be a College Principal at Oxford when he takes on the role at Jesus College.

When Nigel takes over from Lord Krebs as Principal of Jesus College in August 2015, he will continue his scientific research, taking up a professorship in Oxford's Department of Computer Science. Here, he will carry on leading the SOCIAM (the theory and practice of social machines) project, remain Chairman of the Open Data Institute and continue to advise the UK Government.

Nigel is currently Professor of Artificial Intelligence, based at Southampton University. In 2009, he began advising the government across a range of data-related topics. In 2012, he co-founded the Open Data Institute with World Wide Web pioneer Sir Tim Berners-Lee. Nigel was knighted in the Queen's Birthday Honours in 2013 for his service to science and engineering.

Sir Tony opens refurbished Robert Hooke Building

Former Head of Department, Professor Sir Tony Hoare, and his wife, Lady Jill Hoare, formally opened the newly refurbished areas of the Robert Hooke Building on 15 January.

The building was refurbished to house the Doctoral Training Centre in Cyber Security, and the teaching and social space for the Department of Computer Science. These now sit across two floors of the shared building, just a few minutes' walk from the main Wolfson Building.

Preceding the formal opening, Sir Tony gave a seminar entitled 'The unreasonable power of algebra'. The talk, given in the seminar room bearing his name, was very well attended with the overspill audience following via videolink in the adjacent room. A reception was then held in the central ground floor area of the building with speeches by Professors Bill Roscoe and Alex Halliday, Heads of Department and Division, respectively.

Oxford Prof among top 10 inspirational leaders

Sadie Creese, Professor of Cybersecurity at Oxford, *(pictured right),* has been named as one of the UK's top 10 most inspirational scientists and engineers for 2014 by the Engineering and Physical Sciences Research Council (EPSRC).

The Council announced the ten RISE (Recognising Inspirational Scientists and Engineers) leaders as part of a campaign, in partnership with the Royal Academy of Engineering, to celebrate the incredible innovation from recent decades and, in particular, the researchers who led it. The RISE leaders are to be paired with individuals from government, business or media to communicate the importance and impact of their research, helping their partners to become champions for science.

Sadie, a Fellow of Worcester College, Oxford, is engaged in a broad portfolio of cyber security research spanning cyber security policy, situational awareness, security metrics, visual analytics, risk propagation prediction and communication, threat modelling and attack detection, network defence, dependability and resilience, and formal analysis. Previously, Sadie was Professor and Director of e-Security within the University of Warwick's International Digital Laboratory, and worked at the defence company, QinetiQ.

The leaders were asked to nominate researchers who they see as 'Rising Stars', tipped to lead internationally excellent research in the future. Sadie nominated Dr Jason Nurse, a postdoctoral researcher in the Oxford Cyber Security Centre, working on the Identity Security in Cyberspace, and the Corporate Insider Threat Detection: Cyber Security Inside and Out research projects. He also acts as a lecturer and teaching assistant within the Centre for Doctoral Training in Cyber Security.

Jason, *(pictured left below),* now a Junior Research Fellow at Wolfson College, Oxford, previously completed a PhD in Computer Science at the University of Warwick, an MSc in Internet Computing from the University of Hull, and a BSc in Computer Science and Accounting from the University of the West Indies. He attended the final RISE award ceremony with Sadie on 10 June at the House of Commons.

Most Influential

Professor Sadie Creese has also been named by Debrett's as being one of the 500 most influential people in Britain in recognition for her work in cyber security. She is one of only 20 people recognised in the technology sector by Debrett's, a luxury lifestyle brand, and a source of recognition of achievement and influence, as well as etiquette and style.

Photos courtesy of EPSRC

Doctorate to put UK ahead in intelligent autonomy

Our society will be revolutionised in the next decade by autonomous, intelligent machines and systems, according to the Oxford team running a new doctoral training centre in these technologies.

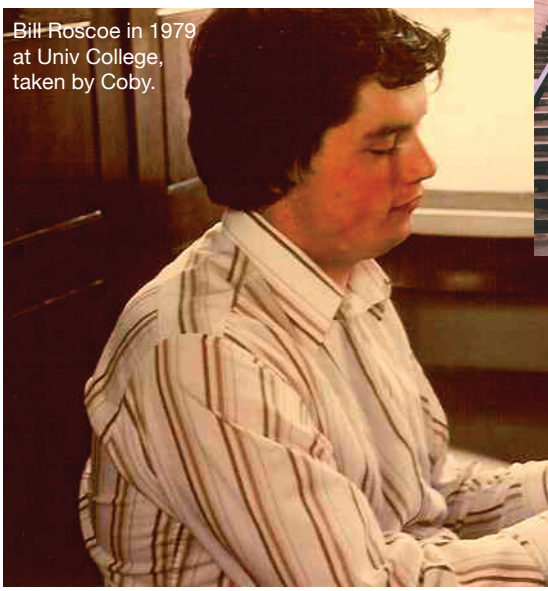
The EPSRC Centre for Doctoral Training in Autonomous Intelligent Machines and Systems (AIMS) is opening its doors in October to its first cohort of students. Their four-year DPhils (PhDs) are fully funded by the UK's Engineering and Physical Sciences Research Council (EPSRC) and industrial partners. By offering training now, the UK has the opportunity to become a world leader in developing these technologies for sectors such as energy, transport, manufacturing and aerospace.

The Centre brings together AIMS-related expertise from two departments, Computer Science and Engineering Science, creating the first programme to combine theoretical and systems training in all four AIMS themes: robotics, vision and perception; machine intelligence and multi-agent systems; control and verification; and pervasive networked sensing and actuator systems.

The programme is led by the Centre for Doctoral Training Directors, Professor Stephen Roberts of the Engineering Science Department, and Dr Niki Trigoni of the Department of Computer Science. They are supported by a team of more than 20 academic supervisors and 14 industrial partners.

http://www.eng.ox.ac.uk/aims

End of an era: Bill Roscoe steps down as head


Bill Roscoe in 1979 at Univ College, taken by Coby.

Below is an edited version of a speech given on 4 July 2014 by Bill Roscoe at the dinner given at University College, Oxford to mark his retirement as Head of Department, a role he has held, with a year's break, since 2003.

Since I hope this really is me retiring from my career in big admin jobs, I thought I should concentrate in this speech mainly on that aspect of my career and the influences on it. Or in other words, how did I end up in this job?

I joined the University of Oxford as a Maths undergraduate at University College (Univ) almost 40 years ago in 1975. My main tutors were Michael Collins and Gordon Screaton, both of whom have had huge influences on my life and career, including my admin work. Michael has had much to do over the years with the development of Computer Science at Oxford, not least chairing the committee that set up the Maths and Computer Science undergraduate degree. My first big admin job for this Department was being secretary to Michael's Chairman on this committee, a job which eventually led to me chairing the group that proposed our single honours degree in Computer Science.

My interactions with Gordon, Estates Bursar at Univ until 2001, taught me a lot about how to manage money and accounts. But the most important thing Gordon did for me was to invite me back to Oxford in 1978, the summer between my undergraduate and graduate studies here, to fix his computer.

He had bought the HP in 1977 to run the college's accounts. This was one of the very first desktop computers and cost £15,000 (or the price of a small Oxford house at the time). Whoever had sold it to Gordon had given him a suite of accounting software to go with it, but regrettably there were lots of bugs in this software and it was in any case hopelessly ill-suited to the needs of an Oxford college. So I ended up either re-writing existing software or in some cases starting from scratch.

The HP project was my first experience of developing and maintaining a large piece of software for others to use. This was an invaluable experience for a theoretical computer scientist. Of course it also intensified my training in accounts, financial management and dealing with support staff – all essential attributes for a head of department at Oxford. However the most important part of it for me was that I had to write a rentroll – a database of investment property. Why was this important? It was because I designed it with and for Gordon's secretary Coby, who later became my wife.

I became a College Lecturer for Univ in 1979. At the time our Head of Department (HoD) was Leslie Fox, as he had been since the Department was founded in 1957 a few months after I was born. Since the separation between we computer scientists and the numerical analysts whom Fox led was not only disciplinary but also, until 1982 geographical, he did not impinge much on my life. I became a tutorial fellow here at Univ in 1983, the same year that Fox retired and we entered a period of 16 years during which Tony Hoare and Bill Morton passed the headship between each other almost like a hot potato.

