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ABOUT NICTA

NICTA is Australia’s Information Communications Technology (ICT) Research Centre of Excellence and the nation’s largest organisation dedicated to ICT research. NICTA’s primary goal is to pursue high-impact research excellence and, through application of this research, to create national benefit and wealth for Australia. We aim to be one of the world’s top ICT R&D centres.

NICTA’s research addresses the technology challenges facing industry, the community and the whole nation. We seek to improve the international competitiveness of both academic ICT research and industry innovation by tightly linking the two to achieve greater economic and social impact.

Research Excellence
Research undertaken at NICTA is undertaken within six large-scale Research Groups.
• Software Systems
• Networks
• Machine Learning
• Computer Vision
• Control and Signal Processing
• Optimisation

These groups each have a long-term vision for innovative ICT research with the aim of becoming the leading groups in their field.

Wealth Creation
NICTA focuses on wealth creation opportunities that draw on and exploit its areas of research excellence. These take the form of funded industry partnerships, startup companies or research outcomes which have major societal impact. Four Business Teams drive commercial outcomes in the following recognised application domains for ICT:
• Broadband and the Digital Economy
• Health and Life Sciences
• Infrastructure, Transport and Logistics
• Security and Environment

NICTA is especially focused on developing outcomes that have major national benefit.

History
NICTA was established in 2002 by the Federal Government as part of the Backing Australia’s Ability initiative, following a competitive bid process. Funded by the Australian Government through the Department of Broadband, Communications and the Digital Economy and the Australian Research Council through the ICT Centre of Excellence program, we are further supported and funded by our six Members: the Australian Capital Territory Government, the Australian National University, the New South Wales Government, the University of New South Wales, the Victorian Government and The University of Melbourne. We are also supported and funded by our partners: the Queensland Government, The University of Queensland, Queensland University of Technology, Griffith University, The University of Sydney and Monash University.

NICTA has created 11 new companies, collaborated on joint projects with a range of ICT industries, developed a substantial technology and intellectual property portfolio and continues to supply new talent to the ICT industry through a NICTA-supported PhD program. NICTA has more than 700 people across five laboratories around the nation.
FROM THE CHAIRMAN

Moving into its tenth year, NICTA is an established, internationally recognised centre of research excellence in ICT. We continue to connect world-class research in ICT to the major challenges faced by government, industry and society.

NICTA delivers impact by applying digital and information communications technologies to transform the productivity and processes of existing industries. In 2012, we opened the Digital Productivity Showcase—a purpose-built demonstration facility designed to showcase new digital tools to improve Australia’s productivity. Housed within our Australian Technology Park Laboratory, the showcase was launched by Senator the Honourable Stephen Conroy, Federal Minister for Broadband, Communications and the Digital Economy and Minister Assisting the Prime Minister on Digital Productivity. By the end of the year, the showcase had grown to encompass an impressive membership which included CSIRO, the ABC, Senath, SIRCA, Technicolour and CineTV.

In 2012, we commissioned an independent economic impact analysis from Deloitte Access Economics in which 11 NICTA projects were analysed. It is estimated that together these projects have contributed over $3 billion per annum to the national economy. The entire ICT community should be proud of this achievement.

We also welcomed three new Board members to NICTA: Professor Mary O’Kane, NSW Chief Scientist and Engineer; Mr Theo Theophanous, former Victorian Minister, and Mr Tony Henshaw, who has worked in industry for over 35 years in a variety of senior roles. As a national organisation tackling national problems on a national scale, each of these Board appointments reinforce our unique position in the national innovation landscape spanning research, government and industry.

NICTA aims to be ranked amongst the top global ICT research institutions. Our enduring research program has enabled us to attract some of the very best research talent internationally and to build research groups in areas such as optimisation, machine learning and software engineering which are arguably the best in their respective fields worldwide. As an example, Broadband and Digital Economy Director Dr Terry Percival received a prestigious European Patent Office (EPO) Inventor Award in 2012 for his role in developing and patenting the core technology of Wireless LAN, now used in billions of electronic devices worldwide.

Much of NICTA’s research excellence is made possible through our strong university ties. With 340 graduates and current enrolments at 260, NICTA is Australia’s largest ICT PhD factory training around one quarter of all the ICT PhDs in the nation.

All of our work in research excellence and wealth creation has been underpinned by major long-term investment by the Commonwealth Government, specifically the Department of Broadband, Communications and the Digital Economy and the Australian Research Council, as well as by the Australian Capital Territory, Victorian and New South Wales Governments. Last year the ACT and NSW Governments announced continued and generous support amounting to over $40 million over the next four years. In addition we now partner with 10 universities across Australia, with another seven expected to come on board in the near future.

We thank all of our funders and supporters for their commitment to NICTA. I look forward to sharing our continued success in 2013 and to continue to foster our strong leadership and engagement in research, innovation and commercialisation, for both small and large businesses.

Neville Stevens AO
FROM THE CEO

2012 was a stellar year! NICTA continues to be at the vanguard of the ICT revolution. We connect our ICT research to major wealth creation outcomes for Australia, transforming existing industries, creating and growing new businesses and building advanced skills capacity.

NICTA is internationally recognised in areas such as trusted systems, optimisation, signal processing and large-scale data analytics and has strong collaborations with seventeen universities and contracts with key industry players.

We continue our commitment to the health and wellbeing of the nation using our ICT expertise in the diagnosis and treatment of major diseases such as cancer, diabetes and chronic pain management. In November 2012, NICTA scientists embarked on a research grant to help doctors tell the difference between lethal and non-life-threatening prostate cancers.

Our technologies will reduce costs associated with transportation and infrastructure maintenance as well as improve capacity and productivity at major ports. For example, our continued work with Tip Top Bakeries in NSW using our cost-to-serve fleet logistics innovations resulted in a 15 per cent saving in transport costs.

NICTA innovation in cloud computing, data analysis and machine learning will enable SMEs to run more efficiently and reduce compliance costs. It will also help enhance the educational and entertainment capacity of the National Broadband Network. We continue to provide global competitive advantage in data analytics to major Australian banks and financial services businesses.

NICTA technology will enable robust decision making in the allocation of valuable resources such as water and will improve the viability of geothermal energy. Last year, NICTA led a $5 million ICT-enabled geothermal energy initiative announced by the Australian Centre for Renewable Energy which draws on our world-class expertise in big data analytics and machine learning. We also embarked on a multi-million dollar contract with the US Government Defense Advanced Research Projects Agency to develop a new breed of software to protect the critical systems of unmanned vehicles from cyber-attack.

NICTA has exited several startup companies and there is a healthy pipeline in store for 2013. Our startups are already building their own ecosystems and spawning new companies themselves. Audinate, launched in 2006, has become a global leader in live-sound over Ethernet, distributing audio at major public events including the 2012 London Olympics. Open Kernel Labs surpassed the incredible 1.5 billion milestone for the amount of devices in which NICTA technology resides. In 2012, Scalify, NICTA’s startup in the online video games space, also attracted a further cash injection of $2 million from Starfish Ventures for its continued business in the peer-to-peer networking technology area.

NICTA’s research is now ranked among the very best in the world. NICTA produces over 550 high impact publications a year. More than 50 NICTA staff have over 1,000 academic citations and are regarded as world-class researchers in their own right. Much of this is made possible through collaboration with our 10 university partners. Through these strong university linkages, and with 700 of the best and brightest scientists, students and business professionals, NICTA also works with schools to promote the myriad of opportunities available in ICT.

This report allows you to see the scale and reputational reach that NICTA enjoys both in Australia and internationally. Moving into 2013, the excitement surrounding NICTA’s research excellence and wealth creation activities is palpable. I for one am looking forward to the coming year leading NICTA as the nation’s pre-eminent ICT research centre of excellence.

Prof. Hugh Durrant-Whyte
NICTA is transforming industries through the application of digital and information communications technologies to transform the productivity and processes of existing industries, by

• Helping doctors tell the difference between lethal and non-life-threatening prostate cancers through a National Health and Medical Research Council grant

• Transforming farming practices in Australia through algorithms that communicate public data (such as weather and crop production information) to farmers through an easy-to-use web portal

• Helping the United States Government develop new breeds of software that protect the critical systems in unmanned vehicles from cyber-attack.

• Connecting industry with research through targeted industry events (for example globally renowned Big Data expert Dr Rami Mukhtar leads a 600-strong Australian community of academics, industry and government participants)

• Joining the search for geothermal energy sources deep beneath the Earth’s surface through a $5 million ‘big data’ analytics initiative with the Australian Centre for Renewable Energy

• Saving Tip Top Bakeries 15 per cent of transport company costs through intelligent fleet logistics technologies

• Working towards an estimated $100m in water pipeline maintenance savings for Sydney Water

NICTA is creating new businesses and new industries through innovation and the application of ICT research.

• Reducing roadside assets’ maintenance costs by around $60 million per year through algorithms which are used in more than two million navigation devices

• Contributing to CUPGuide, a predictive analytics tool based on NICTA technology, which identifies the primary site of cancerous tumours and was launched by Healthscope and Circadian Technologies during the year.

NICTA is building advanced skills and capacity for Australian industry by attracting and training the best ICT students, engineers and researchers.

• Eminent NICTA researchers Dr Terry Percival and Professor Stan Skafidas were elected as Fellows of the Australian Academy of technological Sciences and Engineering. Terry Percival also won the European Patent Office Inventors Award for his role in developing and patenting the core technology in wireless LAN.

• Partnering with Optus, Australian university students were put to the test to build a unique Android app aimed at “Making Life Easier”.

• Daniel Harabor, NICTA Graduate Researcher, was awarded at CeBIT Australia and at NASSCOM for his research breakthrough analysing computer animated characters in video games

• Research Group Leader Professor Bob Williamson was elected as a Fellow of the Australian Academy of Science.

• NICTA has now graduated 340 PhD students representing around one quarter of all ICT PhDs in Australia.
Matthew Sladescu received the University of Sydney Engineering & IT Faculty’s Tutoring Award, the highest tutoring award offered annually by the university.

Sam Lichter was awarded second place in The University of Melbourne’s 3 Minute Thesis competition for her paper “Carats that REALLY improve your eyesight: an all-diamond Bionic Eye”.

Vasanta Chaganti is the lead ambassador for Girl Geek Coffees in the ACT, a forum through which young women interested in computer programming and engineering can meet.

Daniel Harabor’s research breakthrough promises a future where animated characters in computer games move more efficiently, naturally and intelligently. Daniel received a Highly Commended NASSCOM Innovation Student Award for his research.
STUDENTS AND STRONG UNIVERSITY TIES

NICTA plays a critical role in delivering ICT skills and capacity for Australia. We do this in four primary ways. First and foremost, through our enhanced PhD program, we provide funding to PhD students and deliver advanced student training in technology and entrepreneurship, as well as the opportunity for students to engage in industry and commercial projects.

Second, we work with our university partners to develop advanced tertiary ICT education for Australian industry. Third, we play a significant role in catalysing the interest and engagement of school students in ICT. And finally, through supporting and developing our professional staff and researchers, we produce highly trained ICT researchers and technologists who have expertise in commercialisation and wealth creation.

**Enhanced PhD Program**
NICTA trains high quality postgraduate research students who drive innovation and the creation of new industries. NICTA has graduated 340 PhD students to date, and currently trains about one quarter of the total number of PhD students in ICT in Australia each year.

