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UNIVERSITY OF OXFORD

DEPARTMENT OF COMPUTER SCIENCE

CompSciOxford

DepartmentOfComputerScienceUniversityOfOxford

Inspired Research

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Letter from the Head of Department

As I scan through the articles to appear in this edition of *Inspired Research*, I find myself struggling with an embarrassment of riches.

In this issue, you will read about how our research is helping to keep workers safe on railways, and how it helps to deal with the problem of bacterial resistance to antibiotics; you will read about how our researchers are helping to build safer buildings, by embedding sensors into structures to monitor them for bending or twisting; you will read about how our security researchers are helping governments to construct IT systems that are safe against malicious attacks, and how social media can be managed to prevent digital wildfires…

What I find remarkable about all this is, apart from the sheer diversity, how clearly it demonstrates the ever-increasing role that computing plays in our lives. As these examples clearly show, Oxford remains at the heart of the ongoing digital revolution, and I have no doubt that we will continue to be surprised and delighted by the innovations of Oxford's computer scientists.

We have just welcomed a new cohort of undergraduates, eager to drink their fill at Oxford's fountain of knowledge – or possibly at the Kings Arms. Everyone who gains a place to study at Oxford does so against fierce competition, but this year's intake of Computer Science undergraduates has a special distinction: the programmes on which they will study are now amongst the most competitive and sought after in Oxford, and indeed in the UK.

We now receive 10 applicants for every undergraduate place we are able to offer. Most applications we receive are very strong, and the upshot of this is that we end up having to turn away large numbers of outstanding candidates, simply because we don't have enough places to offer. I would dearly like us to be able to offer more undergraduate places, and this means expanding the number of tutorial fellows in our colleges.

There are very promising signs that more colleges are interested in offering Computer Science, or expanding their student numbers in our subject. I am particularly pleased to be able to welcome new tutorial fellows at St Catherine's College (Shimon Whiteson), St Anne's College (Alex Rogers), and Magdalen College (Rahul Santhanam). It has been many years since our department welcomed three new tutorial fellows in the same year – I very much hope that we will welcome more new tutorial fellows in the years to come.

We hope you enjoy reading this edition of *Inspired Research*. As ever, we'd be delighted to hear from you if there's anything of particular interest that you'd like to explore further; do get in touch via enquiries@cs.ox.ac.uk

Professor Michael Wooldridge
October 2015

News in brief

Royal Society Research Professor, Luca Cardelli has been awarded the Programming Languages Achievement Award by ACM SIGPLAN. The award recognises individuals who have made a significant and lasting contribution to the field of programming languages.

Blanca Rodriguez and the Computational Cardiovascular Science Research Group have been nominated for the Lush Prize, for their work that supports the replacement and reduction of animal testing. The Prize is a collaboration between Lush, the well-known manufacturer and retailer of handmade cosmetics, and Ethical Consumer, a research, publishing and campaigning co-operative.

Dr Andrew Ker, a University Lecturer in the Department of Computer Science, received an MPLS teaching award in June 2015. This followed Andrew 's nomination for Most Acclaimed Lecturer in the 2015 Oxford University Student Union (OUSU) Teaching Awards. Professor Andrew Martin, Director of the Centre for Doctoral Training in Cyber Security, was the second member of the department to receive a nomination, for Outstanding Supervisor.

A league of our own

In 2015 Oxford has been recognised as the best UK University for Computer Science.

The latest subject-specific tables produced by higher education data specialists QS rank Oxford as the top University in Europe. In the Academic Reputation and Employer Reputation categories we surpass any other University in the world for Computer Science.

Not only are we rated highly by the academic community and industry, but by the student community too. In University league tables produced by *The Guardian*, for Computer Science and Information Systems Oxford was awarded 100/100 for student satisfaction and scored very well across all other categories.

Oxford University is also the top choice for anyone who wants to graduate and continue into a career in Computer Science or related industries. Tech commentator website *Business Insider* has said Oxford is the best University in both the UK and Europe to attend if you want a great job in tech. It identifies investment from Google as just one reason for our success.

Assessing models: Web Lab

In September the department hosted the Cardiac Electrophysiology Web Lab Workshop. The Web Lab (https://chaste.cs.ox.ac.uk/WebLab) is a new online system developed in the Computational Biology Group, that supports easy definition of simulated experimental protocols, and allows any heart cell model to be tested under these protocols. This enables examination of the behaviours of such models under different experimental conditions: both to characterise a model's behaviours, and to compare hypotheses by seeing how different models react under the same protocol. https://goo.gl/AXjc1a

Fellowship awarded for verification of linear dynamical systems research

Professor James Worrell has been awarded an EPSRC Established Career Fellowship for a research project called Verification of Linear Dynamical Systems. Current computer-aided design tools allow engineers to create models and test them, but not to *verify* them, ie, to conclusively prove that they meet their specification. The goal of this project is to develop techniques to analyse linear dynamical systems for the purposes of automated verification.

EPSRC Established Career Fellowships are awarded to academics who have an outstanding track record of research, impact delivery, leadership and innovation. Fellowship holders at this level are recognised internationally and are known for pushing the boundaries of enquiry within their field. In addition to their strong academic profile, they show an on-going commitment to inspire and maximise the potential of future research leaders.

Let's get physical: embedded systems

Kasper Rasmussen has been awarded the Royal Society University Research Fellowship (URF) for 2015. Kasper joined University of Oxford in 2013 as a Lecturer in the Computer Science Department. Before coming to Oxford Kasper completed his PhD at the Department of Computer Science at ETH Zurich, and then worked as a post-doc at University of California, Irvine. Below he discusses the background to his research.

The small computers that are automating more and more aspects of our lives are collectively called 'embedded systems' or sometimes cyber-physical systems. An embedded system consists of a micro controller, ie a small chip capable of performing calculations, and some form of interaction with the physical world. Such systems permeate every aspect of modern life: they are used in anything from modern cars where embedded systems manage braking, power steering, engine performance, etc; to factory control systems where such systems control sensors and actuators as well as the flow of diagnostic information.

A lot of research has been devoted to how embedded systems can be made more robust against deliberate attacks from an adversary. This includes research in different mobility and adversarial models, as well as secure communication and tamper-evident hardware, ie hardware that is difficult to alter without leaving an obvious trace. For many embedded systems, wireless security is also a crucial area; countless protocols have been proposed for use between embedded systems, to solve everything from key exchange to routing.

There is one aspect of embedded systems that has so far received very little attention, namely the interface between the physical world and the embedded system. The interfaces with embedded systems that have most often been considered in the past are radio interfaces, or components that allow interaction with people, eg buttons, keypads, etc. The interface that this project aims to explore is the interface between the embedded system and the sensors and actuators that are attached to the system.

Any embedded system that wishes to control or measure something, must have a sensor or an actuator attached as a peripheral element. Sensors come in many different varieties but most are 'dumb' devices that convert the quantity they are supposed to sense into an analog electrical signal that can be processed by a micro controller. As an example consider a microphone measuring sound. A condenser microphone consists of a diaphragm which acts as one plate of a capacitor (an electrical component consisting of two parallel plates that never touch), and the sound vibrations affect this diaphragm to produce changes in the distance between the plates. The voltage maintained across the capacitor plates thus changes with the vibrations in the air. Given this construction there is no way for the microphone itself to authenticate the signal coming out of it. The signal is simply the result of a physical process. This means that the micro controller has no choice but to consider whatever comes from the microphone as authentic.

Initial experiments have shown that it is possible, indeed quite easy, to induce a current in the wires connecting a microphone to an embedded system using an electromagnetic signal. This means that such an embedded system could be fooled into believing that sound was present at the microphone, while in fact the audio signal was being induced using (inaudible) radio waves from (potentially) far away. Due to that lack of authentication the micro controller has no way of differentiating between a signal generated by the attached microphone and one induced by adversarial electromagnetic interference (EMI). The fact that this can be done from far away, only makes the problem more serious and potentially more damaging, since an attacker can have a large circle of influence.

There has been surprisingly little research on this topic so far. Some work has been done in the area of electromagnetic interference, in the context of fault tolerance and reliability. Notably, NASA has done several experiments on the behaviour of electronic circuits in outer space. This work is mainly concerned with the impact of bit flips (changing a 0 to a 1 or vice versa), caused by cosmic radiation; how to shield wires from radiation and so on.

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Shielding is certainly going to help reduce the impact of EMI, however no shielding method can completely block an electromagnetic signal. RF (Radio Frequency) signals are only attenuated by shielding and thus it becomes a race between the adversary who can buy bigger and more powerful equipment, and the defender who can put on a thicker, heavier, more durable shield. It is not feasible in all scenarios to just increase the amount of shielding. Consider for example the field of implantable medical devices (IMDs), where embedded systems are packaged in sealed containers and implanted into the human body to control things like pacemakers, insulin pumps and so on. In IMDs form factor and size, and to some degree weight, play a huge role in the functional characteristics of the device. It is not possible to simply add more lead shielding, even if that is desirable from an EMI point of view.