As Senior Tutor of Univ between 1993 and 1997, my romantic enthusiasm for administrative software was further evidenced during this time by my commissioning and substantially writing the teaching database for Univ that was eventually adopted by all colleges until the web-based and utterly unrelated OxCORT took over from it. Fortunately for my marriage, no further romance ensued.

I joined the Mathematical Sciences Faculty Board in the mid-1990s and immediately found myself on its power committee. Little did I realise this, but this put me in the firing line as a potential Board Chairman, and indeed in 1996 Peter Collins, then just becoming Board Chairman, made it clear to me that I should follow him. Arguably that was the biggest step in my admin career, and I hold Peter largely to blame for it.

Being Board Chairman was essentially a friendly bureaucratic counterpoint to the Senior Tutorship I'd just had. One thing I had to do as Board Chairman was organise the selection of a new Head of our

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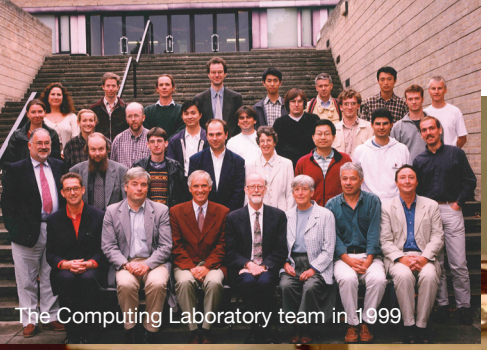
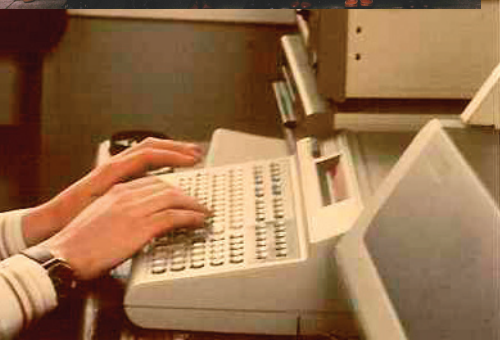


The Computing Laboratory team in 1999



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Department when Tony and Bill retired close together. The choices on such occasions are rarely wide and I found myself basically having to twist Richard Bird's arm. It came as little surprise to me when he twisted my arm in a similar way a few years later – I fear there was little choice.

So that's how I got this job in 2003. My not-so-secret plan in doing it was to rectify the position in which Computer Science was a small department at Oxford when it was a major one at just about every other leading university, and I think the main part of that job is done.

This summer I am handing over to Mike Wooldridge. Given his background in Liverpool he is just as well trained for the job as I was, except in knowing how Oxford works. Actually knowing too much about Oxford can be a disadvantage, because it is more likely to convince you that something is difficult or impossible rather than tell you how to achieve things. So go for it, Mike, cherish your ignorance while you have it! But most of all I wish you luck and the same sort of enthusiastic support from the Department that I have had.

May Oxford Computer Science move on to be ever mightier yet!

Letter from the new Head of Department

An autumnal nip in the air is one of the signs we get used to as academics that a new university year is upon us. As the days begin to noticeably draw in, lectures are planned and prepared, rooms for classes are booked, and the University seems to take a deep breath, ready for the dizzying influx of students. I have witnessed this annual ritual at six universities over the past 30 years; first as a student, and since 1992 as an academic. But for me, this year will be very, very different as I begin the new academic year as Head of Department of Computer Science at the University of Oxford; the first new Head of Computer Science for more than a decade. I am very pleased to report that, by all the indicators I can think of, the Department is in rude good health. We seem to be winning grants and research awards daily, and, as the articles in this issue of *Inspired Research* demonstrate, there is no shortage of innovation.

I should begin by paying tribute to the work of the outgoing Head of Department, Bill Roscoe, who has occupied this position since 2003. A rule of thumb for assessing how well you did a management job is whether you left the place in better shape than when you took over. In Bill's case, the evidence is overwhelming. Over the past decade the Department has been fundamentally transformed from being small and narrowly focussed into a broadly based Department that is routinely ranked as one of the world's leading centres for Computer Science research and teaching. The current size, shape, and direction of the Department is almost entirely due to Bill's energy and enthusiasm. I hope I can do justice to Bill's very substantial legacy in years to come.

Looking to the future, I see many opportunities and challenges ahead. One exciting new development is the appointment of Sir Nigel Shadbolt, the first computer scientist to have been a Head of House at an Oxford college. And in October 2014, we welcome the first intake on our Centre for Doctoral Training in Autonomous Intelligent Machines and Systems, an exciting area for further development and one we hope to build on in years to come.

Another important new direction for the Department is the appointment of Frances Wheare as Development and Alumni Manager. As part of her role, Frances has taken over management of our alumni relations, and we hope that having somebody permanently in this role will enable us to keep in much better contact with all our former students. One event that you may wish to make note of is our inaugural alumni drinks reception, to be held on 4 December in London: see page 11 for details.

I hope this will be the first of many introductions I write for *Inspired Research*, and I look forward to keeping you informed of key developments as they occur. Of course, if you are able to attend the London drinks event in December, I would be delighted to discuss developments with you in person!

Professor Michael Wooldridge
September 2014

Architecture to solve the genome data mountain

The 100,000 genomes programme, which aims to read and decipher the genetic codes of 100,000 NHS patients, is receiving assistance from Oxford Professor of Software Engineering Jim Davies. As chief technology officer, he will define the information architecture. His goal is to sift, analyse and present the huge amounts of raw data to doctors in a way that they can understand.

The UK Government recently announced an investment of almost £300 million in Genomics England, a new initiative to read and decipher the genetic codes of 100,000 NHS patients. The project has the potential to transform the future of healthcare, with new and better tests, drugs and treatment, and to enable further scientific discoveries.

The human genome is the complete set of genetic information for humans, as recorded within DNA. Sequencing the human genome is another way of saying that the genetic code of the DNA molecule is 'read' letter by letter, until all three billion letters are written down in the right order. So, sequencing the genome of a person with cancer or someone with a rare disease – or better still thousands of people – has the potential to help scientists and doctors understand how disease works.

The Human Genome Project, which started in the 1980s and was completed in 2003, produced the first, complete sequence of individual human genomes. Originally it took 13 years and many hundreds of millions of pounds to sequence a full genome, but now it can be done in a few days for less than £1,000.

Now that gene sequencing has become relatively straightforward the real difficulty lies in making sense of the genomic information, and in designing software that can see patterns in the DNA that are too complex for the human eye.

Genomics England, which is wholly owned and funded by the Department of Health, has been set up to sequence 100,000 whole genomes from NHS patients by 2017. The data needed to do this is large and complex: to get to 100,000 genomes, Genomics England will be collecting 10 petabytes of sequence data, and detailed, relevant health data on up to 100,000 people. The genome data is also precious and needs to be stored securely and with rigorous conditions for access.

This 'big data' problem is where Oxford Professor of Software Engineering Jim Davies comes in. He's the chief technology officer for Genomics England, where he is helping to define the information architecture for the UK 100,000 genomes programme.

The raw data from one genome would occupy almost all of the average laptop's memory. Just the annotations would easily fill a DVD by themselves. This mountain of data needs to be sifted, analysed and presented in a way that is helpful to doctors, most of whom will not have specialist knowledge of gene changes.

Jim explains: 'The largest files are those that record the alignments of the reads from the sequencing machines: a whole genome sequence generated from a blood sample (at "30x" coverage) takes up 70 gigabytes, which is 16 DVDs in old money; the file for a cancer tumour sample (at "50x" coverage, or greater) will take up 100 gigabytes or more. Many of the users of the service won't be interested in looking at these files, but we need to keep them around.'

Further information about Genomics England: http://www.genomicsengland.co.uk/uk-to-become-world-number-one-in-dna-testing-with-plan-to-revolutionise-fight-against-cancer-and-rare-diseases/

More from Jim Davies about the big data challenges: http://www.genomicsengland.co.uk/prof-jim-davies-on-the-challenges-of-big-data-for-gel/

Paper tackles breeding rabbits and loop termination

The best paper award at the 41st International Colloquium on Automata, Languages, and Programming, held in Copenhagen this July, was won by Professors Joel Ouaknine and James Worrell for their paper 'Ultimate Positivity is Decidable for Simple Linear Recurrence Sequences'.

