InspiredResearch Winter 2013 Issue 4

Research News from the Department of Computer Science, University of Oxford

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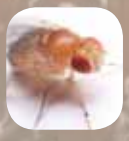

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University of Oxford

Department of Computer Science

InSpired Research…

is a twice-yearly newsletter published by the Department of Computer Science at Oxford University.

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NEWS

Oxford sweeps up BCS accolades


Dr Boris Motik


Prof. Samson Abramsky FRS

Two academics from Oxford's Computer Science Department have been recognised by BCS, The Chartered Institute for IT, for their outstanding contribution to the field. Dr Boris Motik has been named as the recipient of the BCS Roger Needham Award while Professor Samson Abramsky FRS has received the BCS Lovelace Medal.

Their prizes include the opportunity to deliver a public lecture about their research. Dr Motik will present the 2013 BCS Needham lecture in November, and Professor Abramsky will deliver the Lovelace lecture in 2014.

Boris, whose work has had an impact both inside and outside academia, has made major contributions to the design and standardisation of the OWL2 ontology language, which is widely used in industrial research and applications. His research is around the development of techniques for intelligent management of large amounts of data.

Samson is pre-eminent in setting the modern agenda in the foundations of computer science, an area where he has made immense contributions since the 1980s. His contributions in each of the past three decades had a major impact on the field, notably: Domain Theory in Logical Form, Game Semantics and Categorical Quantum Mechanics. His work over the past decade has shown that methods and concepts developed in theoretical computer science can be applied very directly in quantum information, and the foundations of quantum mechanics itself.

Prominent Paper Award for artificial intelligence research

Thomas Lukasiewicz and his co-authors have won the prestigious AIJ Prominent Paper Award 2013 for the paper 'Combining answer set programming with description logics for the Semantic Web'.

This paper proposes dl-programs, a formalism that integrates description logics with rule-based logic programs under answer set semantics. It provides not only detailed theoretical analyses of these programs in terms of their expressive power and computational complexities, but also an implementation that illustrates the usefulness of the proposed formalism in the Semantic Web.

This work highlights many difficult issues in the problem of adding rules and default rules into description logics, and has been very influential in subsequent work in this area.

Professorship links industry and academia

The Royal Society has for the first time awarded a Research Professorship to an industry scientist, which will enable him to embark on academic research while retaining his position in industry. The award has been made to Dr Luca Cardelli, a top computer scientist at Microsoft Research, to take up an honorary position at Oxford's Department of Computer Science.

He will use his professorship to work at the interface of biology, nanotechnology and computing, as he believes that the convergence of these scientific disciplines will bring about the greatest future changes in healthcare and technology. He has strong interests in investigating computational structures in biology and in engineering computational structures from biologic materials.

Fellowships galore

Oxford computer scientists have received a lot of recognition for their research over the past few months, receiving fellowships from the EPSRC, the Royal Society, the ERC and the Wellcome Trust, plus an Honorary Fellowship from ESCMSET, and the Birkhoff – von Neumann prize.

Dr Chris Heunen and Dr Phil Blunsom have been successful in gaining highly sought after five-year EPSRC Fellowships. Chris of the Quantum Group has received funding for his project 'Combining Viewpoints in Quantum Theory', which intends to use computer science, physics and mathematics to progress our understanding of and capabilities in quantum computing. These advancements could greatly ease the future development of protocols for quantum hardware. Chris has held a Junior Research Fellowship since joining the Department in 2010.

Chris has also been awarded the 2012 Birkhoff – von Neumann prize for his research, which includes the analysis of quantum logic from the perspective of categorical logic and the study of how algebraic quantum mechanics can be related to topos theory so as to construct new foundations for quantum logic. The prize is awarded once every two years during the award ceremony held at the bi-annual conference of the International Quantum Structures Association.

Phil was awarded the EPSRC fellowship for his project entitled 'Bayesian Models of Grammar Induction and Translation'. His research programme aims to develop large-scale and language-independent algorithms to allow for syntactic analyses of real world language data, without the need for traditional hand annotation. The development of such a model could increase our understanding of how children learn languages and could lead to the development of advanced language technologies for processing online data.

Additionally, prestigious Royal Society University Research Fellowships have been awarded to Dr Stefan Kiefer and Dr Stanislav Živný, which will fund their research for the next five years.

Stefan's project 'Quantitative Analysis of Infinite-State Systems' centres on computer-aided formal verification to ensure that dynamic, infinite state systems behave as they are intended. Improved computer-aided verification could, in future, ensure that incidents such as the 2003 power blackout in the Northeast of the United States no longer occur. Stefan joined the Department of Computer Science as a postdoctoral research assistant in November 2009.

Stanislav has returned to take up a post at Oxford this October where he will work on his project 'Optimisation of separable functions'. He obtained his Doctor of Philosophy in Computer Science at Oxford in 2009. Since then he has worked for Microsoft Research Cambridge, the University of Oxford, and was most recently at the University of Warwick when he applied for the Fellowship.

Dr Blanca Rodriguez has been awarded a five-year Wellcome Trust Senior Research Fellowship in Biomedicial Sciences, and Dr Gary Mirams the five-year Henry Dale Fellowship, which will support their work in the field of Computational Medicine. See p13 for more details of Blanca and Gary's work.

Professor Kevin Burrage has been awarded an Honorary Fellowship by the European Society of Computational Methods in Sciences, Engineering and Technology (ESCMSET), its highest distinction, for his outstanding contribution in the fields of Computational Mathematics and Numerical Analysis.

ERC advanced grant awarded

Professor Leslie Ann Goldberg has been awarded a five-year European Research Council Advanced Grant for her project 'Mapping the Complexity of Counting', to start in March 2014. The overall objectives are: to map out the landscape of computational counting problems, determining which problems are tractable, and which are intractable; and to discover complexity characterisations which elucidate the features that make counting problems tractable or intractable.

NEWS FLASH

£1.26 Million Platform Grant for Information Systems

The Information Systems Group has just been awarded a highly sought after Platform Grant from EPSRC. Platform Grants provide a base of flexible funding to support the retention of key staff, feasibility studies, longer term research and international networking. Congratulations to all involved in making this application a success. We will bring you details of the research in future editions.

Cities of slime

Most bacteria live together in quasi-social colonies, which are known for exhibiting fascinating behaviour. The way that these biofilms grow is currently being modelled by The Oxford Computational Biology Group. In this article, Will Smith explains why slimy layers of bacteria are so important, and describes some of the group's current research.

What do you imagine when you hear the word 'bacteria'? Perhaps some little green blobs swimming about, no doubt plotting to infect some unattended kitchen surface and cause domestic havoc. This is the picture often painted by, for instance, disinfectant advertisements – but it neglects to tell the full and awesome story of the bacterial lifestyle.

Now, imagine a complex, dynamic community where countless species of bacteria live and die together – billions of organisms competing, sharing and interacting within microscopic architectures built of cells and slime. Sounds fantastic? Welcome to the amazing world of the biofilm.