A key objective of the NICTA enhanced PhD program is to build the quality and quantity of ICT graduates across Australia. NICTA staff contribute to university teaching both through the delivery of technical and entrepreneurship courses, and by acting as mentors in final year projects. Equally, many universities have contributed staff to NICTA and these academics work on industry and commercial projects that inform their teaching. This is enhanced by the Summer Scholars Program, a summer school run in partnership with universities which hosts around 50 undergraduates across all NICTA laboratories for 8 - 12 weeks each year.

In 2012, NICTA offered undergraduate scholarships for the first time. The new scholarship program is aimed at high-achieving students interested in engineering, mathematics and computer science. It offers undergraduate students the opportunity to have eight months of hands-on research training during their degree.

In addition to the training and experience received at NICTA, students are offered a range of intern opportunities with industry, both nationally and internationally, at institutions such as Bell Labs (USA), the National Institute of Informatics and WIDE Project (Japan), and Microsoft Research Asia (China) and INRIA (France).

The calibre of NICTA’s students is demonstrated by the range of awards and prizes that they have been awarded. In 2012, NICTA research students were awarded, among other prizes and awards, the 2012 ICAPS Best Dissertation Award, the CORE Distinguished PhD Thesis Award, the 2012 Association for Constraint Programming Doctoral Research Award, the 2012 Google Anita Borg Memorial Scholarship as well as Google Publication Prizes.

Furthermore, the majority of NICTA’s research papers are co-authored by students, and more than half of NICTA’s papers appear in the highest ranking conferences and journals. NICTA students have also been co-inventors on 20 per cent of NICTA’s patent applications.

NICTA PhD graduates are sought internationally, with many gaining employment at leading international institutions including Carnegie Mellon University (USA), INRIA (France) and Microsoft Research (USA, Brazil) and in industry including Google, HP Labs and Yahoo!. A substantial portion of graduates stay in Australia and are employed at leading research organisations and ICT companies including DSTO, Canon, IBM, SAP, Dolby Labs and Ericsson.

**Advanced ICT education for Australian industry**
NICTA engages with industry and the ICT ecosystem to deliver advanced training around new technologies. These initiatives range from collaborating with industry on joint courses which provide deep skills in areas such as machine learning or computer vision, (such as the recent SCALA programming course run with Atlassian, a major Australian software company), to informal events such as the monthly ‘big-data mash-up’, which has acquired 600 new members in only nine months.

**Catalysing the interest and engagement of school students in ICT – NICTA’s outreach program**
NICTA is addressing the decline in enrolments in ICT-related degrees through initiatives run with both university partners and industry organisations to attract school students to a career in ICT.

NICTA has been actively involved in the GroupX initiative which has had a marked effect in increasing applications to ICT degree courses in Queensland, and is working with partners to roll this initiative out across other states. NICTA also provides major support for the National Computer Science Summer School, a computer programming school for high school students run with the University of Sydney and the Australian National University, and is an active member of the Scientists in Schools program – a national initiative.
TOP PUBLICATIONS

COMPUTER VISION

- Taghavi Namin, S., Petersson, L., Classification of Materials in Natural Scenes using Multi-Spectral Images, IEEE/RSJ International Conference on Intelligent Robots and Systems, Vila Moura, Portugal, pp. 6, October, 2012. In this paper, a novel method was developed for roadside material classification using a camera with six visible sub-bands and one near infra-red sub-band. Key issues occurring in real-world outdoor data was considered which guided a choice of features robust to, in particular, varying lighting conditions.

- Harandi, M., Sanderson, C., Hartley, R., Lovell, B.,Sparse Coding and Dictionary Learning for Symmetric Positive Definite Matrices: A Kernel Approach, European Conference on Computer Vision, Florence, Italy, pp. 216-229, October, 2012. Natural images and videos can be efficiently described as a combination of a few primary signals (called visual words). Generally, these are learnt in Euclidean space (for example assuming parallel lines meet at infinity). However, Euclidean spaces may not be the ideal choice in many applications since the problem space is curved (for example earth hour lines are parallel but intersect at poles not infinity). In this work, we learned visual words on Riemannian manifolds (curved spaces), leading to improved results.

- McCarthy, C., Barnes, N., A Unified Strategy for Landing and Docking using Spherical flow Divergence, IEEE Transactions on Pattern Analysis and Machine Intelligence, January, 2012. This paper describes a novel algorithm based on a visual cue that facilitates the control of autonomous systems with respect to looming surfaces inspired by behavioural models of insect flight for docking and landing.

CONTROL AND SIGNAL PROCESSING

- Duffy, K., Wellard, C., Markham, J., Zhou, J., Holmberg, R., Hawkins, E., Hasbold, J., Dowling, M., Hodgkin, P., Activation-Induced B Cell Fates are Selected by Intracellular Stochastic Competition, Science, vol 335(6066) pp 338 – 341, 2012. This groundbreaking paper reports that cells have some control over their own destiny, a major addition to scientists’ understanding of what determines the fate of cells. John Markham’s work has been instrumental in developing technology and techniques used by the team to analyse vision of 2,500 individual immune cells growing in vitro over three days.

- John Markham’s second Science paper for 2012, co-written with colleagues at the Asia-Pacific Centre for Animal Health at the University of Melbourne, has prompted the Australian Pesticides and Veterinary Medicines Authority to review guidelines relating to the use of live attenuated vaccines in livestock. Lee, S., Markham, P., Mauricio, J., Coppo, C., Legione, A., Markham, J., Noormohammadi, A., Browning, G., Ficorilli, N., Hartley, C., Devin, J., Attenuated Vaccines Can Recombine to Form Virulent Field Viruses, Science, vol. 337 no. 6091 p1188.

- Tom Conway and Andrew Bromage’s 2011 paper Succinct Data Structures for Assembling Large Genomes, Bioinformatics 2012, vol 7(4), has been steadily accumulating citations over the last 12 months. The paper demonstrated a method for de novo genome assembly that could be utilised on desktop computers. Recent citations suggest that the paper is driving a whole new direction in the genome assembly literature.

- Meffin, H., Tahayori, B., Grayden, D., Burkitt, A., Modeling extracellular electrical stimulation: I. Derivation and interpretation of neurite equations, Journal of Neural Engineering, 9:065005, 2012, has been chosen as one of the journal’s Highlights of 2012. The Journal of Neural Engineering Highlights is a collection of papers that represent the breadth and excellence of the work published in the journal in 2012. Papers are selected for their presentation of outstanding new research, receipt of the highest praise from our international referees, and the highest number of downloads last year.

- A central goal of medical genetics is to accurately predict complex disease from genotypes. In the recently published paper by NICTA-funded PhD student Gad Abraham and co-authors, a comprehensive analysis of genome-wide SNP profiles across eight complex diseases within cross-validation is presented. The findings show that the methodology is robust across different disease architectures and produces as good as or better phenotype predictions than other methods to date. This has fundamental ramifications for the selection and future development of methods to genetically predict human disease. Abraham, G., Kowalczyk, A., Zobel, J., Inouye, M., SparSNP: Fast and memory-efficient analysis of all SNPs for phenotype prediction, BMC Bioinformatics 2012.

- Parker, J., Compound action potentials recorded in the human spinal cord during neurostimulation for pain relief, Pain, March 2012. This journal is consistently the highest ranking journal in the field of anaesthesiology.

IMPLANT SYSTEMS

- This year the Machine Learning group had six papers published at the International Conference on Machine Learning (Edinburgh, UK, June, 2012) and four at the Conference of Neural Information Processing Systems (Nevada, USA, December, 2012), the two top conferences in machine learning.

- Noel, J., Sanner, S., Tran, K., Christen, P., Xie, L., Bonilla, E., Abbasnejad, E., Della Penna, N., New Objective Functions for Social Collaborative Filtering, International World Wide Web Conference, Lyon, France, pp. 1–10, April, 2012. This paper reports very exciting results on how to substantially improve the performance of collaborative filtering algorithms by simple adjustments to the objective function. The results are compelling because of the large scale experiments carried out using Facebook.

- van Erven, T., Reid, M., Williamson, R., Mixability is Bayes Risk Curvature Relative to Log Loss, Journal of Machine Learning Research, pp. 1639–1663, May, 2012. This paper provides a new, geometrical characterisation of when it is possible to learn quickly from expert advice in terms of the loss function that is used to assess a learner’s performance.

- McAuley, J., Caetano, T., Fast matching of large point sets under occlusions, Pattern Recognition journal, pp. 563-569, May, 2012. This paper proposes a new graphical model that can handle occlusions and is much faster than previous approaches for solving the isometric point-pattern matching problem.

NETWORKS

- Borghol, Y., Ardon, S., Mahanti, A., Carlsson, N. and Eager, D., The Untold Story of the Clones: Content-agnostic Factors that Impact YouTube Video Popularity, 18th ACM Conference on Knowledge Discovery and Data Mining, August 2012, Beijing, China. This work develops and applies a method that is able to accurately assess the impacts of various content-agnostic factors on video popularity and shows that inaccurate conclusions may be drawn if an analysis does not control for video content.
• Li, Z., Lin, J., Akdogenou-Jeannin, M., Xie, G., Ali Kaafar, M., Jin, Y., Peng, G., Watching Video from Everywhere: a Study of the PPTV Mobile VoD System, ACM SIGCOMM Internet Measurement Conference 2012, (Acceptance rate 20%). This paper shows, while video popularity distribution in video on demand system is skewed, the popularity of a video could be predicted accurately using its very early popularity level.

• Tushar, W., Saad, W., Poor, H. V. and Smith, D., Economics of Electric Vehicle Charging: A Game Theoretic Approach, IEEE Transactions on Smart Grid, October 2012. This paper shows that the problem of grid-to-vehicle energy exchange between a smart grid and plug-in electric vehicle groups (PEVs), can be modelled as a non-cooperative Stackelberg game.

• Thilakarathna, K., Petander, L., Seneviratne, A. and Mestre, J., Enabling Mobile Distributed Social Networking on Smartphones, ACM/IEEE International Conference on Modelling, Analysis and Simulation of Wireless and Mobile Systems, October 2012. This paper proposes and evaluates a mechanism for providing users the ownership of their data and privacy, increasing privacy with comparable costs in the current centralised systems.

OPTICS AND NANOELECTRONICS

• Garret D, Ganesan K, Stacey A, Fox K, Miffin H, Prawer S Ultra-nanocrystalline Diamond Electrodes: Optimisation for Neural Stimulation, Journal of Neural Engineering, vol 9, pp 1-10, 2012. This paper demonstrates that ultra-nanocrystalline diamond can stimulate neurons up to the same charge capacity as platinum (which is the current “gold standard” in neuroprotesthetics). Ultra-nanocrystalline diamond has a number of advantages over platinum, including the ability to modulate its conductivity so as to form hermetic feedthroughs. Such feedthroughs are a key component in any neuroprosthetic system. The hermeticity of the feed throughs was demonstrated for the first time in the past quarter and was a key milestone for the Bionic Eye project.


SOFTWARE SYSTEMS

The first two publications shown below are a result of applying empirical software-engineering techniques (a strength of the ATP part of the group) to the trustworthy-systems work based at NRL.

• Andronick, J., Jeffery, R., Klein, G., Kolanski, R., Staples, M., Zhang, H., Zhu, L. Large-Scale Formal Verification in Practice: A Process Perspective, International Conference of Software Engineering, 2012. This paper analyses the formal verification process used for sel4. It discovered some of the reasons why our verification process succeeded where so many others have failed. It is a first step to making formal verification a repeatable software process.