Another application where arbitrarily thick shielding cannot easily be applied is the aviation industry. In aviation 'fly-by-wire' is seeing more and more use in civilian airliners. Fly-by-wire refers to an aircraft where the control surfaces are moved, not by steel cables as was the case in the past, but by electronic commands, sent through wires to embedded devices located near the control surface. These devices will then interpret the commands and move the control surface accordingly. Fly-by-wire enables much more fine grained control and easier integration of computerised flight control systems, such as auto pilots and auto landing systems, which in turn gives better flight characteristics. However, it also means that the control surfaces of the plane are ultimately driven by electric motors. A plane's internal communication bus can employ shielding and digital signal coding to make sure interference cannot inadvertently create unintended commands, even if the interference is malicious in nature. The same cannot be said for the final analog interface between the controlling device and the electric motor. The embedded device receiving commands from the flight computer will ultimately translate those commands into analog signals driving a stepper motor. The analog motor interface cannot be protected by the same encryption and signal coding mechanisms as are used on the communication bus, because the motor is a 'dumb'

analog device. If an adversary can inject signals into the electric motor (wires) directly, they will be able to influence the control surfaces. Perhaps ultimately be able to control the plane remotely.

These vulnerabilities do not only apply to control surfaces of planes but also to more subtle functions in a wide variety of vehicles and other areas. For example fuel injection in an engine is controlled by a valve that is opened and closed by a solenoid connected to an embedded micro controller. If the solenoid can be opened or closed directly, bypassing the micro controller, an adversary would be able to stop or accelerate a running car. For similar reasons the brakes could be influenced by an adversary to either brake, or prevent braking of a moving car.

By focussing on the interface between the physical world and the embedded system it is hoped that this research will improve security across a range of different industries.

Computer Science granted Bronze Athena Swan Award

The department's work in advancing gender equality has been recognised with an Athena SWAN Bronze departmental award. The award recognises commitment and success in developing practices to support the careers of women in science, technology, engineering, maths and medicine (STEMM) in academia and research.

Professor Michael Wooldridge, Head of Department commented *'I'm tremendously proud of this award, recognising our firm commitment to support women in Computer Science. The department is a recent development for Oxford University – we trace our origins to the 1950s, which is nothing when set against the university's eight century history. But even in the 1950s – comfortably within living memory – an initiative like Athena Swan would have been unimaginable. Since then, the working environment for women in science has surely improved immeasurably. But this is not the end of the story: there is still a lot more work to do, and we will see many more changes in the years to come. This is fantastic news, and testament to the incredible amount of work that went into the submission.'*

An awards ceremony was held on 15 June 2015 at the University of Greenwich. The award was collected by Professor Marina Jirotka and Department Administrator Sharon Lloyd on behalf of the department.

The University of Oxford was a founder member of the Athena Charter and has held an institutional Bronze award since 2006. More information: ecu.ac.uk/equality-charter-marks/athena-swan/

News in brief

Professor Ursula Martin, Associate Professor Edith Elkind and Senior Research Fellow Dmitrii Pasechnik are involved in an open source software project to extend the capacity of computational mathematics and interactive computing environments. OpenDreamKit is a €7.6 million project funded by the European Union's Framework 2020 project, and brings together 15 academic and industry partners from France, Germany, Norway, Poland, Switzerland and the United Kingdom. The resulting code, together with associated data and research publications, will be made available as open source software. opendreamkit.org/

Aurore Lyon [pictured right] has been awarded the Young Investigator Award at the 2015 Computing in Cardiology (CinC) Conference in Nice, France. Aurore's work is part of her DPhil in computational medicine at the interface of Computer Science and medicine. It focuses on the analysis of the electrocardiogram to identify potentially lethal abnormalities in cardiac function in patients with hypertrophic cardiomyopathy using signal processing and machine learning techniques.

Alan Turing Institute announces Director

In the summer of 2015, The University of Oxford became a founding partner in the newly formed Alan Turing Institute, the UK's national institute for data science.

This collaboration between EPSRC (Engineering and Physical Sciences Research Council), The British Library, Oxford University, Cambridge University, University College London, Warwick University and Edinburgh University will be headed up by Professor Andrew Blake, who will be the first Institute Director. Andrew is currently a Microsoft Distinguished Scientist and Laboratory Director of Microsoft Research.

The institute is headquartered at The British Library, at the heart of London's knowledge quarter, and will bring together leaders in advanced mathematics and Computer Science from the five founding universities and other partners. It marked its first few days of operations with the confirmation of £10 million of research funding from Lloyd's Register Foundation, a research partnership with GCHQ, a collaboration with Cray Inc. and EPSRC. The institute will commence research work this autumn.

The institute's mission is to: undertake data science research at the intersection of Computer Science, mathematics, statistics and systems engineering; provide technically informed advice to policy makers on the wider implications of algorithms; enable researchers from industry and academia to work together to undertake research with practical applications; and act as a magnet for leaders in academia and industry from around the world to engage with the UK in data science and its applications. Further information: turing.ac.uk/

Rewiring perceptions – Creating a generational gender shift

Computer Science is a subject notorious for harbouring preconceived perceptions about those who study, and work in the sector. The department is taking a leading role among higher education institutions to try and break down those perceptions. In April this year, Anne-Marie Imafidon [pictured below] was invited to give a keynote address at the department's annual Women in Computer Science event. This full-day conference held at the department saw up to 60 secondary-school students attend lectures given by various speakers about Computer Science.

Anne-Marie was accepted to read for a degree in Mathematics and Computer Science at Oxford when she was just 15. After graduating with a Master's at age 19, she went on to set up STEMettes, with a vision of creating a world where 'girls will be able to make informed decisions about careers in science, technology, engineering and maths, so that eventually women can be proportionally represented in the field'. More information can be found at www.stemettes.org

Anne-Marie's keynote lecture was just one in a diverse programme of lectures and talks given at the event. Facebook led a session on life as an Engineer at the company and many female members of the department talked about their own areas of research, including game theory, quantum computing and cyber security.

Women in Computer Science is among many other events that the Department of Computer Science organises throughout the year to help break down barriers and perceptions held by young people about Computer Science, and the University of Oxford. Further information: www.cs.ox.ac.uk/opendays

News in brief

The 12th International Workshop on Quantum Physics and Logic (QPL) took place at the department in July 2015. QPL is a workshop that brings together researchers working on mathematical foundations of quantum physics, quantum computing, spatio-temporal causal structures, and related areas such as computational linguistics. The prize for best student paper was won by Oxford DPhil student Amar Hadzihasanovic for his paper: *'A diagrammatic axiomatisation of the GHZ and W quantum states'*.

Professor Peter Millican spoke at the Sunday Times Festival of Education in Berkshire in June. His session was titled 'Coding and Computer Science in the Classroom (KS2-5)'

ACM A.M. Turing award winner Shafi Goldwasser gave the Oxford Women in Computer Science Society (OxWoCS) Distinguished Speaker Lecture in April. She spoke on 'Modern Cryptography in the Age of Cloud Computing'.

Pirates, philosophy, cyberwar and censorship – lots of inspiring topics were covered in the research showcase held at the Centre for Doctoral Training in Cyber Security on 1 October.

Media wall

Our pick of the latest podcasts and vodcasts that feature Computer Science research at Oxford.

- **Oxford in your Day**
  Work from the University of Oxford appears in your daily life more than you might think... http://goo.gl/5PP1qL
- **Cyberspace Governance – Sadie Creese**
  'Cyberspace is the new nervous system for the world,' says Professor of Cyber Security Sadie Creese, 'We are all interdependent and interconnected.' The video explores some of the challenges of governing and protecting this collective space. http://goo.gl/KPzdl4
- **Howard Bentham – Ashutosh Natraj**
  Ashutosh Natraj appeared at BBC Oxford on Howarth Bentham's morning talk show, discussing UAVs (Unmanned Aerial Vehicles) safety, and how intelligent software can ensure safe use of UAVs. http://goo.gl/fmM0Lg

Resistance is futile

A new computational model helps to find innovative ways to tackle the dangerous problem of antibiotic resistance in bacteria. Doctoral student Dan Nichol [pictured below] explains his research.

Antibiotic-resistant strains of bacteria are currently causing an annual worldwide death toll totalling hundreds of thousands of lives. A recent report from the *Review of Antimicrobial Resistance*, commissioned by the government, suggests that this number could reach 10 million by the year 2050. This rapid increase in the rate of antibiotic resistance has been coupled with a drastic slowdown in the discovery of novel antibiotic compounds. It is becoming ever clearer that this crisis cannot be solved simply by discovering novel antibiotics; instead we must find new uses for existing drugs in treating highly-resistant disease.

Traditional medical wisdom is that to effectively treat infections we should prescribe the most effective drugs, at the highest tolerable dose, for as long as is needed to clear the infection. However a new paradigm, known as *adaptive therapy*, which has emerged from mathematical modelling of the treatment of bacterial infections, viruses and cancer suggests that this strategy may be driving resistance.

By considering disease from the Darwinian perspective, where treatment imposes selective pressure and drives the evolution of resistance, mathematical modelling (coupled with biological experiments and clinical observation) suggests that the optimal treatment strategy may be to prescribe multiple drugs, in sequence or in combination, to pre-empt or exploit evolution.

Using a simple computational model which encodes the population dynamics of an evolving bacterial population as a Markov chain, Daniel Nichol and Jacob Scott have built a tool capable of predicting sequential adaptive therapies for E. coli which reduce, and in many cases entirely prevent, the risk of highly resistant disease emerging.