The vast majority of bacteria on the planet live – like us – together in quasi-social colonies, grouped under the heading of biofilms. These dense, slimy layers of bacteria can form on virtually any surface, and can be a great nuisance if allowed to grow unchecked – blocking pipes, fouling ships' hulls, and contaminating water supplies. Biofilms are also notorious pathogens, accounting for some 80% of all chronic infections, and are well known for their robust resistance to antibiotic treatments. Dental plaque, associated with tooth decay and gum disease, is a well-known instance of a bacterial biofilm.

But on top of their industrial and medical infamy, bacterial biofilms exhibit a great deal of fascinating biological behaviour, which has made them popular targets for computational modelling. For example, biofilms can form intricate structures during growth; tower-like edifices, internal nutrient supply channels and fractal-like growth patterns are all common examples of the amazing emergent configurations observed.

They can also display remarkably sophisticated sociobiology: film bacteria can cooperate to achieve common goals, coordinating chemical counter-attacks on assailants and producing communal materials for the benefit of the colony. A good example of this is the slime (termed 'Extra-cellular Polymeric Substance' or EPS) that holds the biofilm together: the contributions of many bacteria combine to form a viscous protective blanket, anchoring the colony to surfaces and shielding it from chemical attacks – such as disinfectants.

However, it's not all peace, love and understanding. Whilst cooperation between film inhabitants is sometimes observed, vicious competition is usually the rule of thumb, with rival populations of bacteria constantly contending for coveted space and resources. Again, slime plays a critical role here: like Roman soldiers in a tortoise formation, subgroups of bacteria can use EPS as a barrier to eject and exclude other microbes, allowing them to progressively dominate the biofilm territory (see background photo).

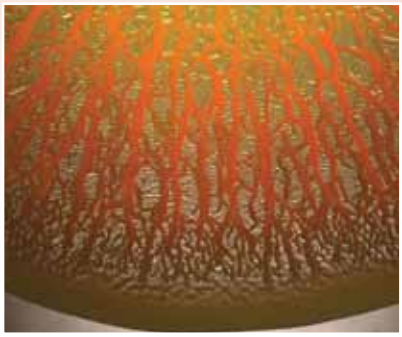
Recent work performed in the Computational Biology Group has begun to direct the power of the Chaste (Cancer, Heart And Soft Tissue Environment) platform towards the modelling of biofilm biology. An exciting new collaboration between the Foster group (Oxford Zoology), the Toulouse Institute of Fluid Mechanics, and the Oxford Computational Biology Group has been using Chaste to create new computational models of biofilm growth.

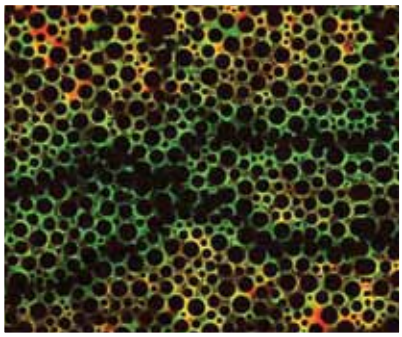
So far, this work has focused on the development of new modelling frameworks, designed to examine the role that cell shape plays in biofilm growth and structure formation. Could cell shape affect the evolutionary strategies adopted by bacteria in competing for space and resources? We aim to find out.

Boosting human understanding of biofilm growth is crucial for predicting and manipulating the behaviour of these fascinating systems, and is providing us with stunning insights into the fundamentals of evolutionary biology. The computational modelling of biofilms has much to teach us about the microorganisms with which we share our daily lives, and could prove to be a key resource for unlocking the secrets of the cities of slime.

You can find out more about the Chaste Biofilm project at www.cs.ox.ac.uk/chaste or by contacting Will Smith (william.smith@cs.ox.ac.uk).

◀ *[background photo] Slime as a weapon: by producing extra EPS, a biofilm subpopulation (stained green) is able to burst through a dense mat of bacteria and expand into the space of their competitors.*





Acknowledgments: Many thanks to James Osborne, Joe Pitt-Francis, Yohan Davit, and Kevin Foster for their help with the project, and to IMFT and the ESPRC for their funding. Images kindly provided by Wook Kim and Katharine Z. Coyte, Kevin R. Foster, and William M. Durham.

Volunteer power

By engaging members of the public and their computers in a climate modelling project, Oxford University has helped establish a software platform for scientists to use in creating secure volunteer computing projects.

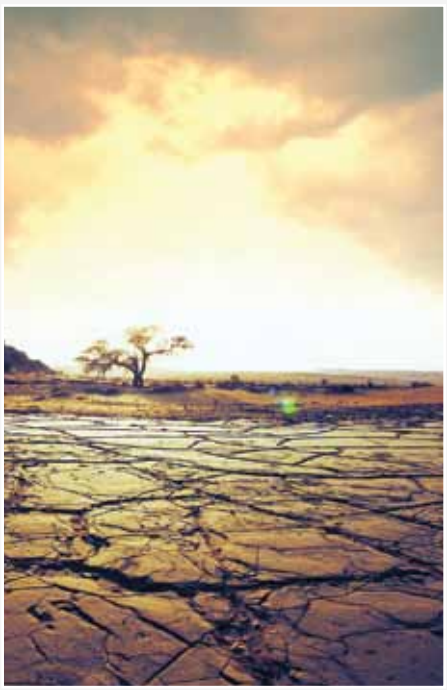
Climate modelling research at Oxford has underpinned the development of the current version of Berkeley Open Infrastructure for Network Computing (BOINC), a technology to enable secure volunteer computing. This was done as part of the climateprediction.net project which is currently managed as CPDN through the Oxford e-Research centre supporting international climate modelling. CPDN models climate change using donated cycles on users' computers, with almost 700,000 users registered by 2013.

Significant work to develop the BOINC technology in the CPDN has enabled scientists to embrace volunteer computing to solve scientific modelling challenges. BOINC has become recognised as the key open-source resource for volunteer computing, supporting significant international scientific endeavours.

The work on BOINC by the Oxford team enabled the uptake of the technology to grow enormously. It meant community users were confident of its ability to harvest compute cycles without compromising the security of their PCs, as well as modellers being able to develop more complex codes to run out in the community and return timely results. It enabled the public to engage in science in a way which had not been achieved before with thousands of users observing a changing globe graphic on their machines showing the results of their own models running on behalf of the climate scientists. CPDN was, and still is, producing climate modelling results which are used by the Met Office.

BOINC is managed as a community-developed tool out of Berkeley, and Oxford's contribution is acknowledged by the now head of this group. BOINC is now widely used by scientific communities across the world. According to www.boincstats.com 2,599,338 people have installed the BOINC software on their machines and there are currently 272,459 active users. The global reach of the CPDN project using BOINC is significant.

Of the 82 BOINC projects, in May 2012 climateprediction.net was the fourth most popular by work-units in progress. Over 129 million simulation-years have been performed since the project's inception and registered users are located in 221 countries. Since 2008, 40,702 distinct individual users have successfully completed one or more model simulations. The computing time required for all the model simulations run successfully since 2008 is equivalent to a 32,220 core machine running full time for one year and producing 100% successful results. An estimate of the value of this CPU time is $22.5M, based on the rate of the Amazon Elastic Compute Cloud Standard Spot instance ($0.08/hour default).



Chips with confidence

Collaboration between the University of Oxford and Intel Corporation has developed new methods to check that electronic chips do what they're meant to do, before they are manufactured.