• Kuz, I., Zhu, L., Bass, L., Staples, M., Xu, X., An Architectural Approach for Cost Effective Trustworthy Systems, Tenth Joint IEEE/IFIP Conference on Software Architecture and Sixth European Conference on Software Architecture. The paper introduces an approach for building real-world systems with provable security or safety, by specifying a formal architecture description, proving that it meets the requirements and identifying the requirements that must be proved about the components. This approach will be used in the DARPA project (see the Security and Environment Business Team page 27).

• Sutcliffe, G., Schulz, S., Claessen, K., Baumgartner, P., The TPTP Typed First-order Form and Arithmetic, 18th International Conference on Logic for Programming Artificial Intelligence and Reasoning6. The TPTP (Thousands of Problems for Theorem Provers) is a library of about 6000 test problems, which forms the basis of the annual automated theorem prover championships. The paper extends the TPTP problem language, the de-facto standard in the area, to logical formulas over arithmetic expressions.

• Xu, X., Weber, I., Zhu, L., Liu, Y., Rimba, P., Lu, Q., BPMashup: Dynamic Execution of RESTful Processes, Tenth international Conference on Service Oriented Computing. This paper presents the world-first highly dynamic Javascript-based workflow engine that is embedded inside a browser. It enables local offline and private task processing using the notion of process fragments in the context of participating in a global distributed process.

• Murray, T., Matichek, D., Brassill, M., Gammie, P., Klein, G., Noninterference for Operating System Kernels, Second International Conference on Certified Programs and Proofs. This paper extends the traditional non-interference security property so it is conserved under refinement, and thus compatible with the formal verification of sel4. This enabled the confidentiality proof of sel4 (see below).

• Amani, S., Chubb, P., Donaldson, A., Legg, A., Ryzhik, L., Zhu, Y., Automatic Verification of Message-Based Device Drivers, System Software Verification Conference. This develops a practical approach to the automatic verification of the interface between device drivers and the OS, making it possible to verify properties beyond the reach of traditional techniques.
## PEOPLE AND ACHIEVEMENTS

<table>
<thead>
<tr>
<th>Name</th>
<th>Award</th>
<th>Venue</th>
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<tbody>
<tr>
<td>Geoffrey Chu</td>
<td>2012 Association for Constraint Programming Doctoral Research Award for “Some observations on optimal frequency selection in DVFS-based energy consumption minimization”</td>
<td>Constraint Programming 2012 Conference</td>
</tr>
<tr>
<td>Alan Zhang and Mark Morelande and a group of undergraduate students (Glen Kuhne, Liam Appelbe)</td>
<td>1st prize in Endeavor Melbourne School of Engineering ACP Doctoral Research Award for “Some observations on optimal frequency selection in DVFS-based energy consumption minimization”</td>
<td>Melbourne School of Engineering, The University of Melbourne</td>
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<tr>
<td>Graeme Clark</td>
<td>Australian of the Year 2012</td>
<td>Australian Federal Government</td>
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<tr>
<td>Silvia Richter</td>
<td>Best Dissertation Award for “Landmark-Based Heuristics and Search Control for Automated Planning”</td>
<td>International Conference on Automated Planning and Scheduling 2012</td>
</tr>
<tr>
<td>Wei Liu</td>
<td>Best Dissertation Award for “Landmark-Based Heuristics and Search Control for Automated Planning”</td>
<td>The 25th Australasian Joint Conference on Artificial Intelligence</td>
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<tr>
<td>Peter Stuckey, Geoffrey Chu</td>
<td>Best Paper Award for “Systematically Identifying and Exploiting Dominance Relations”</td>
<td>18th International Conference on Principles and Practice of Constraint Programming</td>
</tr>
<tr>
<td>Andreas Bauer</td>
<td>Best Paper Award for “Decentralised LTL Monitoring”</td>
<td>18th International Symposium on Formal Methods</td>
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<tr>
<td>He (Jason) Zhang, Liming Zhu, Ross Jeffery</td>
<td>Best Paper Award for “An Initial Evaluation of Requirements Dependency Types in Change Propagation Analysis”</td>
<td>16th International Conference on Evaluation &amp; Assessment in Software Engineering</td>
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<tr>
<td>Sachintha Karunaratne</td>
<td>Best Student Paper for “Bayesian Conjugate Analysis for Multiple Phase Estimation”</td>
<td>Fusion 2012 Conference</td>
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<tr>
<td>Lin Gu, Antonio Robles-Kelly</td>
<td>Best Student Paper Award for “Shadow Detection Via Rayleigh Scattering and Mie Theory”</td>
<td>21st International Conference on Pattern Recognition 2012</td>
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<tr>
<td>Wayshe Tushar</td>
<td>Best Student Paper Award for “Non-cooperative Power Control Game in a Multi-Source Wireless Sensor Network”</td>
<td>Australian Communications Theory Workshop</td>
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<tr>
<td>Zijie (Jeffrey) Zhang</td>
<td>Chinese Government Award for Outstanding Self-financed Students Abroad</td>
<td>China Scholarship Council</td>
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<tr>
<td>Patrik Haskum</td>
<td>Best Paper Award for “Semi-relaxed plan heuristics”</td>
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<td>Mark Reid</td>
<td>Discovery Early Career Researcher Award</td>
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<td>Terence Percival</td>
<td>European Inventor Award 2012</td>
<td>European Patent Office</td>
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<tr>
<td>Sandra Mau</td>
<td>Finalist, The Australian Innovation Challenge</td>
<td>The Australian (newspaper)</td>
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<tr>
<td>William Billingsley</td>
<td>Finalist, The Australian Innovation Challenge</td>
<td>The Australian (newspaper)</td>
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<tr>
<td>Germae Shih May Phua</td>
<td>First prize in The Digital Future for “Read between the lines: Search query based re-identification”</td>
<td>University of NSW Taste of Research summer scholarship programme 2011/2012</td>
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<tr>
<td>Graeme Clark</td>
<td>Fletcher Award in Technical Application</td>
<td>New York League for the Hard Hearing</td>
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<tr>
<td>Nargess Nourbakhsh</td>
<td>Freelancer Prize for Software Engineering for “Galvanic Skin Response for Cognitive Load Measurement”</td>
<td>FreeLancer.com; USYD Research Conservazione 2012</td>
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<tr>
<td>Tim Baldwin</td>
<td>Future Fellowship</td>
<td>University Of Melbourne</td>
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<tr>
<td>Nikzad Babailiz Rizvandi</td>
<td>Google Best Publication Prize ”Some observations on optimal frequency selection in DVFS-based energy consumption minimization”</td>
<td>Google Australia</td>
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<td>Lexing Xie</td>
<td>Grand Challenge Multimodal Prize for ”Analyzing social media via event facets”</td>
<td>Association of Computing Machinery Multimedia</td>
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<td>Name</td>
<td>Award</td>
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<tr>
<td>Daniel Harabor</td>
<td>1st Prize Best Poster for “Jump Point Search”</td>
<td>ANU College of Engineering and Computer Science</td>
</tr>
<tr>
<td>Yan Shvartzshnaider</td>
<td>Institute of Electrical and Electronics Engineers Best Paper Presentation for &quot;Design For Change: Information-Centric Architecture to Support An Agile Disaster Response System&quot;</td>
<td>4th Annual Student Research Conference</td>
</tr>
<tr>
<td>Mahboobeh Moghaddam</td>
<td>Institute of Electrical and Electronics Engineers Best Paper Presentation for “A Combinatorial Procurement Auction for Composite Web Service Selection”</td>
<td>4th Annual Student Research Conference</td>
</tr>
<tr>
<td>Desmond Wang</td>
<td>Institute of Electrical and Electronics Engineers Optics Society Fellowship</td>
<td>Institute of Electrical and Electronics Engineers Optics Society</td>
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<tr>
<td>Sejuti Rahman</td>
<td>National Institute of Informatics Internship</td>
<td>National Institute of Informatics (Japan)</td>
</tr>
<tr>
<td>Thanassis Boulis</td>
<td>NSW iAward for e-logistics and supply chain for “Structural Health Monitoring for Bridges” Project</td>
<td>Australian Computer Society, Australian Information Industry Association, Pearcey Foundation</td>
</tr>
<tr>
<td>Thanassis Boulis</td>
<td>NSW iAward for Tools and Infrastructure for “Structural Health Monitoring for Bridges” Project</td>
<td>Australian Computer Society, Australian Information Industry Association, Pearcey Foundation</td>
</tr>
<tr>
<td>Scott Sanner</td>
<td>Outstanding PC Award</td>
<td>Association for the Advancement of Artificial Intelligence 2012</td>
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<tr>
<td>Nina Narodytska</td>
<td>Outstanding Program Committee Member Award</td>
<td>25th anniversary of the Australasian Joint Conference on Artificial Intelligence</td>
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<tr>
<td>Patrik Haslum</td>
<td>Outstanding Reviewer Award</td>
<td>22nd International Conference on Automated Planning and Scheduling 2012</td>
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<tr>
<td>Richard Hartley</td>
<td>Significant Researcher Award</td>
<td>Institute of Electrical and Electronics Engineers Computer Society</td>
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<tr>
<td>Sandra Mau</td>
<td>Tech23 iLab Germinate Program Award</td>
<td>Tech23</td>
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<tr>
<td>Gemot Heiser, Kevin Elphinstone</td>
<td>Vice Chancellor’s Award for Teaching Excellence</td>
<td>University of NSW</td>
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<tr>
<td>Graeme Clark</td>
<td>Zulch Prize</td>
<td>Getrud Reemtsma Foundation, administered by Max Planck Society</td>
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**Impact Awards**

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<th>Name</th>
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<tr>
<td>Carly Perry</td>
<td>Impact Awards Operational Excellence Winner</td>
</tr>
<tr>
<td>Adam Kowalczy</td>
<td>Impact Awards A.Richard Newton Research Excellence Joint Winner for contribution to Cancer Genomics Research</td>
</tr>
<tr>
<td>Leonid Rzychy</td>
<td>Impact Awards A.Richard Newton Research Excellence Joint Winner for Device Driver Solution</td>
</tr>
<tr>
<td>Intelligent Fleet Logistics</td>
<td>Impact Awards A. Richard Newton Wealth Creation Joint Winner for major impact with fast moving consumer goods sector</td>
</tr>
<tr>
<td>Business Adaptation and Interoperation</td>
<td>Impact Awards A. Richard Newton Wealth Creation Joint Winner for major impact in Australian software engineering</td>
</tr>
<tr>
<td>Spectral Imaging Team led by Antonio Robles-Kelly</td>
<td>FB Rice Prize for Best Patent Activity</td>
</tr>
<tr>
<td>Evoked Response Telemetry Method, Implant Systems Team led by John Parker</td>
<td>Inaugural NICTA Best Invention Prize for Evoked Response Telemetry Method</td>
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### BROADBAND AND THE DIGITAL ECONOMY

Digital technology permeates modern life, transforming traditional sectors and creating new digital services, which leads to higher productivity and subsequent economic growth. Australia’s future prosperity depends on technology-enabled innovation, now an essential global commodity.