To design these adaptive therapies it is first necessary to predict how a population of bacteria will evolve. Recently published empirical measures of the fitness landscapes of E. coli under fifteen different antibiotics have made these predictions possible. A fitness landscape is a mapping which assigns to each possible bacterial genotype an associated level of resistance, or fitness, to a given drug. The landscape metaphor, first introduced by Sewell Wright in the 1930s, is a visualisation of this mapping as a surface on which an evolving population 'climbs' uphill. By considering the relevant bacterial genotypes as the vertices

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of a weighted directed graph, where the edge weights encode the probability of a change in the population genotype, this 'uphill climb' in the fitness landscape can be reduced to a biased random walk on a graph. By encoding this random walk formally as a Markov chain, the complex process of evolution within a population of bacteria exposed to an antibiotic is reduced to a single matrix multiplication. The immediate consequence of this model is that, as matrix multiplication is non-commutative, the order in which drugs are given will have a significant impact on the final state after evolution. This observation leads to a natural question: are some orderings better than others?

In their work, published this month in *PLOS Computational Biology*, Daniel and Jacob show that the answer is 'yes'. Using the recently published landscapes for E. coli, the research demonstrates that it is possible to prime the disease population using sequences of one to three antibiotics such that resistance to a final antibiotic cannot emerge. This finding suggests a new treatment strategy in fighting antibiotic disease: adaptive therapies which use sequences of drugs to steer, in an evolutionary sense, a disease population to a configuration from which it is both readily treatable but also from which resistance cannot emerge.

As well as demonstrating the possibility of adaptive, sequential therapy for treating highly-resistant bacterial infections, Daniel and Jacob also provide a cautionary warning regarding current clinical practice. When antibiotics are prescribed in sequence, as is often the case in treatment of H pylori, Hepatitis B or the transition from broad to narrow spectrum antibiotics, no guidelines presently exist to specify the order in which drugs should be given. Instead this decision is left to the clinician's personal preference.

By checking all possible sequences of two, three or four antibiotics for which empirical landscapes are known, the research reveals that the majority, over 70%, of drug sequences *increase* the likelihood of resistance emerging to the final drug (when compared to giving that drug alone).

In particular, giving Piperacillin+Tazobactam, an antibiotic often used after others fail, as the final drug in a sequence of two or three antibiotics increases the likelihood of resistance arising in over 90% of cases. By giving drugs in arbitrary orders we may be inadvertently encouraging the emergence of antibiotic resistance just as giving drugs with incorrect doses can do so.

To move their theoretical findings towards the clinic, Daniel and Jacob have partnered with microbiologists at the Louis Stokes Department of Veterans Affairs Hospital in Cleveland to perform empirical tests of evolutionary steering. They are also working with Dr Alexander Anderson and Dr Robert Gatenby at the Moffitt Cancer Research Center, to adapt their model to predicting the effectiveness of cancer therapies.

A major impediment to designing adaptive therapies using their method is that measuring fitness landscapes is a complex problem where the number of strains that need to be synthesised grows exponentially with the number of mutations of interest. Despite this difficulty, empirical fitness landscape research, aided by machine learning techniques which help to reduce the number of strains that need to be synthesised, has grown rapidly in recent years. As this trend continues the potential for therapies exploiting evolutionary steering, and with it the role of computational models in designing treatment, will continue to grow - hopefully enabling better treatment for a variety of deadly diseases in the future.

http://goo.gl/WcdxmC

Project contributors:

Daniel Nichol – 1 & 5
Peter Jeavons – 1
Alexander G. Fletcher – 2
Robert A. Bonomo – 3
Philip K. Maini – 2
Jerome L. Paul – 4
Robert A. Gatenby – 5
Alexander R.A. Anderson – 5
Jacob G. Scott – 2 & 5
Eric Haura – 5
Chris Bryant – 6

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4 – School of Computing Sciences and Informatics, University of Cincinnati, Cincinnati, USA
5 – Department of Integrated Mathematical Oncology, H. Lee Moffitt Cancer Center and Research Institute, Tampa, USA
6 – Department of Medicine, Case Western Reserve University, USA.

OxCEPT spin-out finalist at the Mobile Innovations Awards

Oxford spin-out OxCEPT, the technology company behind the development of one of the world's most secure protocols for transmitting data, has reached the finals in the 'Best Management of Mobile Security' category of the Mobile Innovations Awards.

OxCEPT is focused on the development and commercialisation of authentication security technologies and products. The spinout developed Scrambl, a smartphone communications app designed to keep its users safe from hackers and thieves. It is based on the proprietary HCBK authentication protocol originally invented to protect the military communications of the UK Department of Defence.

Bill Roscoe, Professor of Computing and OxCept Director of IP, said *'It's wonderful that our new user-centred model of security has caught the imagination of the panel like this. I am looking forward to the imminent release of Scrambl and its take-up by a number of organisations that have agreed to use it'.*

Annich McIntosh, Director of the Awards said *'This year there was a 100% increase in entries, which demonstrates the level of creativity and ingenuity transforming the way we lead our mobile lives.'*

Further Information: www.oxcept.com

Perfecting the folds: improving techniques in DNA Origami

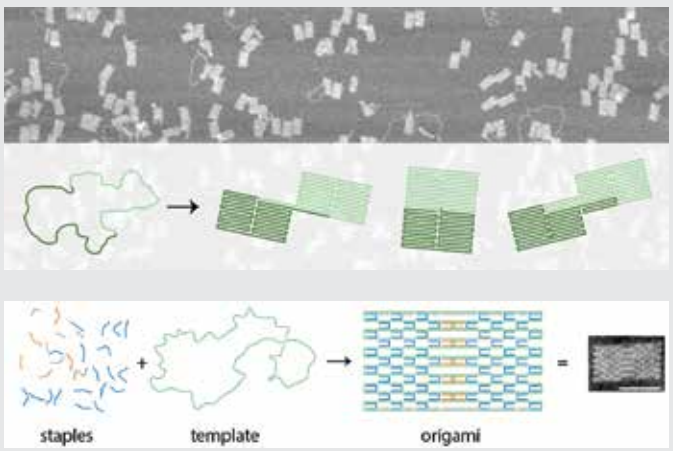
A group of researchers from the Departments of Physics and Computer Science at Oxford have published a paper in *Nature* about their investigation into how DNA origami folds. Computer Science DPhil student Frits Dannenberg, who is supervised by Professors Marta Kwiatkowska and Andrew Turberfield, developed the folding model that was successfully used to predict the outcome of their experiments.

Nearly ten years ago, researchers first described a technique to fold a long single strand of DNA into various two- and three-dimensional shapes. DNA origami has the potential to be developed as the basis for designing and mass-producing nano-sized objects that can interact with molecules and human cells. Such objects would have many important medical applications.

However, while DNA origami is a reliable technique for simple structures, it begins to fail when applied to more complicated structures. Current research is devoted to designing a system so we can better understand the mechanism that makes DNA origami fold in the way that it does. The paper reports on findings that demonstrate the existence of efficient folding pathways – analogous to the folding landscape of proteins.

Read more on the University's Science Blog: www.ox.ac.uk/news/science-blog/origami-life The full report can be read in *Nature* and is co-authored by Katherine Dunn, Jon Bath, Andrew Turberfield, Tom Ouldridge, Frits Dannenberg and Marta Kwiatkowska.

http://goo.gl/qfXlWq



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Digital Wildfires

(Mis)information flows, propagation and responsible governance are the key themes of new research around social media, being conducted by Professor Marina Jirotka and Dr Helena Webb.

Social media platforms such as Facebook, Instagram, Snapchat and Twitter are a popular feature of modern life which enable users to share content with others around the world. The increasing popularity of social media brings many benefits but also risks such as 'digital wildfires' in which provocative content spreads rapidly and can cause serious harm. This provocative content may take the form of a rumour, false information, hate speech, or a malicious campaign against others. When it spreads rapidly it can damage the reputation and well-being of individuals, groups or entire communities. The prevalence of digital wildfires in modern life has led to questions over the appropriate regulation of social media. Should the police and legal system take more interest in what is posted on social media or should social media companies do more to limit the spread of provocative content? What should individuals do to ensure they post responsibly? What about rights to freedom of speech?

The Digital Wildfires project seeks to address some of these important questions. A collaborative group of computer scientists and social scientists from the Universities of Oxford, Warwick, Cardiff and De Montfort are analysing social media datasets to assess how digital wildfires emerge and unfold. They are identifying forms of 'self-governance' through which social media users manage their own and others' online behaviours and will examine how these practices may be consolidated to limit the damage caused by digital wildfires. They are also identifying and drawing on the perspectives of social media companies, legislators, the police, civil liberties groups, anti-harassment organisations, and educators. Through these activities the researchers will explore potential regulatory tools and mechanisms on social media.

It is anticipated that the project will advance the responsible governance of social media in relation to the risks of digital wildfires. Research Associate Helena Webb explains: *'We will produce an "ethical security map" that will assist stakeholders to navigate through current policy and make informed decisions about appropriate behaviours on social media. We will also develop materials that aim to promote digital maturity amongst potentially vulnerable social media users, such as children and teenagers. We are holding a range of project events, including a one-day workshop in London in January 2016. We will present some of our project findings and invite other researchers to discuss their work on social media, provocative content and responsible governance.'* The workshop will also include a youth panel in which young people will discuss their concerns about social media and Baroness Beeban Kidron, founder of the iRights campaign for young people, will deliver a keynote address.

Further information: www.digitalwildfire.org, contact helena.webb@cs.ox.ac.uk or on Twitter @EthicsWildfire.