Integrated electronic chips, such as the processor in a laptop, contain many billions of interconnected transistors, all working together to run programs. The engineering design of a new chip is extremely challenging, and ensuring that the finished chip works correctly is vitally important. Almost half of the several years spent creating a new chip goes on testing it for potential errors.

Fabricating a prototype chip to test a design is prohibitively expensive, so computer simulations are widely used to validate designs. But simulation of every possible internal set of connections in every possible operating condition would take many millions of years to test a chip exhaustively, so is clearly not feasible.

Tom Melham, Professor of Computer Science, has been working with Intel Corporation since the late 1990s to develop and apply a mathematical validation technique known as formal verification. This entails building a mathematical description of the chip design and then analysing its correctness by rigorous mathematical proof. The proofs are very large, so a simplification technique called abstraction is used to pick out salient features for testing; one such technique has been patented by Intel and Tom. Twenty-five years ago these advanced formal verification techniques were thought unachievable; today they are in routine use by Intel and other companies worldwide.

Tom's collaboration with Intel is a prime example of knowledge exchange between academia and industry. Intel, led by experts such as Senior Principal Engineer Dr Carl Seger, has pioneered the use of formal verification on the hardest industrial chip design problems. Tom has worked closely with Intel engineers for over a decade, and Intel researchers have spent time at the University of Oxford – including Carl as a Visiting Fellow of Balliol College during 2006-7.

The ability to rapidly identify design errors in a chip is cost-effectively driving forward new designs that use less power and are more environmentally friendly. The technique also has applications in safety-critical systems, such as aeroplane, automotive, or rail control, where confidence in the chips is vital.

Carl commented: 'Having Professor Melham working with us and helping us articulate and evaluate the "big picture", which often gets lost in the daily struggle to get the next design out the door, has been invaluable. Some of this joint work provided the foundation for methods that are today used at half a dozen design centres on three continents. In addition, I believe the benefits have been mutual in that we have also provided Professor Melham with a wealth of interesting, challenging, and relevant research problems.'

This research has been funded by Intel Corporation and the Engineering and Physical Sciences Research Council.

This article first appeared as part of The Oxford Impacts series. To find more articles in the series visit: http://partnership.ox.ac.uk/category/impact/

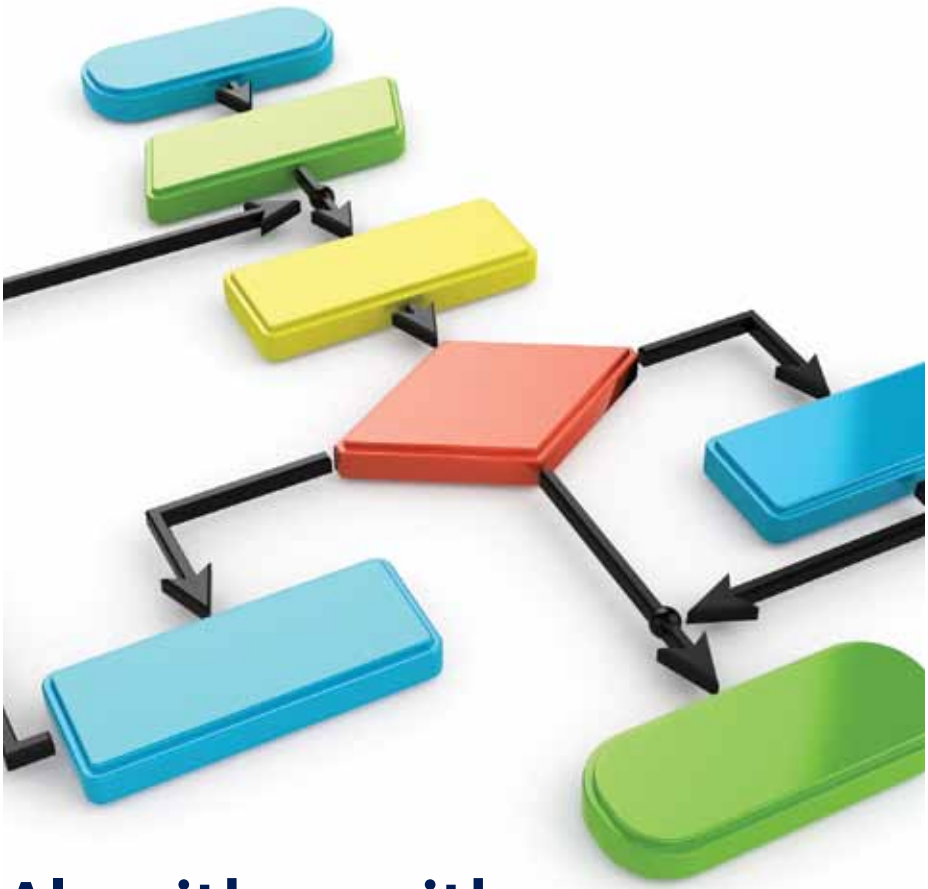
Women in CS Society launched

The Oxford Women in Computer Science Society (OxWoCS) was started in June 2013 with the goal of supporting and promoting women in computer science. OxWoCS is a society within Oxford's Department of Computer Science and aims to provide networking opportunities and a support network comprising role models, mentors, and peers. It exists for all women – students, faculty, and staff.

OxWoCS organises a variety of activities and events, including weekly coffee meetings, and a Distinguished Speaker Seminar Series featuring accomplished female speakers from either academia or industry who – through talking about their career path and experiences – could become role models and inspirations.

Other events include a welcome event for freshers, trips to lectures and conferences, most notably the London Hopper Colloquium, as well as some joint events with the Cambridge women@CL Society.

More information: http://www.cs.ox.ac.uk/societies/women/



Algorithms with the right incentives

Research into algorithmic game theory under the leadership of Professor Elias Koutsoupias from the Department of Computer Science is being funded for the next five years.

The project 'Algorithms, Games, Mechanisms, and the Price of Anarchy (ALGAME)', which aims to investigate fundamental questions about algorithms, has received an advanced grant funded by the European Research Council (ERC) to run from 2013 to 2018.

Elias' objective is to bring together a local team of young researchers who will work closely with international collaborators to advance the state-of-the-art of algorithmic game theory and open new avenues of research at the interface of computer science, game theory, and economics. The project consists mainly of three intertwined research strands: algorithmic mechanism design, the price of anarchy, and online algorithms.

The price of anarchy attempts to capture the loss of efficiency resulting from competing selfish individuals or companies. For example, average traffic delays on streets could be reduced if drivers were following a centralised plan instead of choosing their own best route.

The explosive growth of the web and the internet has radically changed the economy and society and shifted the focus of many scientific fields, and has especially transformed computer science. It used to be about software and hardware systems designed, built, and operated by a single team, but now it is more about systems that are created and operated by many different entities, usually competitors.

With this dramatic shift in the foundational assumptions of computer systems, we have now to focus on algorithms that are not simply efficient but which also provide the right incentives to the computing agents involved.