- Digital Productivity Showcase
- Australian Centre for Broadband Innovation Collaboration
- Big Data Analytics for Enterprise (Ambiata)
- Compliance by Design (Regerous)
- Australian eGovernment Technology Cluster
- Performance Assurance (ePASA)
- High Quality Mobile Experience (Incoming Media)
- Software Bug Detection (Goanna)
- Social TV
- Virtual Counter
- Business Continuity Tools for the Cloud (Yuruware)

### INFRASTRUCTURE, TRANSPORT AND LOGISTICS

The Infrastructure, Transport and Logistics (ITL) Business Team delivers innovative ICT solutions that transform the efficiency, safety and sustainability of transportation systems and infrastructure networks.

- Container Tracking
- Container Control
- TruckOn
- Intelligent Water Pipes
- Structural Health Monitoring for Bridges and other civil infrastructure
- SmartGrid
- Intelligent Transport Systems
- Automated Sign Recognition
- Air Traffic Management
- Supply Chain Optimisation
- Future Logistics Living Lab
- Total Port Logistics
- Driver Mental State Monitoring
- Intelligent Fleet Logistics
- Dynamic Under Keel Clearance – Optimising Bulk Commodity Ports

### SECURITY AND ENVIRONMENT

The Security and Environment Business Team focuses on developing innovative security solutions for natural resources, people, and critical computer systems.

- Cybersecurity
  - Security for Critical Systems
  - Verified Real-Time Operating System
  - Online Photo Discovery
  - Robust Control Systems Design
- Disaster Management
  - Event Watch
  - Decision Support Tools
  - Fuel Hazard Assessment
- Environmental Monitoring
  - Fish Surveillance in the Wild
  - Monitoring Analytics Solutions
  - Groundwater Modelling Software
  - Soil Classification Survey Optimisation
- Food Security
  - FarmNet
  - Plant BioSecurity
  - Supply Chain Optimisation
- Renewable Energy
  - Geothermal Discovery Software
  - Power Stability Software
  - Solar Energy Forecast Software
  - Air Quality

### HEALTH AND LIFE SCIENCES

The Health and Life Sciences Business Team is transforming innovative technologies to advance the understanding of human diseases and to improve the health and well-being of Australians.

- Tracking Infections
- Detecting DNA Mutations for Precision Medicine
- Fighting Prostate Cancer using High Performance Computing
- Bionic Eye
- Managing Parkinsons, Stroke and Epilepsy through Motion Analysis
- eHealth: Meaningful Information from Biomedical Data
- eHealth: National eHealth Living Lab
- Computational Genomics: Detecting Cancers of the Unknown Primary
- Bio-medical Imaging
<table>
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<th>Research Group</th>
<th>Projects and activities in 2012</th>
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<tbody>
<tr>
<td>SOFTWARE SYSTEMS</td>
<td>The Software Systems Research Group aims to deliver transformational improvements in the design, implementation and verification of software systems • Modelling and Verification of Data-Intensive Systems • Preventing Failure with Dependable Operations • Protecting your Critical Information • Temporal Isolation - Ensuring Safety-Critical Software Gets Enough Time to Do Its Job • Trustworthy Systems</td>
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<tr>
<td>NETWORKS</td>
<td>The Networks Research Group is developing new mechanisms and techniques that will maximise user privacy, minimise resource usage, and maximise usefulness for both service providers and end users in the domains of entertainment systems (infotainment) and smart energy: • OMF and OML Testbed Suite • Mesh Networks Project • Smart Mobile Content Distribution • Privacy and Trust • Proximity Based Authentication • PrivatePoll: a mobile app for conducting surveys that preserve user privacy • mSpeed</td>
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<tr>
<td>COMPUTER VISION</td>
<td>The Computer Vision Research Group undertakes fundamental research in computer vision with a focus on understanding the world through video: • Spectral Imaging • Smart Transport and Roads • Visual Processing for the Bionic Eye • Autormap • Bionic Vision Australia • Kernel Methods on Manifolds • 3D Reconstruction of Reflective Methods</td>
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<tr>
<td>MACHINE LEARNING</td>
<td>The Machine Learning Research Group develops and applies technologies that make sense of the ever-increasing amounts of data gathered in all areas of human endeavour: • Biomedical Text and Data Mining • Graphical Models • Human Computer Interaction and Cognitive Analytics • Large-scale Machine Learning • Learning Theory • Structured Prediction • Text Analysis and Language Technology • Topic Modelling</td>
<td>57</td>
</tr>
<tr>
<td>OPTIMISATION</td>
<td>The Optimisation Research Group at NICTA carries out fundamental and applied research that addresses grand challenges faced by our society in disaster management, future energy systems, logistics, and supply chains: • Real-time management of renewable energy • Intelligent Decision Theory • Future Energy Systems • Logistics Research for Ports, Roads, Public Transport • Raising the IQ of the Smart Meter • Managing the Cascade of Alarms Generated by the Grid • Resupplying 90% of Customers in 1 min after a major power outage • Disaster Management • Smart Scheduling for the Smart Grid • Improving Canberra’s Bus Service</td>
<td>63</td>
</tr>
<tr>
<td>CONTROL AND SIGNAL PROCESSING</td>
<td>The Control and Signal Processing (CSP) research group develops new tools and methodologies for computational life sciences and large-scale interconnected systems: • Assistive and Adaptive Bionics • Future Grid • Power System Modelling and Fault Detection • Computational Approaches to Immunology • Distributed Control and Estimation in Networked Environments • Large-Scale Genetic Network Modelling</td>
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<tr>
<td>OPTICS AND NANO-ELECTRONICS</td>
<td>The Optics and Nanoelectronics Research Group brings together NICTA’s expertise in optics and nanoelectronics, which draws on the organisation’s longstanding experience in advanced sensor networks and CMOS research: • Nano-devices for Biological Sensing • Radar on a Chip (ROACH) • Stereoscopics Imaging and Binaural Scene Encoding • Engineering Nanometre-Scale Photodetector • Silicene-enhanced 3D Optical Imager System on a Chip</td>
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<tr>
<td>IMPLANT SYSTEMS</td>
<td>The Implant Systems Research Group develops small, sophisticated and low-cost implantable therapies to help relieve chronic pain: To unlock new therapies, we have developed new platform technologies for: • Systems architectures • Device packaging • Tissue packaging</td>
<td>79</td>
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COMMERCIAL PIPELINE

ambiata
Yuruware
AutoMap
ePASA
goanna
CeeQ
UserMetrix

OUR START-UPS

Audinate
Open Kernel Labs.
Be open. Be safe.
Saludamedical
nitereo
Incoming
Opturion
InterfereX
Scalify
Our Start-Ups and Pipeline

**Commercial Pipeline**

**Ambiata**
Ambiata applies state-of-the-art machine learning research to enterprise data assets to deliver near-real time automated business decision-making. This enables traditional bricks and mortar businesses to deliver personalised products and services to each of their customers.

**Yuruware**
Yuruware provides cloud-based business continuity, migration, monitoring and management tools which simplify the cloud while improving reliability and reducing risks and costs. The products offered by Yuruware enable businesses to transition seamlessly between original computer hardware and a replica stored in the cloud in the event of a disaster.

**Automap**
Automap supports the personal navigation market’s rapidly growing data requirements by developing technologies to automatically create and update digital maps, thereby lowering the cost of collecting and processing video data and increasing the accuracy of map information. The software not only provides the GPS-location of infrastructure assets, but also enables monitoring to identify maintenance requirements.

**ePASA**
The Performance Assessment for Service Architecture (ePASA) technology allows organisations to confidently build, manage and alter the large, complex ICT systems that support the delivery of vital services to customers. ePASA helps users uncover the performance details of large systems and to identify problem areas that may cause them to fail.

**Goanna**
Goanna is a fast, scalable and precise software solution that automatically detects bugs and vulnerabilities in source code at the time of development. Goanna targets programming flaws such as memory corruption, buffer overruns, memory leaks and command injections, which lead to potential systems crashes or security vulnerabilities.

**CeeQ**
CeeQ uses facial recognition technology to automatically notify users when photos of them and their friends are posted online—regardless of whether the photos have been tagged—helping users manage their online presence.

**UserMetrix**
UserMetrix helps software developers identify and fix bugs in software by analysing how people engage with a software product. By combining application analytics with traditional error reporting, UserMetrix determines the most likely reproduction steps for software issues, allowing developers to focus on fixing problems, rather than reproducing them.

**Our Start-ups**

**Audinate**
Audinate provides professional audio systems that enable the transport of high-quality media over standard data networks, improving sound quality, simplifying wiring and replacing expensive recording, mixing, and editing hardware with PC-based software. Audinate was founded in 2006 and was NICTA’s first start-up company.

**Open Kernel Labs**
Open Kernel labs is the market leader in embedded virtualisation software (called OKL4) for mobile phones and internet devices. OKL4 enables manufacturers to develop devices that are more secure, with enhanced functions at a lower cost. The software is deployed on 1.6 billion devices around the world. The company spun-out of NICTA in 2007 and was acquired by General Dynamics, an aerospace and defence company, in 2012.

**Nitero**
Nitero is a fabless semiconductor company that is designing an ultra-low power 60GHz Wi-Fi solution that performs at speeds up to ten times faster than current Wi-Fi solutions. The company was established in 2011.

**InterfereX**
InterfereX has developed an ‘interference-cancelling’ modem, which cancels radio interference in femtocell wireless networks (wireless access points for cellular technology). The technology enables improved indoor mobile coverage and better reliability and throughput while minimising the impact on outdoor wireless cellular systems. InterfereX was established in 2011.

**Incoming**
Incoming TV learns what type of video entertainment users love to watch, and downloads the content directly to their smart phone or tablet in advance, using only Wi-Fi. The technology enables users to watch high-quality mobile video, even without a cell signal or data plan. Incoming was established in 2012.

**Saluda Medical**
Saluda medical has developed a versatile medical implant device that treats chronic pain through spinal cord stimulation. Saluda’s Implanted Neural Sensing and Stimulation product both stimulates and senses nerve responses in patients, representing a breakthrough in neurostimulation therapies. Saluda Medical is due to spin out in early 2013.

**Opturion**
Opturion provides solutions to complex resource allocation and scheduling problems using a unique optimisation software platform for freight pick-up and delivery in all major Australian states. Opturion also delivers solutions in conjunction with its major shareholder, Genix Ventures, serving large clients in government and industry. The company was established in 2012.

**Scalify**
Scalify has developed the Badumna Network Suite, a powerful ‘peer-to-peer’ technology suite that helps users create large multi-user applications such as online games and virtual worlds. Badumna uses a unique approach based on a decentralised architecture, rather than client-server, providing almost unlimited scalability, better networking performance, lower operating costs and the freedom to design multiplayer applications. Scalify was established in 2012.
Broadband and the Digital Economy

- Digital Productivity Showcase
- Australian Centre for Broadband Innovation Collaboration
- Big Data Analytics for Enterprise (Ambiata)
- Compliance by Design (Regerous)
- Australian eGovernment Technology Cluster
- Performance Assurance (ePASA)
- High Quality Mobile Experience (Incoming Media)
- Software Bug Detection (Goanna)
- Social TV
- Virtual Counter
- Business Continuity Tools for the Cloud (Yuruware)
Broadband and the Digital Economy

Digital technology permeates modern life, transforming traditional sectors and creating new digital services, which leads to higher productivity and subsequent economic growth. Australia’s future prosperity depends on technology-enabled innovation, now an essential global commodity.

The Broadband and Digital Economy (BaDE) Team develops, delivers and promotes ICT to further power national productivity and create new business areas to help position Australia as an epicentre of technology innovation.