This research complements the work of Dr Jason Nurse, a Research Associate within the department's Cyber Security group, who has focused on innovative ways to use social media for good. Amongst other things, his work has involved the creation of novel tools to assist users in assessing the confidence they should place in social media content when making decisions, and also the development of systems to extract real value from hundreds of thousands of social media posts, to support activities such as tourists planning holiday trips or companies gathering market intelligence.

ALUMNI ROUND-UP

A letter from...
the Development and Alumni Manager

The long vacation has whizzed by here in Oxford, and we find ourselves once again at the start of a new academic year. In the spirit of new beginnings, I'm delighted to let you know that we have recently relaunched the Department of Computer Science Alumni Network website. The new website allows you to update your personal details, interests and communications preferences, as well as featuring news from the department, forthcoming events, and more. We will be writing to you all with information about how to log into the new website, so do check your emails.

We hope that you like the new website and welcome your comments on how we might improve it in future.

Alumni Weekend Events
It was lovely to see so many of you at the recent Alumni Weekend. Computer Science was well represented across the weekend programme, with members of the department participating in a lively panel discussion on Artificial Intelligence and the Software Engineering Programme's annual lecture, delivered by Alan Rusbridger.

Survey
Thank you to all those of you who responded to our recent survey. The results made for extremely interesting reading and we look forward to working more closely with all those of you who were keen to become more involved. As ever, if you have any thoughts, comments or suggestions, please do email alumni@cs.ox.ac.uk.

Changes to the Alumni Office
Finally, I wanted to let you know that after a fantastic 18 months, I will be leaving the Department of Computer Science to take up a new role within the university. I will take this opportunity to say how much I've enjoyed getting to know you over the past year and a half, and to thank you all for your support in getting the alumni network up and running.

The department remains committed to developing and growing its alumni activities and we have a number of exciting plans that will be announced over the coming months. So do keep in touch – follow us on Twitter, like us on Facebook, and register with our new website so that we can keep you up to date with our plans.

Frances Wheare,
Development and
Alumni Manager

From AI to Snowden:
Alumni Weekend 2015

This year, the Department of Computer Science was involved in three events during the 2015 Meeting Minds: Alumni Weekend in Oxford.

We started at the Saïd Business School, the main venue for the weekend's events, where Head of Department Michael Wooldridge joined Professors Nando de Freitas and Stephen Pulman in a panel discussion chaired by Dr Cecilia Tilli, Academic Project Manager at the Future of Humanity Institute. 'The quest for artificial intelligence' considered recent advances in machine learning and assessed the ethical, philosophical and practical consequences of such technological advancement, provoking lively discussion from members of the audience.

Over at the Robert Hooke Building, Software Engineering Programme and Computer Science alumni caught up with members of the department over tea and cakes.

Shortly afterwards, guests arrived at the Museum of Natural History for the Software Engineering Programme Annual Lecture, given by Alan Rusbridger, former Editor-in-Chief of *The Guardian* and incoming Principal of Lady Margaret Hall. Entitled *'The 21st century surveillance state: implications of the Snowden revelations'*, the lecture covered privacy, security, press freedom and public interest, and ended with a simple call to action: *'My appeal is to try and get software engineers to help inform this debate. There are an immense number of complex and interrelated issues and we need to find a way of talking about them.'*

Alumni Profile

Dr Pia-Ramona Wojtinnek (Somerville, 2008)

Dr Pia-Ramona Wojtinnek joined the University of Oxford from Bonn University and the University of Cologne in Germany, with a background in Medieval German Language and Literature as well as Mathematics and Computer Science. Here, she talks about her experience as a DPhil student in Oxford. She currently works for investment management company GSA Capital as Senior Strategist.

Before starting your DPhil in Computer Science, you studied languages and linguistics. What attracted you to Computer Science, and was it a difficult transition to make?

I read for both Mathematics with Computer Science (at the University of Cologne) and Medieval German Language and Literature (at Bonn University) during my undergraduate studies and then proceeded to a Master's in General Linguistics. Doing a DPhil in Computer Science, in particular in Computational Linguistics, allowed me to work on the intersection of these fields. When I started my DPhil, I needed to expand my programming skills, but I found the fact that I had a background in both fields to be very valuable.

What made you decide to focus on Computer Science?

I was attracted to Computer Science as a general field because of its applicability to a variety of areas: during my time as an undergraduate I did research on applying graph theory to sociopolitical networks, my DPhil concerned computational representation of lexical semantics, now I work in quantitative trading of equities.

How did student life in Oxford compare to your time at the university in Germany?

Oxford has a campus-like feel to it, with the university forming an essential part of the city and the college providing a particular social structure for the students. Student life at Cologne and Bonn, both large city universities was more loosely organised, such as being connected through tutorial groups, so there was a different balance between social life within and outside of the university.

What did you enjoy most about your time at Oxford?

I really enjoyed my time at the Department of Computer Science, because there was a very friendly atmosphere amongst students, academics and other staff. The academics were always approachable, which makes for a welcoming study and research environment. I also rowed for Somerville and was part of the Oxford University Salsa Team, which were both great experiences.

How do you think doing a DPhil has helped you?

The DPhil showed me that I enjoyed doing applied research and coding up large projects. I wanted to continue working quantitatively, while learning something completely new and seeing a very direct impact of my research. Quant trading was a great choice as it allowed me to apply some of the techniques I knew to a very different field. At the same time, there is a growing interest in exploiting textual news and sentiment for trading so there is a lot of scope for using my background in Computational Linguistics.

What advice would you give to someone who's unsure about where their degree might take them?

Computer Science is a very versatile degree, so there are a lot of directions you can go into afterwards. The question of what comes next can be daunting and often the reality is that you don't know whether something is right for you until you just give it a go. My advice would be not to get too stressed, and to follow the questions that sound interesting. To get some ideas for jobs outside of academia, job fairs can be helpful such as the one organised by the department or the startup-focused Silicon Milkroundabout in London, as well as talking to people.

News in brief

This year, the University of Oxford marks the 200th anniversary of Ada Lovelace with a series of events celebrating her life and work. As part of this series, the Department of Computer Science will hold the inaugural Lovelace Lecture, the first in an annual series of lectures to be delivered by an eminent female computer scientist. The first lecture will be given by Professor Barbara Liskov, Ford Professor of Engineering at MIT and winner of the 2008 ACM A.M. Turing Award for Computing. The lecture is generously supported by Facebook. Alumni welcome. For further information on all Ada Lovelace events and details on how to book, visit: blogs.bodleian.ox.ac.uk/adalovelace/events/

A symposium, celebrating Ada Lovelace's 200th birthday is being held on 10 December 2015 in Oxford. It is aimed at those interested in the history and culture of mathematics and Computer Science, presenting current scholarship on Lovelace's life and work, and linking her ideas to contemporary thinking about computing and artificial intelligence. blogs.bodleian.ox.ac.uk/adalovelace/symposium/

Cyber Security update

Early-careers researchers symposium for cyber security research in Oxford

On 30 September the inaugural Early-Careers Researchers Symposium for cyber security research was held in Oxford. Organised by the Cyber Security Oxford network, the multidisciplinary event drew together researchers and doctoral students working in the field from across the university. The diverse range of talks making up the day included 'The evolution of computer misuse legislation', 'Exposing insider threats using eye movement biometrics' and 'States' use of proxies in the cyber domain'. The event was hosted by the Computer Science Department with support from Ocado Technology.

Cyber Security Technical Papers available

During their first year, Centre for Doctoral Training (CDT) students embark upon their own research projects that deal with the real-world issues and implications of cyber security, as well as theories and foundations, exploring the topic for the long term. These projects promise to provide a fascinating look into how cyber security affects our everyday lives and where its weaknesses and strengths lie. The research areas covered range from the domestic application of cyber security in the household to the national and multinational level. For example, recently students have been exploring how on a national level we deal with a cyber-crisis and comparing this with other EU states. Other students have been looking into the security implications of cyber-physical systems such as air traffic control.

All of the research projects aim to both provide insights into the strengths and shortcomings of cyber security in the current day, and also what needs to happen in the future to remain secure as an increasing number of objects become linked via networks. As we enter into a new technological age and as digital networking has become integral to our daily lives the security of these networks is paramount and we expect our CDT students to be at the forefront of providing and researching the solutions to problems seen today and anticipated tomorrow.

The CDT's Technical Paper series allows our students to disseminate their work via the Oxford Research Archive to a wide audience, demonstrating the high quality research being undertaken.

For more information on our students' research, please see www.cybersecurity.ox.ac.uk/techincal-papers

Uganda & Kosovo: *going global with cyber security capacity development*

The Global Cyber Security Capacity Centre (GCSCC) is a leading international centre for research on effective security capacity-building. It has created a new kind of model to measure cyber security capacity maturity, which aims to enable nations to self-assess, benchmark, better plan investments and national cyber security strategies, and set priorities for capacity development.

The last few months have been extremely busy, with research teams visiting a wide range of countries to apply the model, most recently to Uganda, with further assessments taking place shortly in the UK and in Indonesia (in cooperation with the Oxford Internet Institute). June saw the successful launch of the first assessment report in Kosovo, in collaboration with the World Bank.

The centre attended the Global Conference on CyberSpace 2015 in the Hague. It secured funding from the Dutch Government to enhance the online Cybersecurity Capacity Portal, which lead to the appointment of Carolin Weisser as a new portal manager. The centre continues to attract international recognition and was pleased to be awarded additional funding from the Norwegian Government. Two new researchers, Lilly Muller and Eva Ignatuschtschenko, joined the team in September.