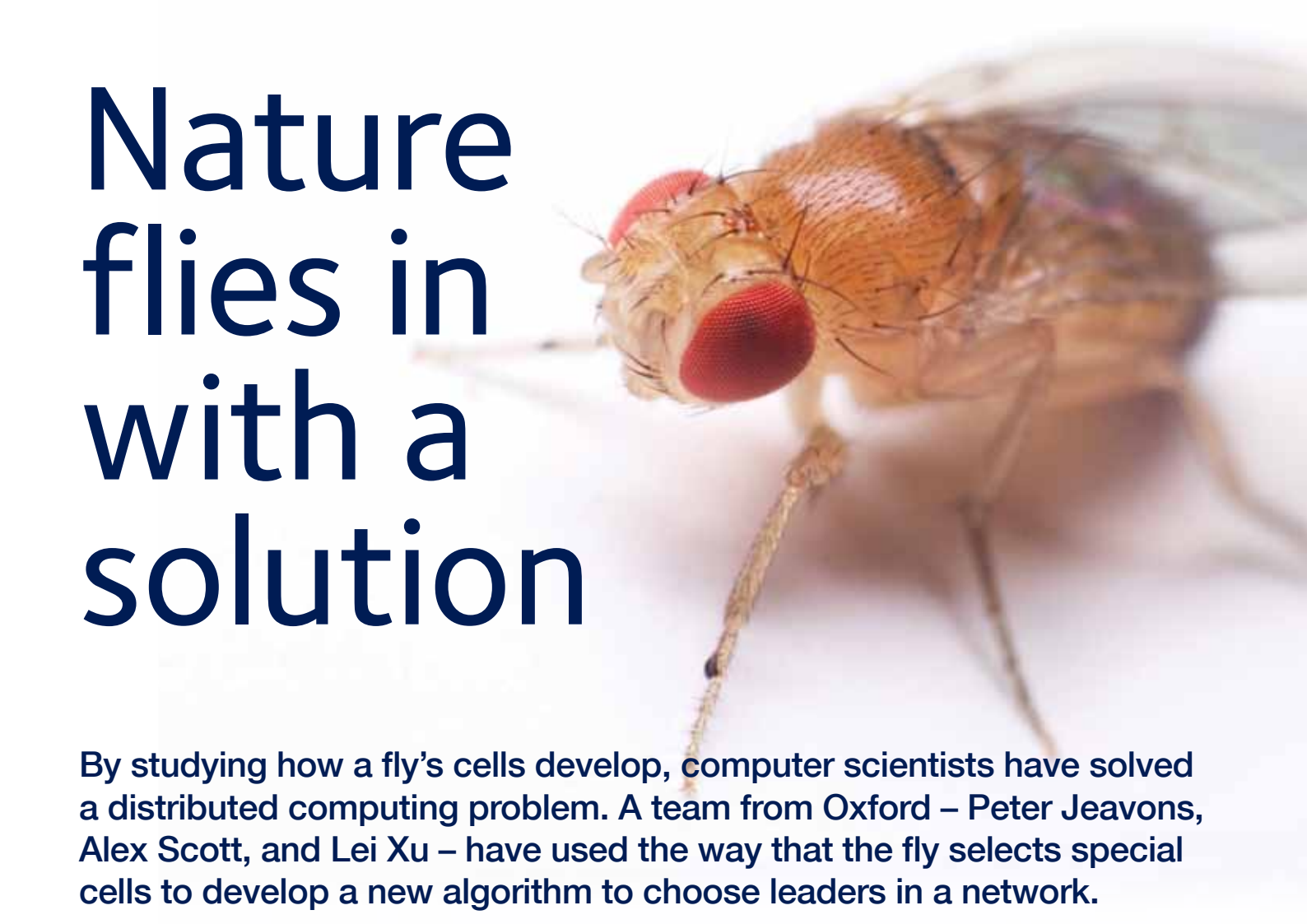
Expanding algorithm research

The new algorithms group in the Department of Computer Science was inaugurated in October 2012 with an international workshop on algorithms. The group, headed by Leslie Ann Goldberg, has brought together existing Oxford expertise in algorithms (including Michael Benedikt, Georg Gottlob, Peter Jeavons, Thomas Lukasiewicz and Joel Ouaknine) under one theme, and has expanded upon it with the appointment of three more experts to the department: Professors Elias Koutsoupias, Leslie Ann Goldberg and Paul Goldberg.

The launch of the new theme was marked by a two-day meeting of world-class researchers in the field, held jointly between the Department of Computer Science and St John's College. The speakers included the winners of the Turing Award, the Gödel Prize and the Knuth Prize.

Leslie Ann and Paul moved to Oxford this summer from the University of Liverpool. Paul was the founding head of the Economics and Computation (ECCO) research group at Liverpool. Leslie Ann specialises in computational complexity, where the aim is to discover which computational problems are feasible, which are inherently infeasible, and why. Elias joined the team from the University of Athens last year, bringing with him extensive expertise in algorithmic game theory, its applications to the internet, the web, and the economy, online algorithms, and, more generally, decision-making under uncertainty.

Nature flies in with a solution



By studying how a fly's cells develop, computer scientists have solved a distributed computing problem. A team from Oxford – Peter Jeavons, Alex Scott, and Lei Xu – have used the way that the fly selects special cells to develop a new algorithm to choose leaders in a network.

During a fly's development, certain cells specialise into an unusual state, which then go on to become cells attached to bristles on the back of the fly. The choice of which cells specialise in this way resembles a fundamental problem in distributed computing known as maximal independent set (MIS) selection.

In MIS selection, a large network of identical agents need to choose a small set of *leaders*. Every agent should be connected to at least one leader, but the leaders should not be directly connected to each other. The need for this sort of selection process arises in many different kinds of computer networks.

The challenge is to compute such a set of leaders *efficiently* in a *distributed* way where each agent makes its own independent decisions and there is no central control.

One new idea about how to tackle this problem comes from looking at nature. The MIS selection problem has some similarity with the 'fine-grained' pattern formation among groups of neighbouring cells that takes place in many living organisms. In particular, Afek et al. recently pointed out in a paper in *Science* that MIS selection is similar to the selection of certain cells during the development of the nervous system of the fruit fly Drosophila.

During development, certain cells of the fly specialise to become sensory organ precursor (SOP) cells, which later develop into cells attached to small bristles (microchaetes) on the back of the fly that are used to sense the environment (see Figure 2). During the first stage of this developmental process each cell either becomes an SOP or a neighbour of an SOP, and no two SOPs are neighbours. These observed conditions are identical to the formal requirements in the maximal independent set selection problem.

However the method used by the fly to select these cells appears to be very different from any of the algorithms designed by mathematicians and computer scientists for choosing an MIS. All of these previous algorithms rely on precise numerical calculations, and generally require explicit information about the number of active neighbours that each node in the network currently has. They also generally rely on exchanging a complex set of messages.

By contrast, the cells of the fly appear to solve the problem using only simple local interactions. These local interactions involve proteins on the surface of the cells that allow the cells to switch between two mutually exclusive states.

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In one state the cells display high levels of a protein called Delta on their surface, and low levels of a protein called Notch. In the other state they display high levels of Notch and low levels of Delta. These two proteins affect the behaviour of neighbouring cells, by a process of negative feedback, so that cells that choose the first state tend to encourage their neighbours to go into the other state. At the multicellular level, this lateral inhibition mechanism can break the symmetry among cells and amplify small differences between neighbouring cells, giving rise to patterns, such as the pattern of bristles on the back of the fly.