Although the paper was motivated by researchers' efforts over the last decade to prove termination of certain types of program loops, it concerns a subject that mathematicians have been studying for well over 1,000 years – linear recurrence sequences.

The most famous linear recurrence sequence is popularly attributed to Leonardo of Pisa, otherwise known as Fibonacci. The sequence of Fibonacci begins 1, 1, 2, 3, 5, 8, 13, 21, 34, ..., with each term being the sum of the two previous terms. Fibonacci introduced this sequence in his 1202 book Liber Abaci to describe a (highly idealised!) population of rabbits.

He assumed that rabbits must be at least one-month old to mate and that each breeding pair produces two offspring every month. Then the population F_n in the n-th month consists of the population F_{n-1} in the previous month and the F_{n-2} offspring from each breeding pair from the previous month. Thus the sequence satisfies the recurrence $F_n=F_{n-1}+F_{n-2}$.

Fibonacci's population of rabbits grows unchecked. A more biologically realistic model, accounting for predators and mortality, could easily be modelled by a more complicated recurrence. However, remarkably, there is no known procedure that, given an arbitrary linear recurrence, determines whether or not it grows to infinity. Fields medallist Terrence Tao said of our inability to systematically determine the long-term behaviour of linear recurrence sequences: 'It is faintly outrageous that this problem is still open!'

Linear recurrences are among the most simply described dynamical systems and are ubiquitous in Mathematics, Computer Science, Biology, and Economics. The ability to systematically determine their long-term behaviour would be an indispensable tool, and the paper by Joel and James gives a procedure that works for 'almost all' sequences. However the research shows that a complete answer to the problem will require significant breakthroughs in an area of number theory called Diophantine approximation.

Relational compression attracts Google funding

The FDB (factorised databases) project led by Dr Dan Olteanu of the Department of Computer Science has been awarded a Google Research Award. Dan will use the funding to investigate how factorised databases can help reduce the communication cost in distributed database systems, such as the F1 system that supports Google's lucrative AdWords business.

Factorised databases exploit algebraic properties of relational algebra and the structure of queries to achieve lossless compression of relational data. Besides achieving much better compression than generic compression schemes for relations representing query answers, factorised data can be queried directly in the compressed domain. Google F1 already factorises its input database to increase data locality for common access patterns and partitions the data across servers into factorisation fragments. The next logical step is to use factorised data for the entire processing pipeline, including temporary results that are frequently repartitioned by the servers.

Factorised representations are useful in further application domains: working with scientists at a US-based start-up called LogicBlox, Dan is looking at scaling machine learning algorithms to very large design matrices represented as factorised relations.

Live programming with Datalog

The Datalog language is central to ongoing research in the Department on query processing, reasoning, and static program analysis. During his recent sabbatical at LogicBlox, Dan contributed to a smart database system with currently scores of commercial applications. The system integrates handling of mixed transactional and analytical workloads, graph analyses, and predictive workloads that involve mathematical optimisation and machine learning, all expressed using a declarative datalog-like language.

One technical challenge addressed by Dan and his LogicBlox colleague Dr TJ Green is efficient handling of updates to datalog programs (rather than source data) on running database servers. This is essential for live programming in the existing LogicBlox applications, where users can alter the program and expect its result to quickly change on the fly. Their solution uses declarative programming to improve the implementation of the declarative system: they introduced an engine for meta-data supporting declarative rules in an object-oriented (again) datalog-like language. Incremental view maintenance in the meta-engine takes care of propagating the effects of program updates correctly and efficiently.

The rise of the friendly drone

Unmanned aerial vehicles (UAVs) on 'friendly' missions, such as delivering packages, need to be able to negotiate environments that are usually unknown to them. As they have no pilot on-board to help them, a research project is aiming to verify the software that runs on any UAV to ensure its safe, reliable, and successful operation. Dr Ashutosh Natraj of the Department of Computer Science explains.

News coverage of UAVs tends to relate their use in the fight against terrorism or other military applications. However, there is increasing interest in friendly UAVs (or drones, as they are sometimes called), which cater for civilian needs, such as for search and rescue operations, delivery of packages, or use as a hobby.

Over the last decade, interest in the field of aerial robotics in general has risen significantly. This rapid growth in interest within industry and academia has been partly due to advances in the technology and miniaturization of the sensors on-board the robots. This has resulted in achieving more autonomy for the robots than ever before, giving birth to this complete new segment of UAVs for civilian and commercial applications. Drones can be classified as civilian purpose UAV, if, and only if, their combined weight and payload capacity is below 7Kgs.

The different types of aerial robots fall into two main sub-classes: fixed wing UAVs, similar to traditional aircraft; and rotor-based UAVs, which resemble a helicopter design. The rotor-based UAVs are named according to the number of rotors used in their design. For example, a four rotor-based copter is called a quad-copter (the most popular design) as shown in figure 1, six rotors a hexa-copter and eight rotors an octo-copter.

Figure 1: Rotor based UAV with four rotor 'quad-copter'

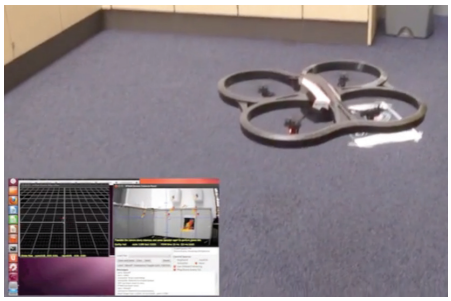

Figure 2: An autonomous UAV performing mapping and localization in an unstructured environment. The software on-board the UAV is now ready for verification to provide reliability in its operation.

The fixed-wing and the rotor-based UAVs each have pros and cons, which influence the choice of platforms for a project. The fixed wing can operate very easily in an open area, can fly to higher altitudes, travels quicker and glides for longer periods of time for less battery power. However, the rotor-based UAVs have their own strengths. They can operate in a confined space, as well as in an open space, and can hover at a single position for as long as required, unlike the winged types. They can also perform vertical take-off and landing (VTOL), crucial for various specific applications in a confined operational envelope. The rotor-based UAVs are therefore an attractive option for various applications.

Rotor-based UAVs are being used for our current research project, 'New Foundational Structures for Engineering Verified Multi-UAVs', at Oxford's Department of Computer Science. It is funded by the Engineering and Physical Sciences Research Council (EPSRC) for three years and is in cooperation with our industrial partner BAE

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Systems. Those involved at Oxford are Professor Daniel Kroening (Principal Investigator), Dr Sonia Waharte (Co-investigator), Professor Stephen Cameron, Dr Michael Tautschnig, Dr Mehrnoosh Sadrzadeh, Dr Samuel Bucheli and Dr Ashutosh Natraj. The project's main goal is to verify the software that runs on any autonomous unmanned aerial vehicle for its safe and reliable operation to achieve the mission assigned to one or more UAVs. Figure 2 demonstrates the mapping and localization of the UAV in an unstructured environment, which is then verified for its overall performance.

In order to work autonomously, these systems need to be highly intelligent and rational so that they can become reliable. They must have high levels of knowledge to accomplish their AI-complex missions, which could occur in any information environment. This implies that they should be able to adapt to unexpected situations, such as recent changes to the environment that were not reflected in earlier information, or the possible loss of GPS due to obstructing buildings or indoor exploration. Reliable operation under such conditions would, for instance, enable them to return safely to their base station. When multiple UAVs are being used, they should additionally be able to communicate with each other to simplify their goals, to learn from each other's information, and to update and share their knowledge.

Given that any mission is unique in terms of deployment areas, tasks and goals to be achieved, etc., and can be critical in the sense that human lives may be involved, the implementation must be verified to be correct with respect to a formal specification.

A famous example of an implementation error and a failure to comply with the specification is the self-destruction of Ariane 5 in 1996 immediately after take-off, caused by a numeric overflow due to an implementation that was not suitable for all possible situations. In 1996, the Lockheed Martin/ Boeing Darkstar long-endurance UAV crashed following what the Pentagon called a 'mishap … directly traceable to deficiencies in the modelling and simulation of the flight vehicle'.