Further information: www.oxfordmartin.ox.ac.uk/cybersecurity/ www.sbs.ox.ac.uk/cybersecurity-capacity

London CyberHack success

Oxford students won two of the four available prizes at the London CyberHack for Financial Security, organised in July by The Accelerator Network, NatWest, and the Department for Business, Innovation and Skills (BIS).

The challenge was to help NatWest better identify and authenticate their customers, providing a seamless experience without compromising security – and ideally improving it. The Oxford team, made up of Katriel Cohn-Gordon, Max Whitby and Martin Dehnel-Wild from the Department of Computer Science, and Linda Geaves from the School of Geography and the Environment, won both 'Best Design and User Experience' and 'The NatWest Challenge' categories, scooping £2,000 in prize money. Their project, based on developing friend-based network authorisation or rejection for potentially suspicious transactions, particularly focused on supporting the elderly or vulnerable people who aren't tech-savvy or smart phone users.

We asked Linda Geaves about her experience participating in the Hackathon: *'The Hackathon was a great experience, especially working in collaboration with the guys from CS, of whom I cannot speak highly enough.*

I saw the Hackathon publicised on the Oxford Entrepreneurs Network, and, having taught myself to code for over a decade and then worked alone on a Computer Science based DPhil project in Oxford's Environmental Change Institute, I really wanted to get some idea of where my skills were in comparison to other computer scientists.

So, taking part in the Hackathon, having such a great, welcoming and open-minded team, and then winning has meant an awful lot to me, as I know all the years I've put in to learning bits and bobs in Computer Science hasn't been in vain! Plus, it was great to combine the theories and issues learned in geography to those in cyber security, as there are many overlapping subjects, and, I believe, many areas for collaboration.'

News in brief

Jassim Happa has been invited to give a course in cyber security, on the topic of cyber situational awareness at the Centro de Investigación en Computación del Instituto Politécnico Nacional in Mexico City, in November.

DPhil student Ines Marusic won an Anita Borg Memorial scholarship. The Scholarship is given annually by Google to encourage women to excel in computing and technology at university, and encourages women to become active role models and leaders within their field.

DPhil student Elizabeth Phillips received a student travel grant to attend the IEEE Symposium on Security and Privacy (S&P) and the Women in Cybersecurity (WiCyS) conferences. She will also attend a two-week summer exchange with the US Embassy for Future Cyber Leaders.

Elizabeth Phillips also won a scholarship to attend the 2015 Grace Hopper Celebration, along with fellow DPhil student Ines Marusic. Grace Hopper is the largest gathering of women technologists, organised by the Anita Borg Institute and the ACM (the Association for Computing Machinery).

Increasing railworker safety: the TrackSafe project

Developing magneto-inductive positioning to protect lives on the railways

Every day, over 70,000 workers access railway lines across the UK to maintain, repair and construct tracks and equipment. Working alongside railway lines is extremely dangerous and strict safety regulations, are in place to reduce the frequency of accidents. Despite these regulations in the UK alone four workers were killed in the last three years from being struck by trains, with many more injured. This is particularly relevant for workers close to operational lines (known as red-zones), where trains can approach at over 100mph, giving very little warning of arrival. As trains become automated (driverless) the need for a technology-driven safety system becomes more and more critical.

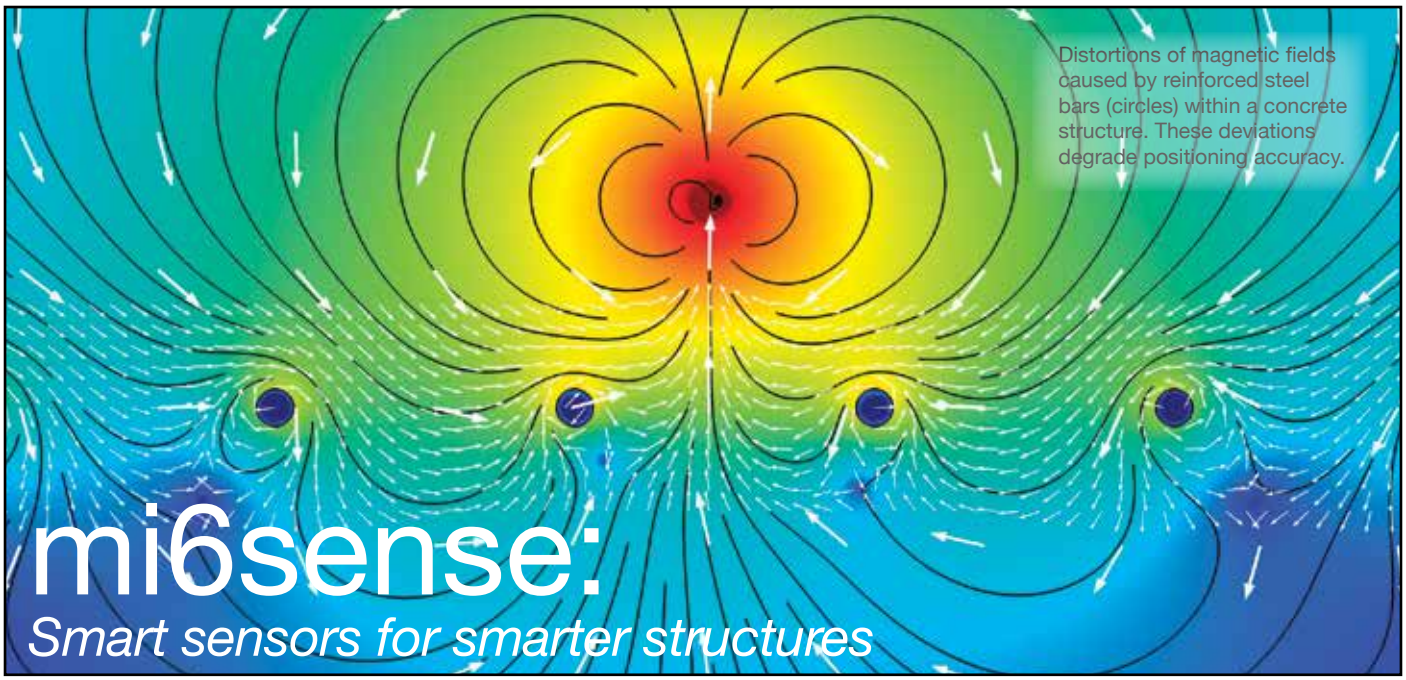
Safe working practice is frequently complicated by dark and confined operating conditions and the use of noisy equipment. As a particular example of a near miss, in May 2014 a train travelling at 100mph almost struck nine track workers. A lookout positioned two miles up the track failed to give a warning over the radio system that would have given the workers 45 seconds to clear the track. As such, they only had three seconds to clear the track as the train came around a bend.

This incident highlights the need for an automated trackside safety system - the key factor is the ability to know, in real-time, the location of every track worker and whether or not they are in a danger ('red') zone. However, track workers often operate in environments where conventional positioning techniques like GPS fail, such as within tunnels, under bridges or next to embankments.

TrackSafe is a £1m Innovate UK funded project between a leading navigation company, Guidance Automation, and the University of Oxford to address the need for safe trackside working. The research component is led by Dr Andrew Markham and Professor Niki Trigoni and revolves around the use of low frequency magneto-inductive fields for positioning through obstacles such as tunnels, soil and concrete. The aim of the project is to develop a GPS-like positioning system that can be used in any trackside environment and is robust and reliable. Restricted areas (geofences) can be created by the site controller, which alert both workers and controllers if they stray into dangerous areas. These areas dynamically change as a train approaches, guiding workers to a pre-designated place of safety.

Magneto-inductive positioning is an innovative, patent-pending approach to determining the location of moving people and objects by sensing the changes in the magnetic vector field generated by a transmitter. Modulated magnetic fields penetrate most materials without loss. Ferrous materials however do distort the magnetic fields and one of the major challenges of this work is to maintain accurate positioning even in the vicinity of large metallic objects such as rail-lines and trains.

This proposal aims to significantly reduce the risk and danger faced by track workers everyday, by providing an automated system that warns of hazards and oncoming trains. It also seeks to improve efficiency, by providing seamless location capability underground and outdoors. As such it has immediate impact on the lives of workers, drivers and rail companies, by potentially reducing the number of fatalities and injuries. Key is the ability to position and communicate with workers who can be working in dangerous areas such as within tunnels and under bridges. As there is simply no other system that can operate through-the-earth, it is likely that this work will have significant impact not only in the UK, but globally as well.



Distortions of magnetic fields caused by reinforced steel bars (circles) within a concrete structure. These deviations degrade positioning accuracy.

mi6sense:

Smart sensors for smarter structures

Catastrophic failure of large civil structures like bridges, dams, embankments and buildings can result in human fatalities as well as other costly and environmentally detrimental consequences. Structural collapse during construction poses a high risk to people working on construction sites and failures can also occur in the surrounding groundwork, for example landslides and subsidence (sinkholes). There is a strong need for a sensing technology that is able to measure the performance of a structure over its entire lifetime, as well as its associated foundations and the surrounding soil and rock supporting the structure. This will help to provide early warning of impending failure, which apart from saving lives will inform repair operations and optimise building methods.