Studying the way that the fly selects special cells leads to a new distributed algorithm for MIS selection: each node signals that it wishes to join the MIS with a certain probability. If none of its neighbours signals at the same time, then it succeeds and joins the MIS. If there is a clash, where two neighbours both wish to join the MIS at the same time, then they both have to wait, and they both lower their probability. If neither a cell nor its neighbours signal in some round, then that cell raises its probability of signalling in the next round.

We have shown that this simple algorithm is just as fast as the most efficient algorithms previously proposed – but is much simpler to implement. Unlike previous algorithms it requires no knowledge of the overall graph, uses very simple messages, and is extremely robust. By a careful mathematical analysis we showed that in any network with n nodes the expected number of rounds needed to select an MIS in this way is $O(\log n)$, which is known to be the best possible performance that is achievable using single-bit messages.

Our description of the algorithm, with some simulations and a detailed mathematical analysis, was presented at the ACM Symposium on Principles of Distributed Computing in July 2013.

Figure 1: Some examples of Maximal Independent Sets.

(A) The red nodes form an MIS in this grid graph. Every black node is adjacent to at least one red node but no two red nodes are adjacent to each other.

(B) The five red nodes form an MIS in this random graph with 20 nodes.

(C) The 13 red nodes form an MIS in this network of UK cities. The nodes of the network correspond to 73 major cities in the UK, and two nodes are adjacent if the corresponding cities are less than 100km apart.

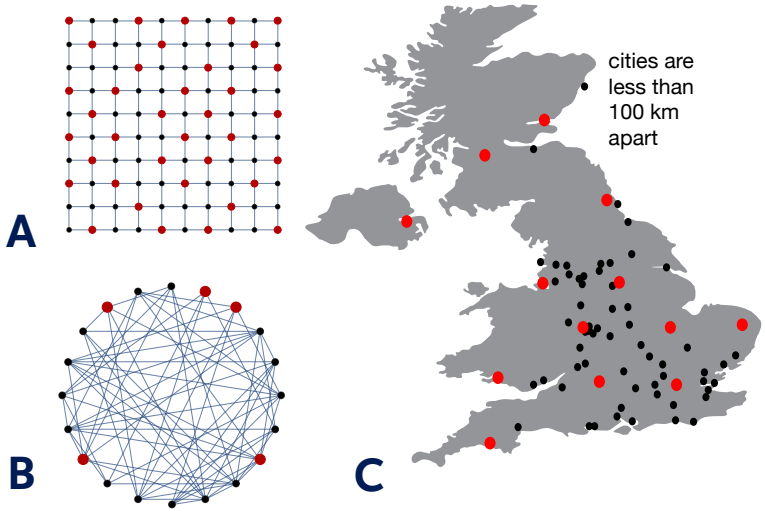
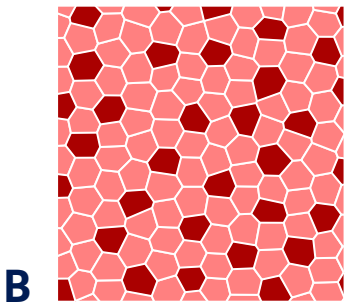
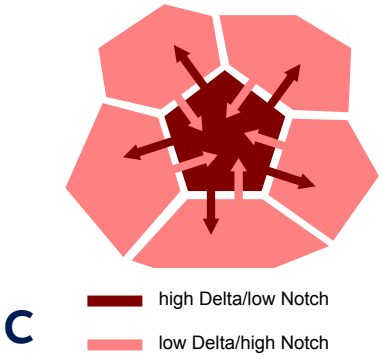


Figure 2: Pattern formation in the fly.

(A) During development, certain cells specialise into an unusual state. These cells then develop into cells that are attached to small bristles on the back of the fly that are used to sense the environment.



(B) The choice of which cells specialise in this way (indicated by darker colour) resembles the MIS selection problem.



(C) The cells of the fly use simple local interactions between the transmembrane proteins Notch and Delta to generate mutually exclusive signalling states.

Underground tracking to become a commercial reality

It should soon be possible to track people in mines or underground emergencies using a commercial application that is being created by Oxford researchers from technology that they originally developed to study badgers.

When Dr Andrew Markham and Dr Niki Trigoni from the Department of Computer Science needed to work out the position of animals underground, they came up with the idea of using technology that generated very low frequency fields. These can penetrate obstacles, enabling positioning and communication even through thick layers of rock, soil and concrete, which conventional technology, such as GPS, cannot do.

'Most technologies are only checking the magnitude of the signal – the signal strength from each transmitter – to work out distance,' Andrew told Mark Piesing of Wired.co.uk. The new technology measures 'vectors, which give you the magnitude and direction... Our technology can work out your position in three dimensions from a single transmitter.'

This contrasts with other approaches such as GPS or WiFi which are based on triangulation and typically require signals from at least four transmitters. As well as being used underground, the very low frequency tracking could also be used for indoor applications, for instance in a shopping centre or airport.

Having successfully used the basic technology in wildlife tracking, the researchers are now aiming to incorporate it into smart mobile devices: Andrew and Niki are developing a demonstrator on an Android platform and, once the technology is perfected, versions suitable for other popular smart phones, such as the iPhone, shouldn't be far behind.

They have started working with Isis Innovation to commercialise their research and are currently raising money for a spinout firm. The team has proven the basic algorithms and software and are working on more sophisticated techniques to increase performance and accuracy.

Oxford plays part in creating database of world's knowledge

A quiet revolution in the way Wikipedia offers access to, and manages its data, has taken place with the recent launch of Wikidata. By creating new ways for Wikipedia to manage its data on a global scale, Wikidata allows users direct access to its data. Dr Markus Krötzsch from the Department of Computer Science is one of the original architects of the project, and continues to be a consultant to the development team on technical questions.

The site, which aims to provide a collaboratively edited database of the world's knowledge, became publically accessible in October 2012. All international Wikipedia editions were connected to the data by March 2013 – the new system most notably serves the links to other languages, shown on the bottom left of every Wikipedia page. As of May 2013, Wikidata became the most frequently edited Wikimedia project with around 15 million contributions per month. Large amounts of data are continuing to be entered by a growing community.

The common-source principle behind Wikidata is expected to lead to a higher consistency and quality within Wikipedia articles, as well as increased availability of information in the smaller language editions. Wikidata should also reduce the maintenance effort for Wikipedia's volunteers.

Wikimedia Deutschland has developed and maintained Wikidata since 2012. The team of eight developers is led by Dr Denny Vrandečić at Wikimedia Deutschland. He and Markus are co-founders of the Semantic MediaWiki project, which has pursued the goals of Wikidata for the last few years.

The initial funding from the Allen Institute of Artificial Intelligence, Google and the Gordon and Betty Moore Foundation, has been extended by a donation from Russian search engine provider Yandex. It will help fund the development of outstanding features, such as support for ranking statements as preferred or deprecated, and adding more major datatypes, such as numbers and URLs. More information about the project can be found at www.wikidata.org

Big expansion in cyber security portfolio

Cyber security activities at the University of Oxford have been expanding with an array of exciting new research projects, education and training. They all sit under the umbrella of the Cyber Security Centre, which was set up in March 2012 and unites experts in the field and other interested bodies.