To achieve the reliability required, we will need to develop a formalism that represents the sets of actions each UAV can perform while allowing the capture of the kinetic constraints of the UAVs. We will then verify that the behaviours of each UAV modelled using this formalism lead to the individual or overall goal of the mission they are to achieve. These need to be extended from individual behaviours to a cooperative level amongst the multiple UAVs. Next, we plan to link the low-level code to high-level abstraction and verify it via advanced model-checking techniques. Finally, logical tools will be used to exhaustively reason about learning as a result of information flow among UAVs and their environment.

Meanwhile, in the process of verification, we have also developed some interesting algorithms, for instance the obstacle detection and avoidance for low cost UAVs using monocular vision, which is mainly inspired by nature. The core of the algorithm is a very simple observation from flies or humans, but assumes we don't have binocular vision. In perceiving the surrounding environment we make most use of the vision as the sensor to navigate within an environment. Thus we decided to make use of monocular vision (a single camera) to detect obstacles and avoid them safely.

To identify an obstacle's location, we made use of the **SURF (Speeded Up Robust Features)**, which is a robust local feature detector. Well-known camera calibration methods enabled us to re-project back the 2-dimensional image's feature points from camera co-ordinates into the

There are various sorts of intelligent unmanned robotics: unmanned ground vehicles (UGVs), autonomous underwater vehicles (AUVs) and unmanned aerial vehicles (UAVs), based on their operational zone respectively of ground, water and air.

3-dimensional world space. As the navigation data provides the exact position of the UAV in the 3D space from the inertial measurement unit on board, this allowed us to interpret the exact distance to an obstacle in its path.

Thus the algorithm not only detects the obstacle, but also provides the distance from the UAV, allowing it to take appropriate control decisions to avoid the obstacle. Figure 3 demonstrates the intermediate steps involved in obstacle detection and avoidance using monocular vision for low cost UAVS.

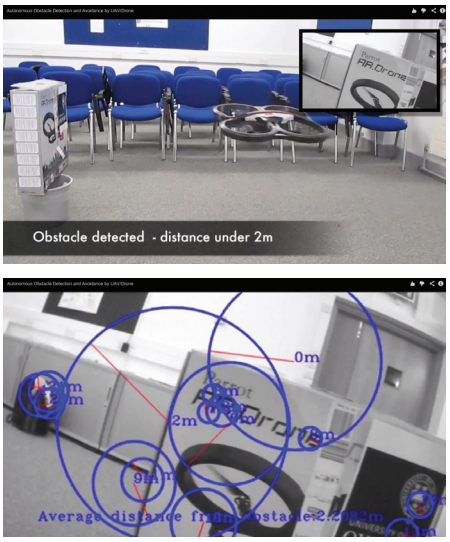


Figure 3: Demonstration of obstacle detection and avoidance using our bio-inspired algorithm.

See videos of our work at: https://www.youtube.com/watch?v=uEZEFCnyItk

Exploration by a UAV in an unstructured environment: https://www.youtube.com/watch?v=RHwnfPLnRg0

Staff changes

Since the last edition of *Inspired Research*, one new Professor has joined the Department, a new Head and two joint Deputy Heads have been appointed internally, and Sir Nigel Shadbolt has been recruited for 2015.

Professor Michael Wooldridge, Professor of Computer Science and Senior Research Fellow at Hertford College, takes over from Bill Roscoe as Head of Department from 1 October. Bill will remain with the Department (see page 4).

From 1 October, there are also two new Deputy Heads of Department: Professor Peter Jeavons, Professor of Computer Science and Fellow at St Anne's College; and Professor Joel Ouaknine, Professor of Computer Science, EPSRC Leadership Fellow, and Fellow of St John's College.

In another internal move, Professor Stephen Pulman, Professor of Computational Linguistics and Professorial Fellow at Somerville College, will become Director of Graduate Studies for the next academic year.

Professor Ursula Martin, Professor of Computer Science, joined the Department on 1 February. She holds an EPSRC Established Career Fellowship for 2014-2017. Prior to this, she held a chair of Computer Science in the School of Electronic Engineering and Computer Science at Queen Mary University of London. She was awarded an Honorary Fellowship from Royal Holloway, University of London, in April.

Professor Sir Nigel Shadbolt will be taking up a Professorship at the Department of Computer Science, and become the next Principal of Jesus College, Oxford, in August 2015. Nigel is currently based at Southampton University where he is Professor of Artificial Intelligence (see page 2).

Alumni Profile

Francis Goodburn (St John's, 2011 – 2014)

Recent graduate Francis Goodburn read for a degree in Maths and Computer Science at St John's College, where he was also an organ scholar. Here, he tells us what made him decide to become a social worker at Frontline, a pioneering organisation dedicated to encouraging high achieving graduates into social work.

Why did you decide to join Frontline?

I wanted to do something that would be a worthwhile and exciting challenge, both intellectually and emotionally, and that would make a contribution to those who most need it. I can't think of anything more valuable than to dedicate myself to protecting society's most vulnerable children and supporting their families, and this is what children's social work is all about.

Frontline is a relatively new organisation and, for me, it was the ideal employer as you are in a practice environment after just five weeks' intensive training. With Frontline, I had the opportunity to be a social work 'pioneer', and was expected to work to the highest standards from day one. Being able to learn such a practical profession on the job made it much more attractive than many other training routes.

How did your time at Oxford help prepare you for this role?

Deadlines and efficient working practices are invaluable in child protection work – children's welfare and sometimes even their lives depend on it – and the rigours of Oxford academic study were a good preparation for this. Studying Computer Science gave me a keen eye for detail and pattern spotting which comes in quite handy too.

What did you enjoy most about studying Computer Science?

What stood out most for me wasn't the great academics or top notch tutorials – of which there were many – but the overall ethos of the Department. The students, the teaching staff and the support staff work together to create a supportive environment which encourages people to have new ideas and push the limits – as well as doing some hard academic graft.

What advice would you give someone who is unsure about where their degree in Computer Science might take them?

A degree in Computer Science could take you just about anywhere, so keep an open mind. Think about what gives you a buzz, be it making money, discovering new things or helping people, and do whatever gives you that buzz – you'll be much happier for it in the long run.

Spin-out financed to tune of US$8m

Semmle, an Oxford spin-out which provides a business analytics platform to manage the software development process, has just received US$8m funding from Accel, a prestigious venture fund. It is the first time that a UK university spin-out has received funding from Accel, which has also backed Dropbox and Facebook.

The Oxford-based company was set up in 2006 by Oege de Moor, a Professor of Computer Science at the University. It properly started trading in 2009. The Semmle platform already supports a range of international clients such as Citi, Credit Suisse, NASA and Dell. It will use the investment to accelerate growth and product innovation, including developing a cloud product.

Computer Science Alumni Network

The Department of Computer Science has recently launched its alumni network, giving former staff and students the chance to stay in touch with the Department after graduation.

The Computer Science Alumni Network has been set up so that our alumni can find out the latest news from the Department, keep up-to-date with our research and attend a range of events organised exclusively for them.

We are delighted to invite all alumni to join us for pre-Christmas drinks on Thursday 4 December 2014 at the Royal Society in London to formally launch the network. This will be a great opportunity to catch up with old friends over drinks and canapés, and to meet new Head of Department, Professor Michael Wooldridge.

The alumni network will also offer professional networking opportunities, careers guidance and support, and we are also able to discuss bespoke opportunities to reach current students.

We are also keen to hear from people who might like to get more involved with the Department by volunteering either their time or resources. You could participate in careers talks; assist with, host or speak at an event; offer internships or work experience placements; or mentor students or alumni. Alternatively, you might like to be mentored by a fellow alum. If you would be willing to assist with any of these tasks, or work with us in another way, please do get in touch with us directly using the contact details below.