Opportunity
Within just five years, a third of Australian industry faces significant digital disruption. The BaDE Team researchers focus on these disruptive technologies, and how the combination of next-generation fixed and mobile broadband networks and rapid growth technology such as cloud computing, can transform potential adversity into new pathways for social and economic progress.

Approach
During 2012, the BaDE team achieved a number of high impact research and commercial outcomes which generated significant benefits to both the corporate and government sectors.

In addition to ongoing market engagement and collaborative partnership strategies, February 2012 marked the launch of the Digital Productivity Showcase (DPS) a hands-on space highlighting the possibilities enabled by the National Broadband Network in the home, small to medium enterprises, corporations and government. Nearly 600 visitors have toured the DPS and gained a cohesive insight into how ICT developments such as cloud, big data and telepresence will shape and streamline their respective businesses.

Through the DPS, BaDE hosted several networking theme days on issues including public cloud, social media for government, business experts, business process compliance and big data. These events provided NICTA the opportunity to educate industry on future trends, and in turn receive valuable industry feedback.

Impact

Big data
NICTA’s work in the area of big data – capturing, analysing and gaining actionable insights from very large and complex data sets – yielded notable results in 2012. This technology has far reaching applications ranging from corporate improvement to applying geothermal analytics.
One key achievement was the release of an open source library, known as ‘SCOOBI’, through the Big Data Team. This software, which simplifies large scale data processing for developers, is used internationally by companies such as eBay, Foursquare and Klout.

In response to demonstrated interest and engagement from industry, a start-up company called Ambiata has been created to consolidate enterprise-level big data professional services, including contracts with five financial services companies. Ambiata is currently planning to spin-out by the end of 2013.

**e-Government Cluster**

After two years of operation, the e-Government Cluster expanded its membership to include more than 100 representatives from research, industry and multiple government spheres. This e-Government ‘think tank’ focuses on delivering innovative ICT solutions to government and recently commenced the first collaborative project, Mobile Canberra, which was developed as a ‘device independent’ mobile app enabling access to data sets provided under the ACT Open Data Initiative. A number of other projects are also in the pipeline.

During the year, the policy framework for the e-Government Cluster was updated, and major revisions made to the e-Government Terms of Reference, Collaborative Project Policy and the Collaborative Project Agreement. The e-Government team has also developed a new brand and website to be launched at Techfest 2013.

**Cloud services**

During the year NICTA established Yuruware, a start-up company powered by NICTA’s cloud research. During 2012, the team engaged directly with the market through delivery of a suite of cloud services tools, and the Yuruware suite is now deployed commercially as a software-as-a-service offering. These tools automate the process of migrating between different clouds and provide cost-effective disaster recovery options.

Yuruware made a product announcement at the Amazon Customer Appreciation Day and attracted its first customers. It also presented at the Advanced Innovation Summit in Silicon Valley, was awarded a place in the Advance ‘50 for the Future’ Innovation Program and was granted Amazon partner status.

**Social TV Project**

NICTA has continued its active role in the Australian Centre for Broadband Innovation, leading the Social TV project to trial new media content distribution and recommendation technology at the University of New England. This collaboration, involving ABC iview, SBS On Demand and Technicolor, is being keenly observed by new media industry players.

**Start ups**

Throughout 2012, two of BaDE’s start up projects expanded operations and attracted venture capital funding:

- Scalify (networking technologies for multiplayer applications) received first round venture funding and spun-out of NICTA.
- Incoming! completed technology trials and achieved over 400,000 Beta application downloads to secure first round venture funding. Establishment of a start-up is scheduled for early 2013.

**Research Group Context**

The BaDE Business Team integrates research from the following NICTA Research Groups:

- Networks
- Software Systems
- Machine Learning
Left to right: Dr Terry Percival, The Hon. Senator Stephen Conroy, Minister for Broadband and the Digital Economy, Prime Minister Julia Gillard and Mike Quigley, CEO NBN Co at the NICTA Digital Productivity Showcase.
Infrastructure, Transport and Logistics

- Container Tracking
- Container Control
- TruckOn
- Intelligent Water Pipes
- Structural Health Monitoring for Bridges and other civil infrastructure
- SmartGrid
- Intelligent Transport Systems
- Automated Sign Recognition
- Air Traffic Management
- Supply Chain Optimisation
- Future Logistics Living Lab
- Total Port Logistics
- Driver Mental State Monitoring
- Intelligent Fleet Logistics
- Dynamic Under Keel Clearance – Optimising Bulk Commodity Ports
Infrastructure, Transport and Logistics

The Infrastructure, Transport and Logistics (ITL) Business Team delivers innovative ICT solutions that transform the efficiency, safety and sustainability of transportation systems and infrastructure networks.

Opportunity
The $61 billion Australian transport industry accounts for 14 per cent of GDP (compared with 7 per cent of GDP in Europe and North America) and provides more than one million Australian jobs in 165,000 companies. Australia’s transportation companies are experts at managing fluctuating customer demands, shifting delivery schedules and varied operational constraints. However as their workloads become heavier and logistics requirements more complex, they are looking for smart ways to optimise their operations.

In addition, Australia spends around $50 billion a year on new infrastructure, and demand for infrastructure and transport services — rail, road, ports and air freight — is forecast to grow by between 50 and 150 per cent by 2030.

In this context, the ITL Business Team is focused on wealth creation through transforming Australian industry by increasing the productivity of existing assets and infrastructure, optimising new investment, and creating new capabilities for the sector.

Approach
Throughout 2012, ITL continued to deliver its strategic vision to draw on NICTA expertise in areas such as optimisation, control, and software systems to create impact over three horizons — delivering impact on existing or near-term opportunities, building new opportunities, and creating platforms for substantial transformation.

By partnering with industry, NICTA solves challenges at a systems level, bringing together multiple disciplines to break traditional thinking in traffic control systems, infrastructure optimisation, air traffic management and the international logistics market.

Impact
Future Logistics Living Lab
The Future Logistics Living Lab is Australia’s first “living lab”, enabling industry and research to work together, investigate real-world problems and demonstrate innovative technology that will provide transport and logistics for the future. During 2012 the lab continued to generate interest from media, industry and government. More than 500 visitors toured the lab, bringing the number of visitors since the lab’s inception in 2011 to around 1200. Visitors in 2012 included the Prime Minister, Government Ministers, Shadow Ministers, Deputy Directors General from the NSW Department of Transport, as well as a group of 40 international product managers from Google. Several new participants also joined the lab in 2012.

Four participant workshops were held throughout the year to define and develop existing living lab Projects. During 2012, the Container Tracking project commenced test runs that involved attaching devices to five Casella wine containers to monitor the movements of the containers through the global supply chain. Separately, the Container Control Project completed a soft launch of its web interface, with a hard launch planned for early 2013. The container booking system aims to reduce unnecessary truck movements generating savings for shipping lines and reducing the congestion and emissions caused by trucks on the road.

The lab also hosted the launch of Green Light Day 2012 in conjunction with Transport for NSW. The event, designed to promote careers in transport and logistics to high school students, attracted 80 students from across NSW.

Structural Health Monitoring
The Structural Health Monitoring project developed by NICTA and Roads and Maritime Services involves the use of light-weight sensor technology to provide real-time monitoring of the structural health of the Sydney Harbour Bridge and the safety of its concrete deck. Using innovative algorithms and simple components the system can detect movements in the concrete deck which are considered to be abnormal, while ignoring normal movements due to vehicle traffic.

An initial ‘mid-scale’ deployment has been very successful, and the project intends to roll out a further 700 sensor nodes on the bridge. There is also scope to include other types of measurements, such as assessing the arch strength of the Sydney Harbour Bridge, measuring the cable integrity of the Anzac Bridge, as well as the possible development of a ship over-height detection prototype.

The project team was awarded an Australian Information Industry Association (AIIA) iAward as well as an Engineers Australia award. The project was also selected to exhibit at the Powerhouse Museum in Sydney until 2014.

Automap
NICTA’s AutoMap technology, which automatically detects and codes road signs and other roadside assets from video footage for use by mapping and survey companies, announced a new three-year agreement with US-based surveying company GeoNav Group International. Under the agreement automatic video analysis technology developed by NICTA will be used to help improve road safety through the creation of accurate inventories - or ‘maps’ - of road signs and power poles. NICTA’s AutoMap technology will help the
What is your research area of specialty?
My research area of interest is in signal processing and machine learning.

What do you see as the big research developments in your area?
A significant amount of data is now available in many businesses and industry sectors. This provides opportunities for insights into business intelligence and operations in a data driven manner. Research based on real data will provide new challenges to research communities, as well as to those businesses that have opened up to analysing the data they already have.

Why NICTA?
NICTA is the place to apply world-class research in solving real-life problems. I am highly motivated by the ability to utilise ICT to increase productivity and business intelligence to help non-ICT driven industries. The theoretic constructs of the problems are similar, although the appearances of the problems are very diverse - from failure prediction of water pipes, to structural health monitoring and even to intelligent transport systems. I really enjoy creating innovative and practical solutions based on real data so that the impact of our research is transparent to industries and communities.

Company respond to a growing requirement for reliable road sign surveys to address maintenance, safety and regulation issues.

Challenges in water, energy, transport and logistics
NICTA’s ITL business team is also addressing a number of other challenges faced by Australia’s infrastructure sectors, including:

• Helping water utilities predict which pipes are likely to fail, thereby reducing damage due to broken pipes and making better use of funds otherwise allocated to water pipe repairs and maintenance
• Working with traffic management agencies and industry to help predict when traffic incidents are likely to occur, and to shape future vehicle to vehicle and vehicle to infrastructure communications capabilities
• Helping fast-moving consumer goods companies reduce their distribution costs, increase customer profitability, improve safety and enhance sustainability for fleet operations, and
• Identifying opportunities to introduce new ICT to:
  - support new electricity network grid architectures
  - develop micro-grid capability
  - enable effective management of renewable energy, and
  - support demand-side management.

Research Group Context
The ITL Business Team integrates research from the following NICTA Research Groups:
• Optimisation
• Networks
• Machine Learning
• Control and Signal Processing
• Computer Vision
• Software Systems
To unlock more content click here or go to http://www.nicta.com.au/business/itl
• CYBERSECURITY
  - Security for Critical Systems
  - Verified Real-Time Operating System
  - Online Photo Discovery
  - Robust Control Systems Design
• DISASTER MANAGEMENT
  - Event Watch
  - Decision Support Tools
  - Fuel Hazard Assessment
• ENVIRONMENTAL MONITORING
  - Fish Surveillance in the Wild
  - Monitoring Analytics Solutions
  - Groundwater Modelling Software
  - Soil Classification Survey Optimisation
• FOOD SECURITY
  - FarmNet
  - Plant BioSecurity
  - Supply Chain Optimisation
• RENEWABLE ENERGY
  - Geothermal Discovery Software
  - Power Stability Software
  - Solar Energy Forecast Software
  - Air Quality
Security and Environment

The Security and Environment Business Team focuses on developing innovative security solutions for natural resources, people, and critical computer systems.

Opportunities

Australia’s environment is harsh yet fragile, with unique and diverse native flora and fauna, limited arable land and extreme variations in the weather. Threats to the sustainability of Australia’s resources, including its water and capacity to produce food, are putting the security of Australia’s food supply at risk. Competing demands for natural resources, including energy, food and water, create greater challenges for governments and society as a whole. Additionally, invasive pests and diseases pose threats to Australia’s native wildlife, environment and agricultural sector, and natural disasters create greater challenges as populations become more dense and weather becomes more extreme. There is a growing need to collate, understand and act on more information — often in shorter time frames.