This year, the Cyber Security Centre has added to its portfolio the recently established Global Centre for Cyber Security Capacity-Building, the Centre for Doctoral Training in Cyber Security, and the Corporate Insider Threat Detection research project.
Various departments are involved in the Cyber Security Centre, and the Centre for Doctoral Training. The main ones are: the Department of Computer Science; The Oxford Internet Institute; Saïd Business School; the Blavatnik School of Government; and Oxford eResearch Centre.

The Centre for Doctoral Training in Cyber Security began PhD training this autumn. Doctoral training will last four years and provide graduates with skills to contribute research-derived expertise to business or government. The training is focusing on emerging technology themes such as the security of 'big data', cyber-physical security, effective systems verification and assurance, and real-time security.

The Oxford centre expects to produce over 40 DPhil graduates, spread over three intakes, in the next seven years. A similar centre has been established at Royal Holloway. Funding for the two centres together is £7.5 million.

The new Global Centre for Cyber Security Capacity-Building was also set up this year. It aims to understand how to deliver effective cyber security both within the UK and internationally. The research, funded initially for two years by the UK Government, is divided into five dimensions: devising cyber policy and cyber defence; encouraging responsible cyber culture within society; building cyber skills into the workforce and leadership; creating effective legal and regulatory frameworks; and controlling risks through technology and processes.

Each dimension has two co-chairs, drawn from Oxford and other leading research bodies. They are working with a wide range of global partners, including governments, international organisations and the private sector.

Another cyber research project got under way in February looking into the risk from insider attacks to organisations and how to combat them. The Corporate Insider Threat Detection research project, a joint venture between the Universities of Oxford, Leicester and Cardiff, aims to examine how to reduce risks to an organisation from disgruntled, corrupt or just poorly-trained employees, deliberately or accidentally harming crucial data or digital infrastructure.

The project has been commissioned by the Centre for the Protection of National Infrastructure (CPNI), and will develop a conceptual model, as well as a prototype monitoring software, designed to detect cyber insider threats and help identify hazards to businesses before the threat is realised.

News in brief

• Nature Scientific Reports has published a paper that uses PRISM to study cell cycle switch as a computing device. PRISM is a probabilistic model checker being developed at the Universities of Oxford and Birmingham.
More PRISM information: www.prismmodelchecker.org.

• A team of computer science doctoral students – William Zeng, Brendan Fong and Miriam Backens – was one of 21 winners in the Summer of Innovation competition for their idea WikiNets: a collaborative, open source, network building tool to share and organise notes and research.

• The Department of Computer Science hosted the 'Internet of Things mash-up day' in September. The Webinos Foundation, an opensource project, ran the day, and gave presentations and advice to representatives from more than 25 companies.

• The 29th British National Conference on Databases (BNCOD) was held in St Anne's College in Oxford in July. The theme this year was 'Big Data', addressing the growing need to manage data that is too big, too fast, or too hard for existing technology.

• The Department has recently taken over the Robert Hooke building, just a few minutes walk from the main site. The newly refurbished area is now home to the Centre for Doctoral Training in Cyber Security, as well as the Department's cyber security theme, plus teaching and social spaces.

• Britain's leading conference on robotics – Towards Autonomous

Robotics and Systems (TAROS) – was held in Oxford in August. The highlight was a public demonstration of driverless car technology being developed at Oxford University by Engineering expert Professor Paul Newman and his team. Other topics included swarms of robots, robot vision, aerial robots and robots inspired by nature. The conference was chaired by Reader in Computing Science Dr Stephen Cameron.

Optimal rhythm to improve life

Professor Marta Kwiatkowska has been awarded a grant for the project, VERIPACE, which aims to lengthen the battery life of pacemakers and improve the patient's quality of life. If successful, it will also mean that the patient needs fewer replacement surgeries, significantly reducing healthcare costs.

Cardiac arrhythmias – irregularities in the heart rhythm – are common diseases that are expected to increase with the aging population. The typical treatment is by expensive surgical implantation of cardiac pacemakers, battery-powered medical devices which stimulate the heart to beat appropriately and need to be replaced every five to six years.

In the UK alone, there are around 25,000 pacemaker implants per year, each costing approximately £20,000. Timing faults in the software embedded in a pacemaker device can lead to discomfort, or even patient death.

The main idea of the VERIPACE project is to develop novel methods to derive optimal pacing rates for a given patient. It aims to exploit the model-based framework for quantitative verification of pacemaker software recently developed within the European Research Council (ERC) Advanced Grant, VERIWARE (www.veriware.org).

The ERC Proof of Concept grant awarded to VERIPACE was introduced in March 2011 to establish the innovation potential of ideas from ERC-funded frontier research projects.

Faster radiotherapy planning

A collaborative project between physicists, oncologists and computer scientists at Oxford and Cambridge Universities is developing new software to plan radiotherapy treatment. Accel-RT will help overcome the time constraints that currently limit the use of complex treatment by developing improved software tools and processes for the planning of high precision radiotherapy.

While modern radiotherapy machines can now deliver highly targeted treatment, the use of high precision techniques is extremely demanding in terms of hours spent. Over three years the team is aiming to develop tools to speed up the process. Accel-RT was launched in December 2011, and is funded by the Science and Technologies Facilities Council (STFC), through its Innovations Partnership Scheme, with the support of Siemens Healthcare.

Once the research is completed, free software tools will be available to radiotherapy treatment centres. These tools will increase patient access to high precision radiotherapy by reducing the bottlenecks in the clinical workflow. The system will operate as a 'virtual oncologist', observing what the oncologist is treating and using novel search algorithms to recall similar cases from a clinical archive. Models of tissue structures will be used to help outline normal tissue automatically, as well as to track the movement of these structures during the course of radiotherapy treatment.

The key players in the project are established leaders in their fields. At Oxford University, Professor Jim Davies and his team from the Department of Computer Science have experience in the handling of 'smart' data systems – using metadata elements to allow data to be searched and processed in more intuitive ways. The team includes Dr Neil Burnet from the University of Cambridge and Professor Andy Parker and his team at the High Energy Physics group in Cambridge.

'In essence, Accel-RT is helping to identify tumours and surrounding organs during the planning and delivery of radiotherapy treatment,' said Andy, Principal Investigator for Accel-RT. 'Tracking the change in position and volume of these structures is a complex problem. To perform these calculations in real time for a single patient would require up to 16 Teraflops of processing power – approximately 100 times the power of a standard PC workstation.' More details: www.accelrt.org.

Experts advise on simulations for drug safety testing

Two Oxford computer scientists were among just six experts invited to advise the US on replacing the way it evaluates medicine to include computer simulations.

Before being released to the market, medicines are evaluated by pharmaceutical companies to rule out the possibility of potentially lethal, adverse side-effects on the heart. Regulatory agencies such as the USA Food and Drug Administration (FDA) assess whether the results for cardiotoxicity provided by the companies are convincing or not before authorising the commercialisation of the drug.

In July, the FDA announced a big change in the way medicines are evaluated before being released to market: they want to replace one of the studies conducted in humans (the thorough QT study) by a combined in silico and in vitro assay using computer simulations and human stem cell derived cardiomyocytes. The move is to be implemented by 2015, a big shake-up for the pharmaceutical industry.