In addition, all University of Oxford alumni are able to access a range of benefits and services, including alumni card discounts, email forwarding and opportunities for professional development. For further information, visit the University's Alumni website: www.alumni.ox.ac.uk

Contact Frances Wheare,
Development and Alumni Manager
Tel 01865 273862
Email frances.wheare@cs.ox.ac.uk

Other exploits

Our students and academics are of course very accomplished computer scientists, but they've got some rather surprising other talents. Here are a few of their non-subject-related achievements from the last few months:

© Suzanna Marsh

Computer Science Tutor, Andrew Ker, is the founder of, and conductor for a 'vacation choir' for University staff and students called Intermezzo. The choir had two sell-out concerts in April and September. The first one featured contemporary music inspired by plainchant – a form of medieval church music that emerged around 100 AD and involves chanting. The summer concert was on 13 September and tickets sold out within three days of going on sale. It featured contemporary music from north-eastern Europe.

Our latest success in rowing was by Elizabeth Polgreen from the Department's administrative team. She raced at Henley Royal Regtta in the women's single event, but was beaten by a member of the Hungarian National Team. She also raced in the England team at Home International Regatta in Ireland, where they won the women's quad event. She will be defending her national championship title in October.

More water-based activity took place on 7 September when over 20 members of the Department took part in the Abingdon Dragon Boat Day. With a lot of hard work, they came 9th of 16 teams and raised money towards the Air Ambulance, The Child Brain Injury Trust and Daybreak – a small charity that operates dementia day clubs in and around Oxford.

Back on land and in the air, Research Facilitator Kelly Ryan has helped to raise over £1,000 for two charities by jumping out of a plane, and completing a 10k walk. The first of the charities is the Steppin' Stone Centre in Oxford, which provides day-long support for homeless and vulnerably housed people, and is run by a charity called The Porch. The second is Forget-Me-Not Animal Rescue.

Claire Hawtin and Julie Sheppard from the administrative team have also been walking for charity. They took part in the Oxford Moonlight Stroll, walking approximately nine miles and contributing £115 to Sobell House Hospice, which provides palliative and end-of-life care.

Walking took an uphill turn in June when members of the Computational Biology Group climbed Mount Snowdon, the highest peak in Wales at 1,085m. Doctoral student Beth McMillan told us they got 'very very damp, never again'.

News in brief

In September, Microsoft held an event called 'Luca Cardelli Fest' in honour of the top computer scientist. Luca was awarded a Royal Society Research Professorship in the Department of Computer Science at the University of Oxford last year. He is best known for his research in type theory and operational semantics.

CBMC (a Bounded Model Checker for ANSI-C and C++ programs) has won the gold medal in the 'Overall' category in the 2014 Software Verification Competition, held in conjunction with TACAS 2014 – the International Conference on Tools and Algorithms for the Construction and Analysis of Systems. It won six medals in total, including Gold in 'Recursion' and 'HeapManipulation'. Professor Daniel Kroening and Dr Michael Tautschnig developed the tool at Oxford. Michael has now moved to Queen Mary University of London.

Oxbridge women hold first conference

Oxford and Cambridge female computer scientists forged many connections at the 1st Oxbridge Women in Computer Science Conference, held at the University of Cambridge's Computer Laboratory on 27 February 2014.

The conference is co-organised by Oxford Women in Computer Science (OxWoCS) and Cambridge women@CL, who intend it to become an annual event.

Oxford's Professor Ursula Martin presented the keynote talk entitled 'From pure maths to sociology and back: my research journey'. It reflected on her education, impressive career and experience as a female computer scientist. The keynote was particularly symbolic as Ursula helped to set up women@CL in 2003 when she was at Cambridge, together with Dr Mateja Jamnik.

The keynote was followed by student presentations, and a poster session, with topics ranging from Social Network Analysis to Computational Analysis of Genomes. The academic portion of the conference was closed by Dr Oana Florescu, from Google. (The conference was free for all, thanks to the generous sponsorship of Google.)

The conference was a great success with over 50 attendees, the forging of many lasting connections between the two societies, and the creation of new working relationships. The 2nd Oxbridge Women in Computer Science Conference will be held at the Oxford Department of Computer Science on 16 March 2015.

Computational Cardiovascular Science Symposium

Experts from a range of disciplines, sectors and countries came together to discuss current trends in computational technologies for cardiovascular science and medicine at a workshop hosted in the Department on 17 September.

Participants at the Computational Cardiovascular Science Workshop represented 11 universities and 12 companies, and came from various European countries, the USA, and Japan. They included experts in cardiology, computer science, physiology, pharmacology, philosophy, and biomedical engineering. The forum was organised and chaired by Professor Blanca Rodriguez and collaborators, and supported by the Knowledge-Exchange fund.

Topics discussed included the impact of Computer Science on cardiovascular science and medicine, and how it could augment cardiovascular physiology, pharmacology and medicine, and replace, refine and reduce animal experimentation.

There was a particular focus on clinical cardiology and the characterisation of cardiac disease patients, cardiovascular pharmacology and the enhancement of recordings obtained from human adult and stem cell derived cardiomyocytes using tools such as the Virtual Assay software (developed with the support of the EPSRC Impact Acceleration Fund), and the identification and mechanistic investigation of heart rhythm disorders.

The workshop culminated with a thought-provoking discussion on novel regulatory and industrial applications for computational medicine methodologies, such as pharmacological safety and efficacy, and heart and nervous system interactions.

More information on computational cardiovascular science: www.cs.ox.ac.uk/ccs.

Grants support machine learning research

Professor Nando de Freitas and DPhil Student Misha Denil received several awards earlier this year to support their research on distributed learning, which aims to improve speech, language and image understanding.

Their grants include a one-year Google Faculty Research Award for research on deep learning, an (Amazon) AWS in Education Machine Learning Research Grant, and a Windows Azure Research Pass Grant for work on distributed learning of probabilistic graphical models. Misha has also received a PhD Scholarship from Microsoft Research for his machine learning research. He will be co-supervised with Antonio Criminisi at Microsoft Research Cambridge.

Nando and Misha have had recent success in scaling up deep learning models for speech and image recognition, and extending them to the analysis of text documents. Deep learning, inspired by neuroscience, has revolutionised the fields of speech recognition and computer vision and is now the driving force behind speech and image analysis at Google, Facebook, Microsoft and other large tech companies.

Nando and Misha have also developed new distributed algorithms for large-scale learning of probabilistic models that allow for unprecedented levels of parallelism. Their work provides new algorithms for distributed reasoning about massive datasets, and lays the theoretical foundation for further developments in this area.

The team plans to use the grants to continue developing techniques to reduce computation, storage and communication costs in large-scale speech, image and language understanding.

Lovelace Lecture delivered by Abramsky

Professor Samson Abramsky FRS *(pictured front left)* gave the BCS Lovelace lecture on 5 June at Imperial College London. He talked about which computer science tools will, and have been, used to help understand the heart of quantum, including contextuality and entanglement. He covered what developments have, and can, come out of this.

Giving a public speech is part of the prize for the winner of the Lovelace Medal. It was awarded a few months earlier to Samson, a Professor of Computer Science at Oxford. The medal is presented to individuals who have made an outstanding contribution to the understanding or advancement of computing.

Samson is a Fellow of Wolfson College, and holds MAs from Cambridge and Oxford and a PhD from the University of London. He is known for his leading role in game semantics and its applications, as well as work on lazy lambda calculus, domain theory in logical form and concurrency theory.

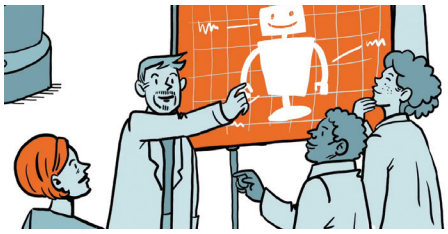
Responsible innovation encapsulated in a framework

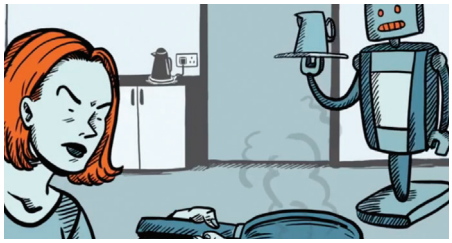
How to innovate responsibly in a digital world was the subject of a one-day event, as a final part of an EPSRC research project examining how innovators might reflect upon the societal impacts of their research outputs and how they might engage in greater public dialogue in the development of novel technologies.