Separately, the functionality, complexity and pervasiveness of computer systems and software continue to grow. Critical functionality is increasingly embodied in software such as medical devices and vehicle control systems, so it is critical that these systems are protected against errors in design, faults and malicious attacks.

Working with a range of private companies and government agencies across the security and environment sector, NICTA's Security and Environment Business Team is developing innovative ICT solutions to address these challenges.

Approach

NICTA’s Security and Environment Business Team addresses two National Research Priorities:

• Safeguarding Australia from terrorism, crime, invasive diseases and pests, strengthening our understanding of Australia’s place in the region and the world, and securing our infrastructure, particularly with respect to our digital systems.

• Developing an Environmentally Sustainable Australia by transforming the way we utilise our land, water, mineral and energy resources through a better understanding of human and environmental systems and the use of new technologies.

This is achieved through addressing industry problems and public challenges in homeland security, defence, biosecurity and natural resource security.

Impact

US Government cyber security project

During the year NICTA, as a core member of an international consortium, won a multi-million dollar contract with the United States Government to develop a new breed of software to protect the critical systems in unmanned vehicles from cyber attack. The contract with the US Defence Advanced Research Projects Agency (DARPA), worth US$18 million over 4.5 years, is part of DARPA’s High-Assurance Cyber Military Systems program, which aims to produce highly dependable systems that are resilient to emerging cyber threats. The project has the potential to have far-reaching future applications protecting the critical systems in motor vehicles, medical devices and aircraft.

Geothermal exploration

NICTA received $1.9 million funding for a geothermal 'big data' analytics initiative in which NICTA is leading a team of university experts from four states to find better, automated ways to define geothermal targets deep beneath the surface of the Earth using machine learning techniques and advanced data analytics instead of drills. The Australian Centre for Renewable Energy initiative, known as Data Fusion and Machine Learning for Geothermal Target Exploration and Characterisation, is a two-year, $5 million dollar program. The first and second milestones of the project — producing a common portal for data to be jointly analysed under open standards, and supporting development of an open-source platform for visualising 3D data such as the structures under the Earth’s surface — were delivered in 2012.

FarmNet

NICTA launched a research collaboration with Shanghai University and the Shanghai Academy of Agricultural Sciences to facilitate the application of NICTA’s FarmNet technology to the Chinese agricultural sector. FarmNet is a web portal that delivers improved farm management decision making through access to real-time information and analysis. It combines public data such as weather and crop production information with NICTA algorithms to transform farm management by providing access to information to help farmers make better decisions in the management of their business.

Farmers using the portal will be able to get quick advice on critical decisions such as when to irrigate, when to fertilise and future cropping options. The collaboration is supported by NICTA technology in...
Water Information Networks, in which algorithms have been developed to use data from sensors to monitor river and irrigation catchment flows and provide control of irrigation.

**Other activities**

During 2012 the Imaging Spectroscopy for Scene Analysis group commenced trials of their hyperspectral imaging technology to identify disease and pests in plant material at Department of Agriculture, Fisheries and Forestry (DAFF) sites in Melbourne.

Earlier in the year the team successfully secured funds from the Australian Solar Institute for the US Energy Collaboration funding round, to develop solar resource forecasting techniques to assist utilities to better manage the load on the power grid.

The Security and Environment team also entered into a two-year service agreement with the NSW Department of Primary Industries for a groundwater modelling project to be jointly undertaken with the NSW Office of Water.

**Research Group Context**

The Security and Environment Business Team integrates research from:

- Computer Vision
- Machine Learning
- Optimisation
- Software Systems
- Control and Signal Processing

**Dr Jodi Steel**

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Director, Security and Environment Business Team  
PhD (Electronics) Macquarie University

**What is your area of specialty?**

When I came to NICTA, I had specialised in telecommunications and technology transfer, and had worked in defence, private industry and academia. Since then I have worked across a range of industry sectors, always with a focus on bringing researchers and industry together to solve problems by transferring technology and knowledge into use.

**What do you see as the big research developments in your area?**

Large amounts of diverse environmental data are now routinely collected, yet typically full value is not extracted from this data. Developments in the integration and analysis of large data sets enable better decisions and better risk management in competing natural resource use priorities, such as groundwater management and food security.

In security, we are concerned with more than just the potential for cyber-attacks on the systems on which our society depends, and consider also the impact that software faults can have. Advances in the area of formal verification have made it possible to be sure of the reliability and integrity of the software that lies at the heart of critical systems, such as medical devices and car braking systems. Anticipated developments will make greater reliability possible and more affordable on larger systems, such as air vehicles in the DARPA project in which NICTA is participating.

**Why NICTA?**

I came to NICTA in 2004 to help build a national institution with the freedom and scale to bring ICT research to truly challenging industrial, environmental and societal problems. I’ve stayed because of the variety of great people I work with both in NICTA and industry and the spark when both see how they can solve problems together and have a real impact.
NICTA researchers on the $1.9M ‘Big Data’ analytics initiative in geothermal exploration.
• Tracking Infections
• Detecting DNA Mutations for Precision Medicine
• Fighting Prostate Cancer using High Performance Computing
• Bionic Eye
• Managing Parkinsons, Stroke and Epilepsy through Motion Analysis
• eHealth: Meaningful Information from Biomedical Data
• eHealth: National eHealth Living Lab
• Computational Genomics: Detecting Cancers of the Unknown Primary
• Bio-medical Imaging
Health

The Health Business Team is transforming innovative technologies to advance the understanding of human diseases and to improve the health and well-being of Australians.

Opportunity
The convergence of technology and medicine has ushered in the 'Age of Personalised Medicine'. The patient-centric model combined with genomic-based approaches to clinical decision making represent the future of medicine, however while this approach offers significant promise, many challenges remain for biomedical researchers, healthcare providers, and the patients themselves.

For medical researchers faced with complex and voluminous biological data, expertise in developing technologies for data analysis, annotation, visualisation and reporting is much sought after. At the same time there is the need to understand the systems biology that underpins the relationships and pathways between levels of biological function. Just as valuable are technologies to automate many of the manual processes used in analysing laboratory generated data.

For medical teams exposed to disparate systems and databases in different departments, there is a clear need for expertise in extracting, mining and making sense of medical records, and in building technology that will guide clinical decision making.

For patients wanting to receive care in their own homes, innovative ways to develop affordable and portable health monitoring devices and applications will pave the way for greater uptake of telehealth services.

From implants to treat chronic pain to wearable devices that monitor a patient’s general well-being, building the ICT and business and management environments for the deployment of pervasive biomedical devices is also essential for a sustainable health system.

Approach
NICTA researchers are driving innovation through a program in personalised medicine that encompasses:

- Bioinformatics: Diagnostic Genomics, Computational Genomics, Biomedical Informatics and Bio-medical Imaging
- Medical Devices: Bionic Eye, Portable Motion Analytics, and Implant Systems, and
- E-Health.

In 2012, the Health Business Team continued to foster important collaborations with Australia’s leading medical research institutions, hospitals, universities, SMEs, corporations, and government departments and agencies. Through these partnerships, NICTA will develop software tools and medical devices for use by researchers and health care providers to improve health outcomes for all Australians.

Impact
Diagnostic and Computational Genomics
NICTA announced its participation in a joint project funded by the National Health and Medical Research Council, which uses computational analysis to distinguish lethal and non-life threatening prostate cancer. As a key member of a cross-disciplinary team led by the University of Melbourne, NICTA will pioneer techniques to analyse genetic information from cancer patients by tracking the molecular changes inside the cells of prostate cancer patients in whom the condition becomes aggressive. As doctors currently do not have a reliable way to determine which cancers are likely to be lethal, the technology will give men diagnosed with prostate cancer a better chance of getting the treatment they need.

In collaboration with the Peter MacCallum Cancer Institute, Healthscope Advanced Pathology and Circadian Technologies Ltd, NICTA continued development of the Cancer of Unknown Primary (CUP) Diagnostic Test. The test identifies a patient’s tumour type by comparing its pattern of gene expression to a database of known tumours. Clinical trials conducted in 2012 showed that the test can detect the primary source of cancers with more than 90 per cent accuracy over 15 different tumour types. Correctly identifying the tumour type better enables clinicians to choose the most effective treatment strategy for the cancer. Healthscope launched the test commercially in Australia, New Zealand, Malaysia and Singapore, with Circadian following in the rest of the world.

NICTA’s Computational Genomics team, in collaboration with the Monash Institute of Medical Research, developed new software for addressing problems in the analysis of DNA sequencing data. This included software for analysing data from xenograft samples which has important applications in cancer research, and software for performing rapid analysis of gene expression sequencing data on desktop computers. A commercial licence for the xenograft processing software was sold to a German biotechnology company.

Portable Motion Analysis System
In collaboration with the Royal Melbourne Hospital, the National Ageing Research Institute and Kingston Health, NICTA has developed software algorithms to provide information about the progress of patients undergoing rehabilitation. The algorithms provide metric information about the position of a patient’s limbs in 3D space in their home environment, enabling clinicians to assess the effectiveness of the program. This will ensure that patients are given individualised rehabilitation programs based on their needs.
Medical Devices
NICTA’s Implant Systems team, which has developed small, sophisticated and low-cost implantable devices to treat chronic pain, raised enough capital to commence arrangements for its official launch as a separate company. Patient trials to date have been successful, are starting to have an impact in the field and have set the stage for pre-clinical trials. The company, Saluda Medical, is expected to launch in early 2013.

Bio-medical Imaging
During 2012, the Health Business Team formed a Bio-medical Imaging team to investigate why advances in computer vision and automated image interpretation haven’t become pervasive in clinical practice. The team develops assistive technologies consisting of smart interfaces, rich displays and helpful tools that exploit the latest in computer vision, making image interpretation more quantitative and efficient, without replacing the expert judgement of users.
In collaboration with researchers at the Royal Melbourne Hospital and the University of Melbourne the team has also developed two software tools: one for radiologists which reports the development of Multiple Sclerosis lesions; and one for neurosurgery clinicians which monitors Gliomas. Academic studies of the effectiveness of these tools are about to commence.

Biomedical Informatics
NICTA is developing techniques for automating in-hospital surveillance of invasive fungal infections which result in more than 1000 deaths and cost the health system more than $100 million each year. In collaboration with clinical researchers from Melbourne Health, Alfred Health, and the Peter MacCallum Cancer Centre, NICTA has developed text-mining techniques to automatically process radiology reports and detect potential evidence of fungal infection. This work has the potential to detect possible infections early, savings lives and reducing health care costs.

Research Group Context
The Health Business Team integrates research from the following NICTA Research Groups:
• Control and Signal Processing
• Machine Learning, and
• Computer Vision
Engineering and Technology Development

The Engineering and Technology Development Group (ETD) creates robust, competitive technology from NICTA's research to maximise NICTA's impact on industry and the wider community. The group was created in April 2011 “to get more technology out the door and make impact”. We are increasing the number of NICTA technologies that are licensed, released as open source, taken out by startups and used in collaborations with industry partners.

The ETD Group has 30 software engineers and user experience designers building technology within 16 projects across all four NICTA Business Teams.

Approach
The ETD Group is a ‘home’ for career engineers (mostly software developers) who are allocated to business-oriented projects to ‘translate’ research results and build systems and software that will be relied upon for real-world use. This work is guided by and funded by NICTA's Business Teams, in most cases together with industry partners.