The current gold-standard for monitoring structural stress and failure are distributed fibre-optic sensors. These use the change in the properties of a thin fibre-optic cable to measure aspects such as strain. However, because fibre-optic sensors are essentially wired into the structure they require deployment effort and provide a point of ingress, weakening the integrity of the structure. More importantly though, fibre-optic sensors can only measure strain along the fibre axis, meaning that the three-dimensional shape deformation of the structure cannot be directly measured. The time-consuming and costly installation of fibre-optic sensors within foundations and surrounding soil/rock limits their use to high risk projects.

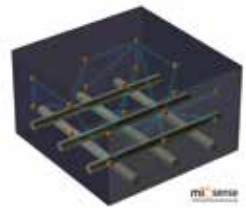
mi6sense is an ambitious two-year project led by Dr Andrew Markham and postdoc Dr Orfeas Kypris. This was one of only four projects funded across the UK by EPSRC in the Civil Engineering Big Pitch challenge, targeting blue-sky ideas. This project seeks to develop a low-cost, wireless, embeddable sensing technology (small enough to add to the concrete mix or be injected into rock) that can measure structural deformations in 3-D from deep within a structure, its foundations and surrounding groundwork. Not only can each sensor measure changes in its position, it can also measure changes in orientation, yielding a full six degrees of freedom sensor.

When mixed into the concrete pour these cm-scale, low cost sensors instantly form a self-organizing and healing communication network. These devices start monitoring from the moment the element (eg a pillar or a beam) is poured, providing information over the entire lifetime of a particular structural element, from the concrete curing process to loading, to monitoring cracks and corrosion. When structural elements are placed next to each other, the network will automatically extend to form a larger, merged communication system.

The sensors can measure their precise position and orientation within the structure and how this changes over time. With a number of these sensors the actual shape of the structural element and how it is bending or twisting with loads can be sensed. A key advantage of low frequency magnetic vector fields is that they have both magnitude and direction in 3-D. This is currently impossible to achieve using any other distributed sensing technology.

The mi6sense project has the potential to make buildings and large structures truly smart, using low cost, easy to deploy sensors that can operate from within the structure and the surrounding groundwork. Real-time monitoring of key indicators of potential failure over the lifetime of the structure will provide early warning of impending disaster, with potentially life-saving results.

Further information: mi6sense.org



View of MI sensors (spheres) obtaining 3-D measurements of position and orientation from within a reinforced concrete beam

Organic 'computers' made of DNA could process data inside our bodies

We invariably imagine electronic devices to be made from silicon chips, with which computers store and process information as binary digits (zeros and ones) represented by tiny electrical charges. But it need not be this way: among the alternatives to silicon are organic mediums such as DNA.

DNA computing was first demonstrated in 1994 by Leonard Adleman, who encoded and solved the travelling salesman problem, a maths problem to find the most efficient route for a salesman to take between hypothetical cities, entirely in DNA.

Deoxyribonucleaic acid, DNA, can store vast amounts of information encoded as sequences of the molecules, known as nucleotides, cytosine (C), guanine (G), adenine (A), or thymine (T). The complexity and enormous variance of different species' genetic codes demonstrates how much information can be stored within DNA encoded using CGAT, and this capacity can be put to use in computing. DNA molecules can be used to process information, using a bonding process between DNA pairs known as hybridisation. This takes single strands of DNA as input and produces subsequent strands of DNA through transformation as output.

Since Adleman's experiment, many DNA-based 'circuits' have been proposed that implement computational methods such as Boolean logic, arithmetical formulas, and neural network computation. Called molecular programming, this approach applies concepts and designs customary to computing to nano-scale approaches appropriate for working with DNA.

In this sense 'programming' is really biochemistry. The 'programs' created are in fact methods of selecting molecules that interact in a way that achieves a specific result through the process of DNA self-assembly, where disordered collections of molecules will spontaneously interact to form the desired arrangement of strands of DNA.

DNA 'robots'

DNA can also be used to control motion, allowing for DNA-based nano-mechanical devices. This was first achieved by Bernard Yurke and colleagues in 2000, who created from DNA strands a pair of tweezers that opened and pinched. Later experiments such as those by Shelley Wickham and colleagues in 2011 and at Andrew Turberfield's lab at Oxford demonstrated nano-molecular walking machines made entirely from DNA that could traverse set routes.

One possible application is that such a nano-robot DNA walker could progress along tracks making decisions and signal when reaching the end of the track, indicating computation has finished. Just as electronic circuits are printed onto circuit boards, DNA molecules could be used to print similar tracks arranged into logical decision trees on a DNA tile, with enzymes used to control the decision branching along the tree, causing the walker to take one track or another.

DNA walkers can also carry molecular cargo, and so could be used to deliver drugs inside the body.

Why DNA computing?

DNA molecules many appealing features include their size (2nm width), programmability and high storage capacity – much greater than their silicon counterparts. DNA is also versatile, cheap and easy to synthesise, and computing with DNA requires much less energy than electric powered silicon processors. DNA's drawback is speed: it currently takes several hours to compute the square root of a four digit number, something that a conventional computer could compute in a fraction of a second. Another drawback is that DNA circuits are single-use, and need to be recreated to run the same computation again.

Perhaps the greatest advantage of DNA over electronic circuits is that it can interact with its biochemical environment. Computing with molecules involves recognising the presence or absence of certain molecules, and so a natural application of DNA computing is to bring such programmability into the realm of environmental biosensing, or delivering medicines and therapies inside living organisms.

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DNA programs have already been put to medical uses, such as diagnosing tuberculosis. Another proposed use is a nano-biological 'program' by Ehud Shapiro of the Weizmann Institute of Science in Israel, termed the "doctor in the cell" that targets cancer molecules. Other DNA programs for medical applications target lymphocytes (a type of white blood cell), which are defined by the presence or absence of certain cell markers and so can be naturally detected with true/false Boolean logic. However, more effort is required before we can inject smart drugs directly into living organisms.

Future of DNA computing

Taken broadly, DNA computation has enormous future potential. Its huge storage capacity, low energy cost, ease of manufacturing that exploits the power of self-assembly and its easy affinity with the natural world are an entry to nanoscale computing, possibly through designs that incorporate both molecular and electronic components. Since its inception, the technology has progressed at great speed, delivering point-of-care diagnostics and proof-of-concept smart drugs – those that can make diagnostic decisions about the type of therapy to deliver.

There are many challenges, of course, that need to be addressed so that the technology can move forward from the proof-of-concept to real smart drugs: the reliability of the DNA walkers, the robustness of DNA self-assembly, and improving drug delivery. But a century of traditional Computer Science research is well placed to contribute to developing DNA computing through new programming languages, abstractions, and formal verification techniques – techniques that have already revolutionised silicon circuit design, and can help launch organic computing down the same path.

Marta Kwiatkowska is Professor of Computing Systems at the University of Oxford. This article was originally published in *The Conversation*. Read the original article at http://goo.gl/YcWeSS It is republished here under a creative commons licence.

News in brief

Following a visual-refresh the new Department of Computer Science website went live in October 2015. The URL remains www.cs.ox.ac.uk

It's a proud moment when one of your colleagues receives a cheque for 1 hexadecimal dollar! Computer Science Tutor Mike Spivey spotted an error in Knuth's *Concrete Mathematics.*

Computer Science and Philosophy undergraduate Nick D'Aloisio was named as number 3 in the FT's 'Top 10 European Tech Entrepreneurs under 30'. Before coming to Oxford, Nick founded Summly, an app that algorithmically summarises the news for the smartphone generation, which was bought by Yahoo!

Undergraduate Computer Science and Philosophy student Miraan Tabrez has been hitting the headlines with his app Tripr. He and two other Oxford students have developed a tool that connects people travelling to the same place at the same time.

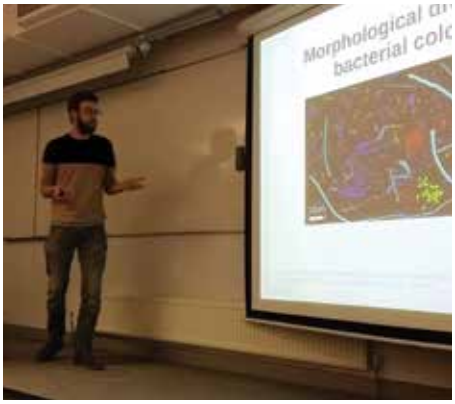
Oxford's Lambros Petrou was in a team of three MSc students who reached the final of the ACM SIGMOD 2015 programming contest. This year's challenge was to build a system to efficiently support thousands of queries over a relational database under heavy transactional updates.

Thinking about applying for one of our full-time graduate courses? Please visit the Department of Computer Science on 31 October 2015 for the Graduate Open Day, where you can find out more about DPhils, the full-time MSc, or studying at one of our Centres for Doctoral Training. http://goo.gl/4LYN2d

Computer Science Student Conference 2015

This year the Computer Science Student Conference took place on 12 June and included an impressive 11 talks and 10 posters, with representation from a variety of research groups. The conference is an annual event (originally established in the late 1990s) open to all students and staff within the department and associated Centres for Doctoral Training. The Conference is organised by students for students. Academic staff are also involved, either giving the keynote speech or helping to judge the talks and posters.