The Framework for Responsible Research & Innovation in ICT (FRRIICT) event on 19 June at the Science Museum in London aimed to foster discussion and debate between NGOs, policymakers, funding councils, academics, major media outlets and members of the public.

It was organised by the research team that has been creating FRRIICT, a tool that helps those involved in research and innovation in ICT to do so responsibly. The three-year project sponsored by EPSRC was led by Marina Jirotka from the University of Oxford and Bernd Stahl from De Montfort University and the fieldwork was conducted by Grace Eden from the University of Oxford.

The June event was part of their consultations with the ICT community to set up the tool. The framework is now online at http://responsible-innovation.org.uk and can be accessed by anyone in the community who wishes to see the set of recommendations and good practice free of charge.





A video of the event and an animation of RRI in ICT can be found at https://www.youtube.com/channel/UCKITrA6PaVRkTsfdJtVP41w

Student conference sets high standard

Congratulations to the four postgraduate students who won awards at the 2014 Oxford Computer Science Student Conference.

The four winners were:

- Sara Dutta: best talk for 'Efficacy of Anti-arrhythmic Drugs during Ischaemia: A Computational Modelling Whole Heart Study'
- Miriam Backens: best talk award for 'Completeness Results for the ZX-calculus for Quantum Computation'
- Stefano Ortona: best poster award for 'ROSeAnn: Reconciling Opinions of Semantic Annotators'
- Varduhi Yeghiazaryan: best abstract award for 'Experiments on the use of Fast Marching for Feature Identification'

Twelve talks were given across a variety of research areas. Almost 50 students and staff attended the conference dinner at Somerville College. The annual conference was open to all students and staff within the Department and associated Centres for Doctoral Training.

The conference keynote was given by Professor Ursula Martin on 'Crowdsourcing, and the challenges of working in a new research area'. Ursula also helped pick the best talks, commenting how impressed she was with the very high quality of professionalism of this student-led event.

News in brief

An Oxford team won a best paper award at the International Conference on Information Processing in Sensor Networks (IPSN) 2014, Germany.
The paper, entitled 'Lightweight map matching for indoor localisation using conditional random fields' was co-authored by Zhuoling Xiao, Hongkai Wen, Andrew Markham, and Niki Trigoni.

Two Oxford computer scientists, Radu Grigore and Hongseok Yang, and their co-authors from the Georgia Institute of Technology, have won a distinguished paper award at the annual conference, PLDI'14 – Programming Language Design and Implementation – run by ACM SIGPLAN. Of around 50 accepted papers (about 20% of those submitted are accepted), only three papers won a distinguished paper award. The winning paper was entitled 'On Abstraction Refinement for Program Analyses in Datalog'.

Kasper Rasmussen and Ivan Martinovic, with two other co-authors, won a distinguished paper award at NDSS2014 - The Network and Distributed System Security Symposium, one of the top conferences in security. Their work was entitled 'Authentication Using Pulse–Response Biometrics'.

Satisfied students push up the Barometer

The Department of Computer Science has seen all three of its undergraduate courses being placed in the top 10 for student satisfaction in terms of 'overall experience' in this year's Student Barometer for undergraduate students at Oxford University.

The part-time MSc in Software Engineering also scored extremely well. With a learning satisfaction rate of 95% it came in at number six in the table for the University's post-graduate taught courses. The MSc in Software and Systems Security scored an excellent 93%.

The Student Barometer is a yearly questionnaire that is sent out to all students within a university in mid- to late autumn, collecting data from newly integrated students as well as from more seasoned students. A single authority, i-graduate, collects and publishes the results, allowing comparisons across departments, colleges and even universities.

With 97% of Computer Science students satisfied with all aspects of the university experience coupled with 100% satisfaction in regards to the quality of tutorials and subject expertise, the Department of Computer Science has reason to celebrate.

The Software Engineering Programme achieved 100% satisfaction rate on factors such as 'subject expertise of academic staff' and 'learning that will help me get a good job'.

Industry involved in practicals

Industry representatives formed part of the judging panel that chose the winners in the second year students' group design practicals. Teams of four to six undergraduates presented their projects in May, having chosen a topic to work on in January from a set of eight different challenges. Project topics were presented as outline design briefs. Part of the work was to undertake a proper requirements analysis, working with the project mentor. The practicals have been designed to allow students to develop and apply theory learnt on the course. Some challenges were set or sponsored by the industry partners, which this year included Winton Capital Management. The judging panel consisted of one representative from each of the other sponsors – IBM, Bloomberg, Metaswitch, and Ensoft – plus University experts. Each industry partner awarded the teams a prize of £400 per winner, based upon their own criteria.

Team 9 (A Tayler, J Wallis, J Clark, M Sjodin and S Heap) were awarded the IBM prize for implementing an augmented reality system that processed and displayed a range of information about the user's current surroundings. Jason Nurse from Oxford's Cyber Security Centre was their mentor.

Team 2 (A Thorley, A Wright, A Menon, G Auger, O Adascalitei and T Lear) won the Metaswitch prize in the task to use a Leap Motion controller to turn a computer into a musical instrument. Computer Science Tutor Peter Jeavons was their mentor. Leap Motion provided the equipment.

Team 8 (A Newby, J Thompson, J Fowler, J Pollard and K Khan) was handed the Bloomberg Prize for an application and web-based system on Technical Talent Spotting. This challenge was set in collaboration with Metaswitch, which asked for the development of web-based software to help assess applicants in the internship process. Research Fellow Joe Pitt-Francis acted as mentor.

Team 3 (A Welch, G Asman, J Mikolajzak and S Green) won the Ensoft prize, for the challenge to create a mobile app that would enable live feedback and interaction between a lecturer and the audience. The group's mentor was University Lecturer Alessandro Abate.

End-of-year examination prizes

Congratulations to all the students who were awarded prizes for their performance in end-of-year examinations in 2014.

Third/fourth year (Part C)

Pernille Hanehoj – Mathematics and Computer Science, New College
The Hoare Prize for the best overall performance (Part C)
Gloucester Research Prize for best Computer Science project (Part C)

Michael Bradley – Computer Science, Balliol College
The Hoare Prize for the best overall performance (Part C)
Microsoft Prize for best Computer Science project (Part C)

Second year (Part B)

Hynek Jemelik – Computer Science, Magdalen College
The Hoare Prize for the best overall performance (Part B)

James Nicholls – Computer Science, Balliol College
The Gloucester Research Prize for best Computer Science project (Part B)

Matje Balog – Mathematics and Computer Science, Merton College
The British Telecom Research and Technology Prize for the best overall performance with special regard for Computer Science papers (Part B)

Dominik Peters – Mathematics and Computer Science, St John's College
The Junior Mathematics Prize for outstanding performance in the mathematical papers (Part B)

New game trades clicks for physics discoveries

Students at CERN have created a computer game that can make particle physics research addictive. The group included Oxford MSc in Computer Science student Jiannan Zhang, who was carrying out a summer internship at CERN.

Particle Clicker was created during a 48-hour hackathon. Modelled after the compulsive clicking game, Cookie Clicker, it allows the player to work through a full career in particle physics over the course of about a day. The game starts with an abstracted image of the Large Hadron Collider. Each time you click on the particle accelerator, you generate data. With enough data, you can select projects that enhance your reputation. As data and reputation increase, so does funding, and with funding, you hire Postdocs or PhD students. You upgrade workers (with beer and coffee), and improve PR until you have a distinguished team of researchers able to discover the wonders of CP symmetry and t leptons. And, if, whilst playing, you realise you are stumped as to exactly what a t lepton or beauty quark is, embedded into each particle is a brief history lesson about its discovery and importance.

In the first week after the game's release in August, the Particle Clicker page has had more than 50,000 unique visitors. The game's code is open source and available on GitHub. Its creators are still working with volunteers at CERN and through GitHub and Reddit to make it even more educational and addictive. The game is available at: http://particle-clicker.web.cern.ch/particle-clicker/

Click at your own risk.

OxTALENT recognises technological innovation

Three projects linked to the Computer Science Department won plaudits at the annual OxTALENT Awards, which recognise staff and students who have been innovative in their use of technology to enhance teaching and learning.