The FDA invited Dr Gary Mirams and Dr Blanca Rodriguez from the Department of Computer Science at the University of Oxford to present their work and inform them of new technologies available for the evaluation of drug-induced effects on the heart using computer simulations. The aim of inviting experts to present their research was to start the process of shaping the details of the in silico assays that the FDA will request from pharmaceutical companies to test for drug cardiotoxicity.

The work in this area in Oxford was initiated by Prof Denis Noble and the award of the preDiCT project funded by the European Commission from 2008-2011, also led by Prof David Gavaghan and Blanca. After that, Gary's research was supported by funding from industry (GlaxoSmithKline) and a grant from the National Council for the Replacement, Refinement and Reduction of Animal Experiments. Blanca was awarded a Medical Research Council Industry Partnership Award, research grants by Janssen Pharmaceuticals and an EPSRC Impact Acceleration Award, to support work done with various members of the Department, including Dr Alfonso Bueno-Orovio, John Walmsley, Oliver Britton, Dr Ana Mincholé and Professor Kevin Burrage.

Blanca has also been invited to present their work, in the context of the FDA changes, at the Annual Meeting of the Safety Pharmacology Society in September in Rotterdam and at a joint Safety Pharmacology and British Toxicological Pathology Societies meeting organised in the headquarters of the pharmaceutical company AstraZeneca in November.

The importance of the world-leading research conducted in the Department in this area of Computational Medicine has also been recognised by the Wellcome Trust through the award of a Senior Research Fellowship in Biomedical Sciences to Blanca and a Henry Dale Fellowship to Gary to support their research for the next five years.

Panton Fellowship sees advances in open science

Sophie Kay (née Kershaw) of the Computational Biology group has recently completed a one-year Panton Fellowship in association with the Open Knowledge Foundation.

As part of her fellowship work, Sophie founded the Open Science Training Initiative (OSTI), an educational scheme for pre-doctoral and early-career researchers. OSTI aims to address the issue of reproducibility in scientific research by driving students' engagement with digital practices and open working techniques. A pilot scheme was run at Oxford's Doctoral Training Centres for Systems Biology, the Life Sciences Interface, and the Industrial Doctorate, in January 2013 and looks set to appear in a network of institutions across Europe, the US and Commonwealth over the coming year.

Sophie's paper addressing the benefits of OSTI's novel education pattern for developing robust scientific research practices was also included in the European Commission's report on Higher Education as part of their vision for Open Education 2030. For further information: www.opensciencetraining.com.

The fellowship involved a significant public aspect, including presentations at the Open Knowledge Festival in Helsinki, an international conference in open technologies, policy and academia, and participation in panel debates at OKFest and Digital Research. Sophie also showcased OSTI at several major institutions in California, including Stanford and Berkeley.

OSTI enjoyed success at the University of Oxford's OxTalent awards in June 2013, winning its category for Open Educational Resources. Sophie has been invited to deliver a workshop at #solo13, a conference of the Nature Publication Group.

Floating Points in Dragon Boat challenge

A team of staff and students – Floating Points @ CS – took part in the annual Abingdon Dragon Boat Race this September.

The team were raising money for SeaSaw (offering grief support to young people), the Thames Valley & Chiltern Air Ambulance, and Daybreak (providing day clubs for dementia-sufferers in Oxford).

The team achieved seventh place in the heats, with their quickest time over the course a very respectable 1 minute, 18.9 seconds. Although this wasn't enough to take the team into the finals, it was less than 1.5 seconds behind the best time posted by the competition's ultimate winners, the 'Wittenham Wannabees'.

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 in the last year:

Doctoral student Adrian Duncan won a gold medal in Archery and a bronze in the Table Tennis at the British Transplant Games. This adds to his silver in Table Tennis from last year's games.

Bob Coecke – aka Professor Bob – has been using music to understand his chosen field of quantum mechanics for years. He's recently been gigging in Beijing.

Doctoral student Martin Lester, is ranked the best Riichi Mahjong player in the UK, having taken silver at the Oranda Sai-kou tournament in the Netherlands.

Karen Barnes from the Admin & Support team has been raising money for local charity NEETS (for young people not in employment or education) by undertaking four daring challenges, including stopping an in-flight arrow with the hollow of her neck, and doing a fire walk.

In August, doctoral student Aistis Šimaitis won third place in the Chlumec International Triathlon (involving a 400m swim, 36km bike ride, 5km run and 3 pints of beer) after leading the race on finishing the bike ride.

Earlier in the year, he was in an Oxford team that won a bronze medal in the British Universities Team Time Trial Championships, and finished seventh overall in the British Universities 25 mile Individual Time Trial Championships, leading Oxford to a bronze medal in the team classification.

At this year's Oxford-Cambridge Boat Race, Oxford jumped to an immediate lead and held it throughout to win the 159th Boat Race, by a length and a half. MSc student Paul Bennett was in the No. 5 seat. Oxford completed a clean sweep of Cambridge, as the Isis crew (featuring DPhil student William Zeng, who was in the Boat Race last year) had beaten Goldie by one-third of a length earlier in the day.

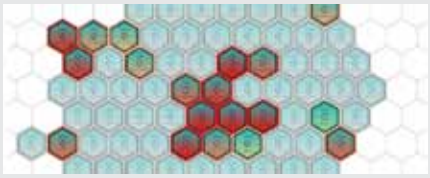
Students present at Eurographics UK

The winners of a student project, which they designed as part of their undergraduate degree at Oxford, have presented their research to the Eurographics UK conference.

The Group Design Practicals are a new element to the Computer Science degrees, and give second-year students the opportunity to work on a development project from a list of design briefs. The IBM prize for Best Group Project was awarded to Team Four for NetVis: a tool assisting users to detect potential network attacks by visualising traffic captures in a variety of perspectives that complement each other. The techniques implemented in NetVis were a collection of both original and well-established approaches developed in a modular fashion, allowing for new visualisations to be appended to the core framework.

'After positive feedback from industry visitors during the departmental demonstration, we – in the Cyber Security Group – encouraged the students to submit their work as a research paper to the Eurographics UK conference, a venue for graphics research,' said Dr Jassim Happa, the departmental mentor for the winning team. 'We assisted in the writing phases, helping the paper conform to conference guidelines and general paper-writing practices. The paper was accepted and presented in early September 2013.

'We are extremely pleased to have worked with undergraduate students who have been both keen and able to deliver this high level of quality work, and hope to see more of it in future projects.'



The members of the winning group were: James Nicholls, Dominik Peters, Albert Slawinski, Thomas Spoor and Sergiu Vicol.

International league table success

Computer science at Oxford has recently topped a number of important international league tables.

The Academic Ranking of World Universities named Oxford in August as best in Europe (and best in the world outside North America) in the 2013 Computer Science league table. Up two places on last year's position, Oxford was the only British university to appear in the top 20 for Computer Science in this year's rankings. The Academic Ranking of World Universities (ARWU) – sometimes known as the Shanghai Rankings – is conducted by researchers at the Center for World-Class Universities of Shanghai Jiao Tong University (CWCU).