Congratulations go to six DPhil students who won awards. The standard of the presentations was so high that it was impossible to pick an overall winner and so there were two winners in each of the three categories. Prizes for the best talks were given to Andrew Paverd for his work on *'Applications of a trustworthy remote entity'* and to Daniel Nichol. You can read more about Daniel's research on antibiotic resistance on pages 8 and 9 of this edition of *Inspired Research*. Prizes for the best posters were given to Varduhi Yeghiazaryan for *'Comparison of evaluation methods for medical image segmentation'* and to Gonzalo Diaz for his work on *'The exact complexity of the first-order logic definability problem'*. Prizes for the best abstracts went to Simon Eberz for *'Looks like Eve: exposing insider threats using eye movement biometrics'* and Ciaran Lee's *'Computation in generalised probabilistic theories.'*



The World outside

Members of the department have some rather surprising talents outside of Computer Science. Below are a few non-subject-related achievements from the last year:

Elizabeth Polgreen, from the administration team, won the lightweight title and silver medal in the women's quads at the British Rowing Championship, with Wallingford Rowing club.

Jan Mikolajczak [pictured below], who reads Mathematics and Computer Science, was a member of the British Quidditch team who made their way to the European Quidditch finals in July. The Brits came second only to France, losing to a score of 90*-50.

© Emily Hayes

Katie Dicks, finance manager, took part in her tenth consecutive Race For Life which supports Cancer Research. Katie promised her mother, who battled cancer for 16 years but passed away three years ago, that she would take part in the run for ten consecutive years, raising at least £100 per race. Katie Dicks: 'Since I have worked here [7 years] I've raised between £500-£1000 each race, so everyone has been really supportive and generous' She was supported by Sharon Lloyd, Jo Leggett, Jo Smith and Jennie Charlton.

James Mountain, who is studying for a doctorate in Systems Biology, rowed for Oxford in this year's varsity match with the reserve crew that beat Cambridge on 11 April, by three lengths.

Julie Sheppard and Claire Hawtin, both members of the administration team, strolled the streets of Oxford for 10.6 miles raising £205 for Sobell House.

Kiri Walden, the department's new PR Assistant, took part in the 70th anniversary of VE Day. Kiri was part of an all-female WW2 Searchlight crew who lit up St Paul's Cathedral with their 1939 searchlight and generator as part of the national anniversary celebrations. Kiri regularly attends events and anniversaries as an ATS (WW2 women's army) reenactor.

Industry involved in practicals

Industry representatives once again 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 and demonstrated their projects at an event in May, having chosen a topic to work on in January, from eleven possible project topics that were presented as outline design briefs. The practicals allow students to develop and apply theory learnt on the course. Part of the work was to undertake a proper requirements analysis, working with the project mentor. Some challenges were set or sponsored by the industry partners, which this year included G-Research, Winton Capital, Palantir and WorldQuant.

Team 3 were awarded the Ensoft Prize for a well-designed user interface. They used information gathered from Twitter to display users' languages on a map of Europe. The team was supervised by Dr Jason Nurse, a researcher in the Cyber Security Centre, and consisted of Dan-Andrei Gheorghe, Toby Cathcart Burn, Alexander Bridgeland, Paul-Stefan Herman and Mariya Lazarova.

Team 4 were awarded a prize from Palantir for an engaging pitch. Their project gathered and analysed the sentiment of Twitter users with the intention of using the data for regional marketing. The team consisted of Christopher Kew, Michal Bock, Blagovest Gospodinov, Miraan Tabrez and Lukas Halgas, and were co-supervised by Dr Ioannis Agrafiotis, a Research Assistant in the department, and Dr Jason Nurse.

Team 6 were tasked with predicting stock movements using information from news headlines. They were given a prize from WorldQuant, for careful assessment of multiple learning models. Professor Alessandro Abate supervised the team, which consisted of Tomas Vaskevicius, Matthew Gripton, Ying Zhu, Robert Carlan and Zichuan Huang.

Team 7 produced a car racing game, driven by an artificial intelligence, and were awarded a prize by Metaswitch for their impressive demonstration. The team were Mateusz Dombrowksi, Ozan Sevsevil, Matthew Boughen, Xin Sun and Mengying Xue, and their mentor was lecturer Dr Peter Minary.

Finally, team 11 were awarded a prize by Bloomberg for their faultless presentation. Again supervised by Dr Jason Nurse, their challenge was to produce an augmented reality map of Oxford. The team were: Richard Appleby, Sonal Vedi, Lawrence Okoth-Odida, Joshua Warwick, Charlotte Smyth and Paul Logan.

Each industry-sponsored prize was worth £400. Companies interested in suggesting project ideas or sponsoring prizes should please contact: shoshannah.holdom@cs.ox.ac.uk

End-of-year examination prizes

Congratulations to all the students who were awarded prizes for their performance in end-of-year examinations in 2015.

Fourth year (Part C)

Dominik Peters – *Mathematics and Computer Science, St John's College*
The G-Research Prize for best Computer Science project in Mathematics and Computer Science 2015

Matej Balog – *Mathematics and Computer Science, Merton College*
The Hoare Prize for the best overall performance 2015 (Part C)

Xavier Wilders – *Computer Science, St Anne's College (joint winner)*
Sergiu Vicol – *Computer Science, Oriel College (joint winner)*
The Hoare Prize for the best overall performance in Computer Science 2015 (Part C)

Kay Douglass – *Computer Science, Worcester College (joint winner)*
Yuchen Cai – *Computer Science, St John's (joint winner)*
The Microsoft Prize for best Computer Science project 2015

Third year (Part B)

Andrew Mowll – *Mathematics and Computer Science, Worcester College*
The British Telecom Research and Technology Prize for Mathematics and Computer Science 2015 for best overall performance, with special regard for Computer Science papers

Pritesh Patel – *Mathematics and Computer Science, Merton College*
The Junior Mathematics Prize for Mathematics and Computer Science 2015 for outstanding performance in the mathematical papers in Part B

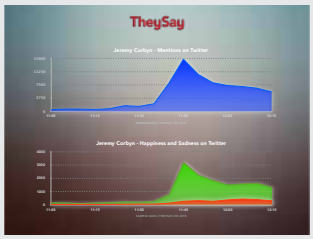
Benjamin Dawes – *Computer Science and Philosophy, Hertford College*
The Gibbs Prize for Computer Science and Philosophy 2015 for Parts A and B, paying particular regard to Computer Science papers

Ashok Menon – *Computer Science, Oriel College*
The Hoare Prize for the best overall performance in Computer Science 2015

Joe Fowler – *Computer Science, Keble College*
The G-Research Prize for best project in Computer Science 2015.

News in brief

Sentiment analysis spinout company TheySay has been grabbing headlines. Analysis of the worldwide Twitter reaction to the launch of Apple Music and Donald Trump's performance in the first republican debate have featured in news outlets worldwide. Professor Stephen Pulman appeared on the Radio 4 programme *Fry's English Delights* alongside host Stephen Fry, and John 'Jonny Rotten' Lydon in August.



NQIT (pronounced 'N-kit') stands for Networked Quantum Information Technologies. The NQIT Hub, part of the UK National Quantum Technology Programme, is led by the University of Oxford and involves 29 globally leading quantum centres and major companies, all working together to realise an entirely new technology sector. The Hub's focus is on systems that can connect together to form flexible, scalable solutions for diverse applications. Three members of the department are involved: Professor Marina Jirotka working on responsible innovation, Professor Samson Abramsky on hybrid classical/quantum computing and Dr Jonathan Barrett on secure communications and verification. Further information: nqit.ox.ac.uk/

Wrapidity offers easier access to big data

Want to know the location and hours of all the restaurants or gigs in the US or the prices of all the houses or headphones on sale in the UK?

Accurate databases covering entire verticals – such as places, products, flights, rentals, or events – promise to be the gold of the 'big data age'. Maintaining those databases has unfortunately often required hundreds of people dedicated to their collection and curation.

Wrapidity, an Oxford spin-off founded by a team of researchers from the Department of Computer Science, has set out to design a system for fully automatic, affordable, and self-maintaining data extraction. Wrapidity builds on DIADEM, a 5-year ERC (European Research Council) advanced investigator grant awarded to Professor Georg Gottlob.

This year Georg, Dr Tim Furche (CTO), Dr Giovanni Grasso (head of data extraction), and Dr Giorgio Orsi (head of entities), all from Oxford, joined with businessman Leon Shpilsky to commercialise DIADEM's success in Wrapidity. In the six months since its founding, Wrapidity has already extracted millions of products, businesses, places, and other entities from hundreds of thousands of sources for companies ranging from social networks and travel search engines to data markets.

Staff appointments and changes

Since the last edition of *Inspired Research*, there have been some changes:

Professor Alex Rogers arrives as Associate Professor in Cyber Physical Systems, and Tutorial Fellow at St Anne's College.

Ms Eva Ignatuschtschenko and **Ms Lilly Pijnenburg Muller** join us as new Global Cybersecuriy Capacity Centre Research Fellows.

Dr Max Van Kleek has been appointed as the Senior Research Fellow on SOCIAM – see p 24 of this edition of *Inspired Research* for more information.

Professor Sir Nigel Shadbolt has joined us as a Senior Research Fellow, and Principal of Jesus College.

Shimon Whiteson has been appointed Associate Professor in Machine Learning and Tutorial Fellow at St Catherine's College.

The Recognition of Distinction exercise 2015 awarded **Bernardo Cuenca Grau**, **Cas Cremers** and **Niki Trigoni** with Full Professor title.