The winners of the OxTALENT Awards, part of Oxford's University Teaching Awards Scheme, were announced at a ceremony on 18 June.

Award: Use of WebLearn to Support a Course or Programme of Study

Winners from the Computer Science Department included Dr Gareth Digby, a visiting lecturer from the USA, who came first in the 'Support for Blended Learning' category. His forensics course is blended, in that students come to the University for a week of face-to-face classes and then have six weeks to complete an assignment and submit it online.

The winning place in the category 'Use of WebLearn to Support a Course or Programme of Study' went to a team from the Centre for Doctoral Training in Cyber Security: Professor Andrew Martin, David Hobbs, Maureen York and Manu Apostolidis. They worked with the University's IT Learning Programme to design a course on presentation skills, which captures the students' presentations using the Panopto system, and then makes them available through the students' WebLearn area.

Sophie Kay, a doctoral student, was runner up in the 'Open Educational Practices' category for her Lego-based teaching scheme to educate young students and researchers about communicating methods and techniques. http://www.cs.ox.ac.uk/news/806-full.html

Photos courtesy of Steve Pierce of IT Services

Spin-out to revolutionise secure payments

Mobile phone users will soon be able to make payments in a highly secure way without needing a card or scanner, thanks to technology that has been developed and spun off by Oxford University, dubbed 'spontaneous security'.

The spin-out company, OxCEPT, will sell an app that enables anyone with a mobile device to make a secure payment to a previously unknown person or merchant. The app uses contextual information to verify their identity, enabling authentication to take place without any details of any kind being disclosed to second parties.

Once a small amount of contextual information has been exchanged by two or more parties, and they have entered a simple four digit key, they can then transmit much larger amounts of encrypted data securely across an unsecure network such as the internet or wi-fi.

The security protocols used in the app were first developed for the US military by a research group led by Professor Bill Roscoe, who was Head of the Department of Computer Science, until this October. Software that used the protocols has been tested on military manoeuvres, and also for securely sharing data in disaster recovery situations.

Bill says: 'The protocols resist many of the threats such as so-called "man in the middle" attacks associated with online security solutions; we create security without having to rely on any pre-existing infrastructure and we do it from the things human users know and trust.'

OxCEPT has been set up by the universities technology transfer company, Isis Innovation. The Chief Technology Officer Dr Bangdao Chen is one of Bill's ex-students. The spin-out company has offices in London, Oxford and San Francisco to try and tap into the growing market for peer-to-peer transactions. As their tag-line suggests, they will 'start OxCepting payment' in the next few months.

The spin-out recently featured in *Wired* magazine, in an article entitled 'Oxford professor develops mobile payment technology with defence-grade security'. It can be found at: http://www.wired.co.uk/news/archive/2013-12/19/spontaneous-security

Pupils get the message

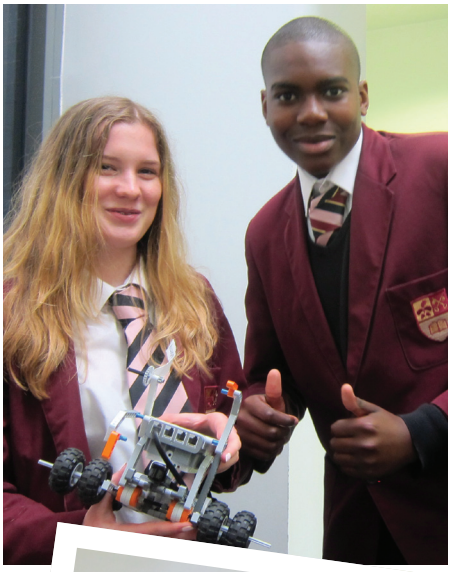
The Department's outreach programme aims to introduce young people to Computer Science, inviting them to share our love of this creative, challenging, and world-changing discipline. In this article, Publicity and Schools Liaison Officer Suzanna Marsh describes the different activities organised for young people.

The existing ICT curriculum in English schools is currently being scrapped. This September, the study of computing – and specifically coding – becomes mandatory across all state primary and secondary schools. There has therefore never been a more important time for Computer Science outreach: to both engage with young people and their teachers.

Oxford University runs more than 2,400 outreach events a year across the UK, spending over £5m. Its activity brings the University into direct, face-to-face contact with three-quarters of all schools in the UK teaching post-16s. Over the last year, student ambassadors, academics and researchers from the Department of Computer Science have participated in outreach activities around the country. These included: giving talks during schools' visits to Oxford; hosting Continuing Professional Development events for teachers in association with the BCS; developing free teaching resources for teachers; speaking at student conferences around the country; helping kids build and race Lego robots as part of the Oxford RobotGames series; participating in Oxford's UNIQ Summer Schools scheme; and volunteering with primary school kids.

The Department of Computer Science continues to lead on two major multi-subject events. The 'Further Maths – What Next?' event is for mathematically gifted year 12 (lower sixth) students, and the 'Lesser-Spotted Sciences' event, for year 11 (GCSE-level) students. Both introduce subjects less commonly seen on the school curriculum, and assist in understanding where subject choice at A Level (or equivalent) can lead. The Department continues to play host to several one-day conferences, including Women in Computer Science events, and an annual conference for pupils in years 11 and 12 in association with the Computing at Schools Group.

An essential part of the CS outreach scheme is its student ambassadors, who often speak at events and talk to pupils individually, giving first-hand views on what doing a degree course is really like. A new influx of students joined the Computer Science's already active student ambassador scheme after being inspired by a talk entitled 'Turning the new school Computing curriculum into reality: opportunity and challenge', given in the Department by Computing at Schools Group founder Simon Peyton Jones last November.



Robot Games March 2014

Increased computer science-related outreach activity over the last few years is starting to show real results. In the last admissions round, there was a 47 per cent increase in applications to Oxford undergraduate Computer Science degrees compared to the previous year.

Information about all of our activities with teachers and young people – including details on how to book, or receive notification about new events – can be found here: http://www.cs.ox.ac.uk/opendays

News in brief

Dr Cas Cremers has been successful in gaining three separate grants from GCHQ to fund his research in security. Cas has received funding for two three-and-a-half year doctoral studentships relating to improving the security of network communications, and building secure component-based systems. The third award covers costs for high-end computer hardware and staff/student time to carry out a feasibility analysis into the parallelisation of the Scyther tool.

Oliver Britton was a finalist in the UK ICT Pioneers Awards 2014, a partnership between EPSRC and key stakeholders that aims to recognise the most exceptional UK PhD students in ICT-related topics who are able to communicate and demonstrate the excellence and exploitation potential of their research. Using computational modelling and simulation, Oliver's DPhil project addresses a key part of understanding any biological system – how the variability between different individuals causes differences in their behaviour.

Automated verification of complex systems in the energy sector

Smart energy grids and power networks are examples of complex systems that could benefit from quantitative analysis and certifiable policy synthesis grounded on formal computational models. Professor Alessandro Abate from the Department of Computer Science explains in this article how research is trying to validate innovative theoretical and computational techniques developed over complex models by tailoring them to real world applications, particularly in the energy sector.

Buildings consume more than 40 per cent of the total energy in Europe. It has been argued that efficient buildings automation systems can reduce their energy consumption by up to 30 per cent. In order to sustainably achieve this goal, reliable commissioning and maintenance of smart buildings automation systems is fundamental.

In an EU-funded project, my partners and I are seeking to show how developing automated verification and synthesis techniques over complex computational models could help achieve this goal. The 'Advanced Building Diagnosis and Maintenance' (AMBI) project is in collaboration with Honeywell Labs in Prague, Dresden University of Technology, and Delft University of Technology.

The project relies on a recently investigated mathematical framework called Stochastic Hybrid Systems (SHS) that is suitable for the quantitative description of devices and platforms where digital techniques are embedded in physical and analogue systems. SHS models are dynamical models that are able to characterise the probabilistic evolution of systems with interwoven and interacting continuous and discrete components.

SHS models can be used to quantitatively describe smart building systems, since they include physical quantities (such as temperature and humidity), as well as discrete elements (users' occupancy) and digital components (for example, ON/OFF taps or air conditioning modules expressible as finite-state models). Further, probabilistic terms originate from the presence of thermal noise, as well as from uncertainty in the weather affecting thermal loads and the associated generation of renewables (via solar and wind power). Uncertainty also affects sensor measurements, which are used to get access to quantities of interest (temperature, humidity).