In May, the QS World University Rankings placed Oxford third globally, and top in Europe, for Computer Science & Information Systems, up from sixth place last year. The table, produced annually by Quacquarelli Symonds (QS), is based on a global survey of opinions of academics and employers. Some 110 UK universities appear in these subject rankings, which look at 30 disciplines. Of these, 65 UK universities are in the global top 200 for at least one subject. According to the BBC, overall, Cambridge was in the top 10 for 27 subjects, Oxford for 15 subjects, and Imperial for 10.

The Department's academics have made it into various top tables too. Both Ian Horrocks and Michael Wooldridge currently rank in Microsoft Academic Search's top ten authors in the field of artificial intelligence. Ian Horrocks is also recognised as one of the top authors in the World Wide Web research domain.

This year also sees an increased number of students starting with the Department of Computer Science on taught courses. In October, we welcomed over 60 students across the three undergraduate computer science courses. In addition, over 60 new students started on the full-time MSc programme. In excess of 30 doctoral students have begun their studies with us, alongside more than 15 students in the newly opened Doctoral Training Centre in Cyber Security. More than 80 students have joined the part-time MSc software engineering programmes in the last year.

The following have joined the Department in the last year (2013) [previous role and organisation in grey]**:**

Dr Cas Cremers – University Lecturer in Computer Science (Software and Systems Security) [Senior Scientist: Institute of Information Security, ETH Zurich]

Dr Dmitrii Pasechnik – Senior Research Fellow [Assistant Professor: Nanyang Technological University]

Dr Edith Elkind – University Lecturer in Computer Science (Computational Game Theory) [Assistant Professor (NRF Fellow): Nanyang Technological University]

Dr Egor Kostylev – Departmental Lecturer in Computer Science (Information Systems) [Research Fellow/Associate: The School of Informatics at the University of Edinburgh]

Dr Kasper Rasmussen – Departmental Lecturer in Computer Science [Visiting Assistant Project Scientist: University of California, Irvine]

Professor Leslie Ann Goldberg – Professor of Computer Science [Professor: University of Liverpool]

Livia Predoiu – Marie Curie Fellow [Computer Scientist: State Archive of Saxony Anhalt]

Professor Luca Cardelli FRS – Royal Society Research Professor. [retains his position at Microsoft Research Cambridge]

Professor Nando De Freitas – Professor of Computer Science [Professor: University of British Columbia]

Professor Paul Goldberg – Professor of Computer Science [Professor: University of Liverpool]

Dr Stanislav Živný *re-joined* – Research Lecturer and Royal Society Research Fellow. [Senior Research Fellow in Advances in Discrete Mathematics: University of Warwick]

Staff who have changed role internally:

Dr Chris Heunen – Research Lecturer
Dr Evgeny Kharlamov – Senior Research Fellow
Dr James Vicary – Senior Research Fellow
Dr Markus Krötzsch – Departmental Lecturer
Dr Stefan Kiefer – Research Lecturer and Royal Society Research Fellow
[all Research Assistants]

Dr Andrew Markham – University Lecturer in Computer Science (Software Engineering). [EPSRC Postdoctoral Research Fellow]

Dr Blanca Rodriguez – University Lectureship in Computational Medicine, and Wellcome Trust Senior Research Fellowship [Medical Research Council Career Development Fellowship]

Dr Gary Mirams – Wellcome Trust / Royal Society Henry Dale Fellowship [College Lecturer]

Dr Vojtěch Forejt – University Lecturer in Computer Science (Software Engineering. [Researcher]

Academic staff appointed:

Professor Michael Wooldridge, Professor of Computer Science as Deputy Head of Department.

Professor Jeremy Gibbons as interim Director of the Software Engineering Programme.

MAKING HEADLINES

Facebook photos: the hidden photo message

Third year student Owen Campbell-Moore made headlines around the world last April with 'Secretbook', a research project creating an app allowing users to embed hidden messages in Facebook images.

Dr Andrew Ker had set the challenge: to develop a steganography app, which allows messages to be securely sent and received inside pictures, using Facebook; and to demonstrate that JPEG steganography can be performed on social media where it has previously been impossible. Owen, under the guidance of Andrew, took up the gauntlet and produced a Chrome Extension, 'Secretbook'.

Secretbook allows users to embed up to 140 characters of data into any image, which is then transmitted using Facebook. Any of the user's friends provided with the pre-shared password can then decode the message using the same extension.

Written in Javascript, Secretbook utilises a technique known as JPEG steganography to make many visually imperceptible changes to encode the data. This technique isn't new, but has always required that images are transmitted unaltered. This is the first time software, which allows the JPEGs to be recompressed without damaging the secret contents, has been publicly available. This solves the problem of social networks altering files when uploaded, which disrupts the intricate arrangement of hidden data, and makes the message unreadable.

The message in Secretbook is hidden in the digital makeup of the picture, not its pixels, so it's comparable to digital invisible ink. Owen replicated Facebook's recompression algorithm, so that whilst embedding the message, the extension automatically compresses the image. It therefore minimises the amount of change the file, and the message, will undergo when processed by Facebook. SecretBook also combines error correction (where the errors cannot be known in advanced) with avoiding the unalterable parts of the image (which are known in advance). The combination is achieved using a nested code, so that even if parts of the data are corrupted, the message is still decipherable.

The goal of Owen's project was to demonstrate a proof of concept of performing steganography on a social network, not to provide total security. Since the images contain a large number of changes, it would be relatively straightforward to write an algorithm to identify ones that have been manipulated.

Andrew commented: 'Tools to maintain privacy are increasingly important, given recent revelations about total surveillance of the internet by government agencies… future research could allow longer messages to be hidden with higher security.'

Owen's research was in headlines worldwide, including the *Daily Mail*, *The Times of India*, *NBC News*, and *Wired*. More about media coverage and Secretbook's creator is at: http://www.owencampbellmoore.com/.

The Unmasking of J K Rowling

Professor Peter Millican hit the headlines in July when he helped unmask JK Rowling's secret identity as 'debut' crime writer Robert Galbraith, author of *The Cuckoo's Calling*.

A *Sunday Times* journalist approached Peter with the hypothesis, following a tip-off that turned out to have originated from Rowling's lawyer. Peter used his 'Signature' software to compare *The Cuckoo's Calling* and other Rowling books against works of several well-known crime writers.

'The analysis corroborated quite strongly the hypothesis that had been put to me that JK Rowling had written *Cuckoo's Calling*,' said Peter. She later 'confessed' that was indeed the case.

Signature can be used to analyse 'literary fingerprints': word length and punctuation, sentence and paragraph length, frequency and patterns of usage of particular words and phrases, etc. It then statistically processes and plots the results of these analyses on the various texts, indicating how far they are apart and whether they 'cluster'. Even very common words, such as 'the', 'to', or 'in', can help reveal authorship, because patterns amongst these, along with their frequency, tend to be unconscious to the author and often quite consistent between their texts.

Peter previously hit the headlines in 2008 with Signature, when he found that it was unlikely that the autobiography of United States President Barack Obama was ghost-written by a former terrorist, Bill Ayers.

More recently, Peter has been heavily involved in setting up Oxford's new undergraduate degree in Computer Science and Philosophy. He has also developed his 'Turtle' software to encourage computer programming in schools and help make it more attractive to students in the humanities.
Further information is at: www.philocomp.net.