Calling Computer Science researchers on a career break

Are you a scientist, technologist, engineer or mathematician who has had a career break of two or more years for family, caring or health reasons and wishes to return to research? A Daphne Jackson Fellowship offers STEM professionals wishing to return to a research career after a break, the opportunity to balance an individually tailored retraining programme with a challenging research project in a suitably supportive environment. Fellows normally carry out their research part-time over two years. Anyone interested in joining the Department of Computer Science under the scheme should contact: Laura Jones, HR manager, or laura.jones@cs.ox.ac.uk

Software Engineering allied with archaeology through ALIGNED

Research project ALIGNED develops new ways to curate archaeology big data

© Mark Byzewski

The rapid growth of web data creates demand for software engineering methods which can build and maintain applications that extract, process and publish web data. However, converting big data sources into high-quality, structured knowledge for use in business processes is a challenging endeavour.

The University of Oxford is one of the key partners in an exciting research project: ALIGNED, which is focussed on quality-centric, software and data engineering. Funded by H2020 (an EU framework programme for research and innovation) ALIGNED will develop new ways to build and maintain IT systems that use big data on the web, using models, methods and tools for engineering information systems based on co-evolving software and web data. The ALIGNED project will develop data-intensive tools to support combined data and software engineering. An ALIGNED system specification will be based on a specialisation of a domain-specific model.

The ALIGNED project brings together research tools developed by computer scientists in Trinity College Dublin, University of Leipzig and University of Oxford and a semantic platform developed by the Semantic Web Company to support four use cases which cut across industrial, not-for profit and academic sectors.

Two departments of University of Oxford are involved in ALIGNED. The Department of Computer Science (Software Engineering Group) leads the research on semantics-driven software engineering. The School of Anthropology and Museum Ethnography leads the work on provision of an expert-curated databank, Seshat, which offers a platform to study the past through well-established scientific techniques. Seshat is also one of the four significant use cases for ALIGNED.

Our collective knowledge about past societies is almost entirely in a form inaccessible to scientific analysis, stored in historians' brains or scattered over heterogeneous notes and publications. The huge potential of this knowledge for testing theories about political and economic development has been largely untapped. The Seshat: Global History Databank brings together the most current and comprehensive body of knowledge about human history in one place. A typical example of such historical knowledge, would be data on population size and density, interlinked with background information such as levels of social complexity for a particular archaeological excavation site, such as Pueblo Bonito, the largest great house in Chaco Canyon, New Mexico.

Seshat systematically collects what is currently known about the social and political organisation of human societies and how civilizations have evolved over time. This massive collection of historical information allows a large international and interdisciplinary team from fields as diverse as evolutionary biology, psychology, and archaeology to rigorously test different hypotheses about the rise and fall of large-scale societies across the globe and human history.

Seshat extracts the data from a combination of databases, Linked Data, websites, academic publications and human experts. ALIGNED will develop new techniques for data curation that build on data quality metric frameworks for data integrity assurance, runtime quality analytics to automate and prioritise data curation tasks and curation workflows that link together data harvesters, domain experts and data consumers to improve data quality.

Further information: aligned-project.eu

Another noteworthy use for ALIGNED is provided by JURION, an innovative legal information platform developed by Wolters Kluwer Germany. JURION merges and interlinks over one million documents of content and data from diverse sources such as national and European legislation and court judgements, extensive internally authored content and local customer data, as well as social media and web data (eg from DBpedia). ALIGNED will enable JURION to address more complex business requirements that rely on tighter coupling of software and data.

The social machine of mathematics

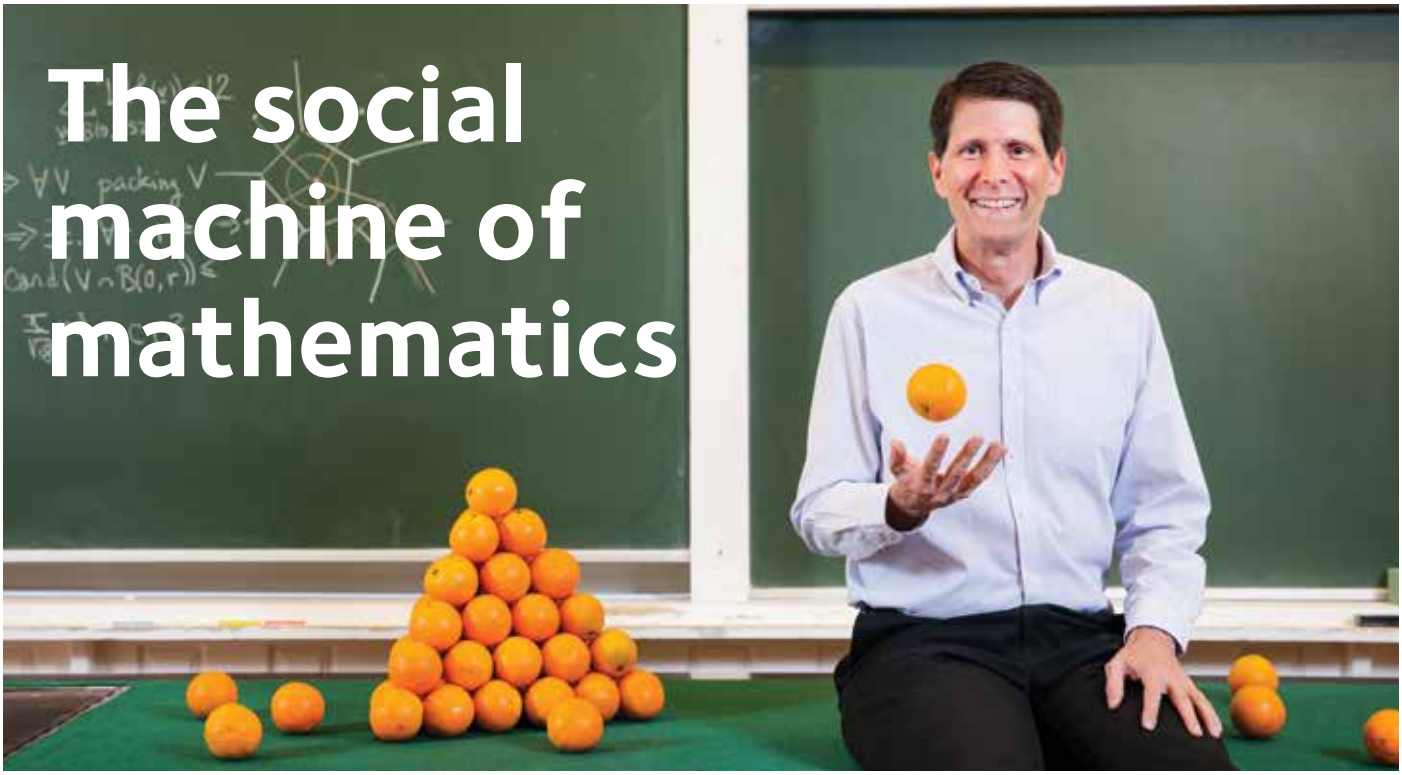


Photo © Balint Hirling Anzenberger Agency

In the summer of 2014 mathematician Tom Hales [pictured above] of the University of Pittsburgh announced his proof of the 400 year old Kepler conjecture, a result that says, essentially, that the most efficient way of packing cannon balls (or oranges) into a box is the obvious one. What was remarkable about Hales' proof was that every step had been written in formal logic and checked line by line by a computer – using HOL and Isabelle – systems more usually used to prove the correctness of complex algorithms in safety critical applications. Hales had previously announced a proof in 1998, but his paper had been rejected by a top journal because the referees did not feel able to trust the complex calculations involved.

The Oxford mathematician Andrew Wiles, who proved Fermat's Last Theorem, famously described mathematical research as being like 'stumbling around in the dark' – eventually the light comes on, and you see the way forward, only to move on to the next problem, and more stumbling around in the dark.

Yet mathematicians like Wiles, and Hales, do solve immensely hard problems, ones where computers would even now be able to make very little progress. The purpose of the 'Social Machine of Mathematics' project is to try and understand how human mathematicians do what they do, and how to best harness the combination of human skill and computer power to improve the process of producing mathematics, with people doing what people do best, and the computers taking care of checking all the details.

This kind of combination of people and machines was dubbed a 'social machine' by internet pioneer Tim Berners Lee, and research on social machines is being led in Oxford by Sir Nigel Shadbolt and David De Roure (Oxford e-Research Centre) as part of an EPSRC Programme Grant, SOCIAM.

To get started on understanding this social machine of mathematics Professor Ursula Martin is looking at another recent innovation – crowdsourced proofs in a format called `polymath'. What happens when a group of experts use a blog to collaborate to prove a mathematical result? As well as new mathematical successes, with the open format allowing people from a range of mathematical backgrounds to contribute, the resulting document – not just the proof but also all the conjectures, mistakes, false starts, red herrings and strategic decisions along the way – provides a unique insight into how mathematics is done.

Ursula is pulling together a team around the world with expertise in mathematics, social science, philosophy, computer proof and the science of the internet. The first steps involve working with social scientists to understand what is going on when mathematicians collaborate in the polymath project – what motivates them to take part, and how do they understand and trust each other? The polymath archives provide a wonderful source for empirical research – for example, how do creative ideas emerge? Or what is involved in a mathematical explanation? To get a handle on everything that is going on we need to find a suitable way of representing such mathematical conversations – not just the logic of proofs, but the logic of guesses, dead ends and back tracking – and that involves experts in analyzing discourse. Finally to build software to support collaborative mathematical proofs, we need to integrate our ideas from these new domains with the rigorous discipline of computer proof, informed by the ideas of our colleagues who are developing the science of the internet.