Part of the role of the ETD Group is to ensure appropriate hiring, skill sharing and skill development for engineers as well as driving a culture for building and deploying genuinely useful and usable new technologies. In addition to engineering, the ETD Group has a User Experience (UX) design capability. To make the ETD Group a success, it works closely with, and supports, NICTA's four Business Teams in all our activities. Some of the successes from the engineering work in 2012 include:

Security and environment
• Geothermal Data Fusion: We developed a web-based portal allowing map-based selection and streaming of merged data from a wide variety of multi-terabyte geoscience data sets. This is used by project stakeholders for access to data for large scale analysis.
• Web-based 4D (3D+time) geospatial visualisation platform: We developed a visualisation platform based on the new WebGL standard for displaying high performance graphics in a web browser with no plug-ins. This platform is now being used by four NICTA projects to provide better web-based visualisation for end users.
• Imaging Spectroscopy for Scene Analysis: We developed a Software Development Kit (SDK) based on NICTA's spectral data processing pipeline (with illuminance recovery, specularity recovery, and spectral unmixing) which is suitable for third party application developers to build new hyperspectral applications. This is suitable for use for material classification and characterisation and is suitable for applications in food security, biosecurity, mining, photography, surveillance and defence.

Broadband and the Digital Economy
• Big Data distributed processing library: We continued to develop an open source software library (called “SCOOBI”) which speeds up the development of software for big data analytics using Hadoop, the widely used distributed processing environment for large scale data analytics. SCOOBI has been adopted by companies needing analysis of very large collections of user data such as eBay, Foursquare and Klout.
• Big Data Analytics: We successfully completed five engagements for Australian financial services companies by building software based on NICTA's machine learning algorithms running on NICTA's SCOOBI library.

Infrastructure, Transport and Logistics
• Automap: We developed robust product-oriented software from NICTA's computer vision research for use in commercial engagements for automated detection of road signs and other roadside objects.
• Structural Health Monitoring: We developed embedded software for bridge-mounted nodes that determine the health status of structural elements based on sensors, and developed software for taking multiple sensor inputs to summarise the health of the bridge.

Health
• Invasive fungal infection surveillance: We developed software using NICTA’s text processing and machine learning techniques to provide early warning of the presence of invasive fungal infections in hospital wards.
HIGH IMPACT RESEARCH

LINKAGES FROM
> UNIVERSITIES
> RESEARCH INSTITUTES
> RESEARCH LABS

ENGINEERING AND TECHNOLOGY DEVELOPMENT

INFRASTRUCTURE, TRANSPORT AND LOGISTICS

BROADBAND AND THE DIGITAL ECONOMY

SECURITY AND SURVEILLANCE

HEALTH

SOFTWARE AS A SERVICE

PRODUCT RELEASES

JOINT VENTURE

CONSULTING

OPEN SOURCE

START-UPS

TECHNOLOGY LICENSING

WEALTH CREATION FOR AUSTRALIA

PROJECT OR ACTIVITY

SOFTWARE SYSTEMS

LEARNING MACHINE

COMPUTER VISION

NETWORKS

OPTIMISATION

OPTICS AND NANO-ELECTRONICS

IMPLANT SYSTEMS

PROCESSING SIGNAL AND CONTROL AND

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OPTICS AND NANO-ELECTRONICS

IMPLANT SYSTEMS

PROCESSING SIGNAL AND Control AND
Our Research

NICTA occupies a unique place in Australia’s innovation system. It connects world-class research excellence in ICT to the major challenges faced by government, industry and society. It has the scale to tackle the biggest challenges and the reputational reach to engage the best ICT researchers and entrepreneurs both in Australia and internationally. NICTA has become an integral and leading part of the ICT research and business ecosystem in Australia.

Connecting research excellence to outcomes
NICTA draws together the very best ICT research from 10 university partners. NICTA amplifies this concentration of research excellence with advanced technical, entrepreneurial and business skills. We then apply these research and business skills to major industry challenges. NICTA is deeply integrated into the best university ICT research: five of the six NICTA research groups are run by leading university researchers seconded into NICTA. NICTA has been uniquely successful in transitioning university-originated research into major impact and outcomes for the ICT industry.

National scale of impact
NICTA is a national organisation tackling national problems on a national scale. We are uniquely positioned to address national ICT issues on a large scale, in critical areas including digital business delivery, transformational health, optimisation of infrastructure and transport, and security and management of Australia’s environment. ICT underpins the future productivity of all industry and business sectors in Australia; only NICTA has the capacity to achieve this national scale of impact for ICT.

International excellence
NICTA aims to be ranked amongst the top global ICT research institutions. Our enduring research program has enabled us to attract some of the very best research talent internationally and to build research groups in areas such as optimisation, machine learning and software engineering which are arguably the best in the world. In turn, this has allowed NICTA to attract and enable some of the best students, engineers and entrepreneurs to achieve major ICT outcomes for the nation. The unique structure of NICTA, as a largely publicly funded but independent company, has engendered a longer-term view of ICT research, where risk taking is key to new innovation, and where there is a strong focus on economic and social outcomes.
A demonstration of the highly secure seL4 microkernel developed at NICTA, which protects the critical components of a computer from cyber-attack. In this demonstration at Techfest2012, NICTA researchers attempted to hack into the Lego robot’s navigation and control system but were thwarted by the highly secure seL4 operating system kernel.

- Modelling and Verification of Data-Intensive Systems
- Preventing Failure with Dependable Operations
- Protecting your Critical Information
- Temporal Isolation
  - Ensuring Safety-Critical Software Gets Enough Time to Do Its Job
- Trustworthy Systems
Software Systems

The Software Systems Research Group aims to deliver transformational improvements in the design, implementation and verification of software systems. Our research is focused on providing provable security, safety and reliability for critical embedded systems. We are also developing integrated and adaptive architectures that meet the performance and business objectives of enterprises.

With 62 researchers (full-time-equivalent), Software Systems is the largest of NICTA's Research Groups. The group is engaged in a wide range of commercially relevant software developments and research including:

- Cyber security
- Software to make the cloud safer, more robust and adaptive
- Business process compliance software
- Improving the energy efficiency of mobile devices.

NICTA’s approach to software systems research

The trend toward the use of more complex software, as well as a reliance on embedded software systems, underpins all future applications of ICT. Our approach to software systems research is radical and unique.

We aim to develop real-world systems and actively plan for their adoption from the outset of each project. We use rigorous techniques to ensure we have complete understanding of each system’s behaviour, and we aim to increase the amount of automation to make the systems easier to build.

We are interested in guaranteeing the security, safety, reliability, interoperability and adaptability of large, complex systems. For the first three, our approach is to use the verified microkernel technology developed at NICTA to achieve provable separation between trusted and untrusted components, minimising the amount of code that needs to be verified.

We use:

- Concurrency reasoning to understand how components react
- Program verification to prove code correctness and separation
- Static analysis for bug hunting in non-trusted components
- Worst-case execution time analysis, enabling reliable, real-time operation

For interoperability and adaptability and for cost-effectiveness, our approach is to use architecture and process technologies to perform early design analysis and development planning.

We use:

- Performance analysis and simulation to enable expert architecture reconfiguration decision support
- Architecture evaluation to assess trade-offs
- Business rules and process analysis to investigate business context and compliance
- Process simulations to reduce cost

Breakthrough results 2012

The Trustworthy Systems team produced some major achievements, consolidating its position as leaders in the field: PhD student Thomas Sewell, in collaboration with Dr Magnus Myreen (Cambridge), extended the previous formal proof for seL4 to the binary level, eliminating correctness assumptions for compiler and C semantics.

A small group led by Researcher Dr Toby Murray completed a non-interference proof for the seL4 kernel, which shows how to configure the general-purpose kernel as a high-assurance separation kernel that can enforce confidentiality. Together, these two results create a complete proof chain from high-level security and safety requirements to the seL4 binary code which runs on the hardware, further strengthening the security of seL4 and proving its suitability as a base of secure systems.

The RapiLog project demonstrated that seL4’s dependability guarantees are not only useful for security, but can be used to simplify database systems and improve their performance, roughly doubling throughput under certain conditions. This creates the potential for significant cost and energy savings in data centres.

Selected publications

Andronick, J., Jeffery, R., Klein, G., Kolanski, R., Staples, M., Zhang, H., and Zhu, L., Large-Scale Formal Verification in Practice: A Process Perspective, The International Conference of Software Engineering 2012. This paper analyses the formal verification process used for seL4. It discovered some of the reasons why our verification process succeeded where so many others have failed. It is a first step to making formal verification a repeatable software process.

What is your research area of specialty?
My research involves using mathematics to prove that software is secure. Our project group has just completed a proof that the seL4 microkernel, originally developed and verified by NICTA, can enforce information confidentiality. That is, it can keep secret data secret. This is a world-first − no other general-purpose kernel has been verified to this degree.

What do you see as the big research developments in your area?
A big development has been extending formal verification techniques and textbook definitions of security, so they can scale to real-world systems. For the first time, we can now perform real security proofs about real operating system kernels. This has been a dream for at least the past 30 years, which we have now realised.

Why NICTA?
Quite simply, I believe that NICTA has the world’s best research group working on formal verification of operating systems. If you want to do cutting-edge work that has tangible results, there is no better place.

Selected awards and achievements
A multi-million-dollar contract with the United States Government will see the Software Systems Research Group team develop a new breed of software to protect the critical systems in unmanned vehicles from cyber-attack. An international consortium, led by Rockwell Collins with NICTA as a core member, won the 4.5-year, US$18 million project with the US Defense Advanced Research Projects Agency (DARPA). The project promises to have far-reaching future applications protecting the critical systems in motor vehicles, medical devices and aircraft.

Impact of seL4 verification: The paper reporting the formal verification of the seL4 kernel (published in October 2009) had initially collected 100 citations per year. This rate has accelerated to 123 in 2012, indicating the lasting impact of what is now widely regarded as a seminal paper. Furthermore, a number of projects have recently sprung up with aims similar to ours - an indication that our work has created a new research direction of increasing popularity and relevance.

Dr Liming Zhu, Senior Researcher, Emeritus Professor Ross Jeffery and Dr He (Jason) Zhang, Researcher, won the Best Paper Award for An Initial Evaluation of Requirements Dependency Types in Change Propagation Analysis at EASE12. Unlike past work on general requirements dependency and isolated changes, this paper is the first to investigate the different types of requirements dependencies and their consequences, which will lead to better handling of change at the architecture level.

Dr Andreas Bauer, Senior Researcher, together with Ylies Falcone, University of Grenoble, France, won the Best Paper Award at this year’s International Symposium on Formal Methods (FM 2012) with Decentralised LTL Monitoring. This work is the first to introduce a truly distributed, runtime verification procedure for a class of distributed systems that have no means of a global trace collection.
The Best Paper Award at the Conference on Intelligent Computer Mathematics 2012 was won by Timothy Bourke, Matthias Daum, Gerwin Klein and Rafal Kolanski for Challenges and Experiences in Managing Large-Scale Proofs. This paper describes problems and solutions specific to large machine-checked proofs such as NICTA’s seL4 microkernel verification or formally verified software stacks as in the German Verisoft project.

The University of New South Wales Vice Chancellor’s Award for Teaching Excellence in the category of “Initiatives that Enhance Learning” was awarded to Research Group Leader and UNSW John Lions Chair, Scientia Professor Gernot Heiser, and Research Leader Dr Kevin Elphinstone for their design and delivery of the Advanced Operating Systems course.