Within AMBI we are currently developing both mechanistic and data-driven complex models tailored to smart building systems, with the overall goal of providing innovative solutions in diagnostics, prognostics and enhanced performance towards smart, optimised energy management.

Models for power networks

Additional current applications in the energy area deal with the use of formal abstraction techniques (see the later part of this article for more detail about this notion) over SHS models. In particular, I am interested in the development of models for demand-side participation of thermostatically controlled loads (that is, energy sinks, the consumption of which can be controlled), where the goal is to provide formal aggregated models for large-scale populations of thermal loads towards a practically useful optimal control of the generated power. This work is conducted in part in collaboration with German and American partners.

Related to this problem is that of formal aggregation of populations of photovoltaic panels (a project in collaboration with RTE, France), which aims to reduce instabilities in the global dynamics of power and frequency over regional, as well as large-scale, power transportation networks.

A notable benefit of working at Oxford is the presence of internationally visible colleagues in Computer Science who share my interests in energy and power applications, as well as the adjacency to the Engineering Department with its strong research emphases on Control Engineering, Artificial Intelligence and Machine Learning, and its focus on the more applicative development of state-of-

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the-art research. Oxford is also home to the Environmental Change Institute, which has an international track record for research in climate, ecosystems and energy.

Cyber-Physical Systems

As well as applications in the energy sector, I am interested in fundamental research in the areas of formal verification and of systems and control theory. The development of quantitative models for complex dynamical systems and the consequent reliance on them is pervasive in technology and in the sciences, and has matured from being a supporting methodology to becoming the foundational cornerstone of various disciplines. Understanding complex systems by establishing trust and control on their models is a goal with relevant downstream applications.

More recently, this trend has extended towards challenging areas, where the development and application of digital techniques is embedded within physical and analogue systems, and where the aspects of communication, computation and control are fully interleaved. Devices and platforms endowed with these heterogeneous physical/software, analogue/digital, continuous/discrete components and a high level of complexity are known as Cyber-Physical Systems (CPS), and are identified as a key research area by numerous industrial stakeholders, as well as governmental agencies such as the European Commission and the US National Science Foundation. The examples in the energy sector mentioned above can also be profiled as instances of CPS.

Effective progress in advanced applications such as CPS requires leveraging highly complex models: the involved dynamical features of CPS have recently led to an increased interest in the mathematical framework of SHS (mentioned above), which is regarded as a natural platform to comprise the elaborate intricacy of real-world applications of interest in CPS. SHS is a class of models presently investigated within the Hybrid Systems community, a research theme that in the past 15 years has brought together the heterogeneous expertise and orthogonal perspectives of researchers from both Engineering (systems & control theory, communication sciences) and the Computer Sciences (formal verification, dependability and performance analysis).

As one can expect, a general modelling framework such as that of SHS raises issues concerning analysis and associated decision (controller synthesis) problems: relying on manual (analytical) approaches towards analysis is ingenuous at best, whereas algorithmic procedures are bound to lack decidability or (optimistically) to tolling computational overhead. Simply put, formally proving theorems on SHS is hard, whereas computing over SHS models likely leads to state-space explosion problems (also known as the 'curse of dimensionality'). Yet we can mitigate these limitations by using new analytical approaches, as well as techniques for abstraction and compositionality, respectively.

Synthesis of formal abstractions

The main objective of this research line is to obtain formal model abstractions (i.e. simplifications that are mathematically related to the concrete, original models), with an explicitly quantified and adjustable approximation error. Such formal abstractions should be automatically employed towards synthesis and verification goals by leveraging modern, state-of-the-art software. In particular, 'finite abstractions' play a key role in dealing with problems that are structurally not decidable over models endowed with an uncountable (and in particular hybrid) state space and with continuous, probabilistic dynamics.

Finite abstractions can accommodate automatic model checking procedures and strategy synthesis algorithms, as implemented in existing software tools (e.g. SPIN, nuSMV, PRISM) that are having an impact in the academic and industrial context alike. It is in particular these new finite abstractions techniques that are used in the energy studies mentioned above.

The automatic synthesis of formal finite abstractions can be often aided and improved by proper a priori analysis of the model structure, which naturally leads to exploiting a modeller's expertise and deductive ingenuity. As an example, the tolling state space explosion problem mentioned above can be mitigated by employing tailored compositional approaches, or by developing results that are specification-dependent or driven by automatically synthesised counter-examples.

Overall, computationally the initiative aims at attaining fast algorithmic procedures that can scale acceptably with the model size, and it generally targets the development and testing of new dedicated software, as well as the integration of the proposed schemes with existing probabilistic verification tools.

An important benefit of working in the Department of Computer Science at Oxford is being able to take advantage of the excellent research environment in the automated and formal verification area, thanks to its emphasis on theoretical work and because of a number of state-of-the-art software tools being developed by colleagues.

In order to provide a clear experimental validation to the developed theoretical and computational techniques, I am engaged in applicative research that, as well as the energy domain, also spans the life sciences. In both areas I collaborate with experts in the specific domains, in order to achieve results that are compelling towards practical advancements, and which only collaborative research can truly foster in modern Engineering and Science.

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More on finite abstraction tools can be found at: http://sourceforge.net/projects/faust2/ and http://sourceforge.net/projects/verisimpl/

Chords program spun into business

A free online music service that transforms audio music into chords has been set up using functional programming by postdoc researcher José Pedro Magalhães and his co-founders of the company, Chordify. In this article, Pedro describes the project, its relationship to his postdoctoral research at Oxford, and the benefits from being involved with industry.

If a musician hears a piece of music they wish to play themselves, it can be very difficult to work out exactly which chords have been played. I set out to solve this issue when I set up Chordify (www.chordify.net) in January 2013.

Chordify automatically recognises chords from the audio signal, and aligns them to the music in a simple and intuitive player. It helps both novice and trained musicians to play the music they wish on instruments such as the guitar, piano or ukulele, making state-of-the-art music technology available to the public. Although it has been online for less than two years, Chordify now handles over 3 million visits a month, with over 170,000 registered users, and around 1,400,000 songs have been 'chordified'.

The technology behind Chordify was born out of research I started working on while still a PhD student at Utrecht University in the Netherlands. There, together with my colleague W. Bas de Haas, we developed a program (written in the functional programming language Haskell) that encodes the rules of musical harmony in a model, and uses this model to improve the recognition of chords from audio sources. When trying to figure out which chord is being played at a given time, often it is unclear exactly which chord it is, but we have a list of possible candidate chords. We then used our model of tonal harmony to select the chord that makes the most sense, in musical terms.

This Haskell program, together with many other open-source tools, works behind the scenes in Chordify to extract the chords from the audio. After that, the chords are displayed in an intuitive way, and played along with the music. We are helped by Tijmen Ruizendaal, our front-end developer, and Gijs Bekenkamp and Dion ten Heggeler, who handle design and communication. The five of us are all co-founders, and the only investors in Chordify.

My research at Oxford continues along the lines of what I did for my PhD. It is about a programming technique that strives to reduce code duplication by increasing its abstraction: generic programming. Generic programs work on a variety of types of data, exploiting the structure of data to adapt their behaviour. The back-end of Chordify makes heavy use of generic programming; there, we have to be able to handle a large collection of complex datatypes (which model musical harmony) in a generic fashion, and be robust to changes in the model.

Chordify serves as a driver for the more practical side of implementing generic programming in the Haskell language; as a large, real-world application, it helps us make sure that we have not forgotten about important practical aspects (which are sometimes easy to overlook in an academic publication alone, for example).

Working on Chordify is a great experience in addition to my work as a postdoc researcher at the University, as it exposes my work to a much wider audience, and gives me an insight into the business side of the world: handling customers, business-to-business affairs, taxation, etc. In the future, we are hoping that Chordify will be able to sponsor research more directly, and we will explore university collaborations for possible research funding, or hosting PhD students. My experience with Chordify has been immensely positive, and I would urge all researchers to try to apply their research topics in a practical setting.