In 2012, Dr June Andronick presented to MIT Tech Review China Summit after being named one of the top 35 under 35 year olds likely to change the world with their technology.
What is your research area of specialty?
My research is tackling the problem of constructing trustworthy, reliable real-time systems, using less hardware, therefore making them more affordable. The key challenge is to be able to combine mission-critical code with code for convenience functionality. For example, an engine controller and a Bluetooth stack could share the same CPU, but still retain strong assurances that the mission-critical functionality cannot be compromised.

What do you see as the big research developments in your area?
We have seen multi-core architectures in servers and desktops, and now we are seeing them in embedded devices, making reliability a big deal. There has been significant progress recently in delivering trustworthy systems on multicore embedded systems, but there are still many unsolved problems.

Why NICTA?
I became interested in several aspects of operating systems research during my undergraduate studies and work in industry. I found that NICTA had a world-class operating systems research group, and that they were actively developing real-world systems, and solving real problems found in industry.

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Graduate Researcher (PhD student)
Bachelor of Engineering (Electrical) (Hons), Bachelor of Computer and Mathematical Sciences (Pure Mathematics)
University of Western Australia
What is your research area of specialty?
My research is in the area of formal methods. Within that, I specialise in analysing software, including building proofs that certain failures are not possible.

What do you see as the big research developments in your area?
Five years ago, when our team set out to prove some properties about an operating system component, we began by paying attention to every microscopic detail of the programming language it was written in, and we expected to address every statement in the program by hand. More automatic approaches had shown a lot of promise but delivered less substance.

Since then there has been evidence that it is possible to sketch what your program ought to do, and automatically compare that to what your machine code actually does. It's also possible to address far fewer problems by hand. This leaves a lot of logic puzzles left over before you have any certainty, but the quality of the solvers available for these puzzles has improved dramatically. The question from here is how best to take advantage of that progress.

Why NICTA?
When I finished my undergraduate studies I was looking for something interesting to work on and by chance I met Gerwin Klein. He was starting up a project which aimed to prove that an operating system could not crash. I found the research area really interesting so I joined the project.
• OMF and OML Testbed Suite
• Mesh Networks Project
• Smart Mobile Content Distribution
• Privacy and Trust
• Proximity Based Authentication
• PrivatePoll: a mobile app for conducting surveys that preserve user privacy
• mSpeed
The Networks Research Group is developing new mechanisms and techniques that will maximise user privacy, minimise resource usage, and maximise usefulness for both service providers and end users, particularly in the domains of entertainment systems (infotainment) and smart energy.

As the world becomes more “instrumented”, generating vast amounts of data and making information available to users, the next generation of networked systems needs to:

• Protect privacy: Maintain the privacy of information users and information providers
• Increase usefulness/utility: Enable service providers and application developers to extract the information necessary to enable the provision of appropriate services/applications, and be easy to use by end users
• Improve Efficiency: Efficiently use available infrastructure and be easy to deploy.

**NICTA’s approach to networks research**

Mobile devices generate and consume huge amounts of data. With trends such as social networking fuelling this growth, the challenge is to provide ubiquitous access while taking into account the characteristics of different networks, especially the disparity between resources available over existing fixed networks and the bandwidth limitations of wireless mobile networks.

We are addressing these challenges by focusing on three key research areas:

• Information discovery and dissemination
• Mechanisms for privacy and trust
• Managing the connectivity of mobile end-points

**Breakthrough results 2012**

The Incoming App (trial of V1.0 Beta) was released to a limited number of users to validate robustness and obtain a first set of measurements when used in various settings. A full release to the general public was made during 2012 and has had more than 10,000 downloads.

The NICTA Australian Centre for Broadband Innovation (ACBI) Social TV project, in collaboration with the Australian Broadcasting Corporation (ABC), was launched.

The Social TV project developed:

• A recommendation algorithm for catch-up TV that was successfully tested with offline data logs
• Beta version of the software and video platform that was deployed at the University of New England, Armidale.

In addition NICTA’s Distributed System Management frame (OMF) version 6 Beta and a new version of the related measurement library (OML) version 2.9.0 were released.

The Polytechnic Institute of New York University (NYU-Poly) has adopted NICTA’s OML measurement technology, and this has been publicised on the NYU-Poly website.

**Selected publications**

Cunche, M., Kaafar, M. A., and Boreli, R., *I Know Who You Will Meet This Evening! Linking Wireless Devices Using Wi-Fi Probe Requests*, Thirteenth International Symposium on a World of Wireless, Mobile and Multimedia Networks, San Francisco, California, USA, June 2012. This paper identifies the privacy threat resulting from using the active discovery mode in Wi-Fi, which is commonly used on most mobile devices like smartphones and tablets. The proposed technique demonstrates how social links between individuals can be discovered purely by passively observing the probes sent by their Wi-Fi-enabled devices, with high accuracy and with a short observation time. This technique has a number of potential applications. For example, it could be used in law enforcement to identify criminal associates, or alternatively in targeted advertising to discovered social groups. This paper was runner up for the best paper award.

Triukose, S., Ardon, S., Mahanti, A., and Seth, A., *Geolocating IP Addresses in Cellular Data Networks*, Passive and Active Measurement Conference, Vienna, Austria, March, 2012. This is the first, large-scale study of IP geolocation in cellular data networks. Using IP addresses to determine the geographic location of hosts (or IP geolocation) has many applications including the provision of location-based services, fraud detection and efficient content distribution. This paper addresses this issue by collecting GPS coordinates and IP addresses from smartphones in 50 countries and 2000 cities. The study shows that both commercial and free IP geolocation databases produce large errors when used to locate users in mobile networks.

Borghol, Y., Ardon, S., Mahanti, A., Carlsson, N. and Eager, D., *The Untold Story of the Clones: Content-agnostic Factors that Impact YouTube Video Popularity*, accepted for publication at the 18th ACM Conference on Knowledge Discovery and Data Mining (KDD 2012), August 2012, Beijing, China. Not all videos uploaded by users attain the same popularity and have the same impact. Popularity differences arise not only
Thierry Rakotoarivelo
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What is your research area of specialty?
My research areas include the experimental evaluation of networking systems, the control of distributed systems, their instrumentation and monitoring.

What do you see as the big research developments in your area?
The federation of large-scale networking evaluation platforms across international institutions is an important development, with significant resources committed by EU and US institutions. This includes the control and instrumentation of resources within these platforms. Another emerging activity is the application of these approaches to other domains involving large-scale distributed entities, such as structural health monitoring or smart grids.

Why NICTA?
NICTA provides an environment to work with teams of highly skilled researchers and engineers in different ICT domains. It also offers many opportunities for collaboration with researchers from universities and institutions around the world. It is great to be able to undertake research and know that it will have impact on many real-life areas.

because of differences in content but also because of other “content-agnostic” factors such as the size of an uploader’s social network, how the content is featured on search engines, or whether the user is the first to upload a video, and so on. These content-agnostic factors are of considerable interest but are difficult to measure. This work develops and applies a method that is able to accurately assess the impacts of various content-agnostic factors on video popularity. It shows that inaccurate conclusions may be drawn if an analysis does not control for video content. While the proposed methodology was developed in the context of video content, it is applicable in other contexts as such as dissemination of news content.

Hu, P., Symons, N., Indulska, J., and Portmann, M., Share your View: Wireless Multi-hop Video Streaming using Android Phones, 8th IEEE PerCom Workshop on Pervasive Wireless Networking, Lugano, Switzerland, March, 2012. This paper presents a practical implementation of a new video streaming application on the Google Android platform, which allows sharing of live video streams among multiple smart phones, without the need for any network infrastructure (e.g. 3G or 4G). Detailed experimental performance evaluations of the application for a range of hardware platforms, video encoding formats and network scenarios show that the latest generation of smart phones can easily support this type of application and can provide high-quality, live video streaming over large areas. Potential applications of the technology include disaster recovery and emergency response scenarios and mobile social networking.

Li, Z., Lin, J., Akodjenou, M., Xie, G., Kaafar M. A., Jin, Y. and Peng, G., Watching Video from Everywhere: a Study of the PPTV Mobile VoD System, ACM SIGCOMM Internet Measurement Conference 2012. In this paper we examine mobile user behaviour and their corresponding video viewing patterns from logs extracted from the servers of a large scale VoD system. It shows that, while video popularity distribution is skewed, the popularity of a video could be predicted accurately using its very early popularity level. These findings provide insights and recommendations that can be used to design intelligent mobile VoD systems and improve the provision of personalised services on these platforms.

Tushar, W., Saad, W., Poor, H. V., and Smith, D., Economics of Electric Vehicle Charging: A Game Theoretic Approach, IEEE Transactions on Smart Grid, October 2012. In this paper, the problem of grid-to-vehicle energy exchange between a smart grid and plug-in electric vehicle groups (PEVGs), such as parking lots or groups of nearby vehicles, is presented. It shows that it is possible to model the problem as a non-cooperative Stackelberg game. Further, it shows that the proposed game possesses a socially optimal Stackelberg equilibrium in which the grid optimises its price while the PEVGs choose their equilibrium strategies. Finally, a distributed algorithm that enables the PEVGs and the smart grid to reach this equilibrium is proposed and assessed through extensive simulations.

2012. Distributed social networking services show promise to solve data ownership and privacy problems associated with centralised approaches. Smartphones could be used for hosting and sharing user data in a distributed manner, if the associated high communication costs and battery usage issues of the distributed systems could be mitigated. This paper proposes and evaluates a mechanism for reducing these costs to a level comparable with those of a centralised system by using a connectivity-aware replication strategy.

Selected awards and achievements
Wayes Tushar, NICTA PhD scholar from CRL, won the 2012 Australian Communications Theory Workshop best student paper award in Wellington, New Zealand, February 2012, for *Non-cooperative Power Control Game in a Multi-Source Wireless Sensor Network*. This paper addresses the important problem of power control for wireless sensor networks with distributed sensors through the application of non-cooperative game theory.

Germae Phua, summer scholar from ATP, won first prize in The Digital Future at the UNSW Taste of Research program poster presentations. The shortlist included 10 posters and all the shortlisted students gave a two-minute talk to describe what they had accomplished.

Nikzad Babaii, NICTA PhD scholar, was awarded the Google Publication Prize 2011 for his paper *Some observations on Optimal Frequency Selection in DVFS-based Energy Consumption Minimisation*.

Athanassis Boulis won the NSW iAwards for e-logistics and supply chain and also for Tools and Infrastructure for his work on Structural Health Monitoring for Bridges.

Yan Shvartzshnaider (NICTA PhD student) was awarded the best paper presentation award at the 4th Annual Student Research Conference 2012 at the School of Electrical and Information Engineering, University of Sydney.

The paper entitled *Evaluating User-centric Multihomed Flow Management for Mobile devices in Simulated Heterogeneous Networks* by Dr Xi Li (NICTA Visiting Researcher), Dr Olivier Mehani (NICTA Researcher) et al was runner up for the best paper award at the 4th International Conference on Mobile Networks and Management 2012, Germany.

Professor Mahbub Hassan was selected as an IEEE Distinguished Lecturer for 2013 and 2014.
What is your research area of specialty?
My expertise is evaluating the performance of distributed systems and computer networks. My current research activities are focused on content distribution systems, ICT for developing regions, network measurements, and smart grids.

What do you see as the big research developments in your area?
Modernising the electricity grid - in particular transforming it into a smart grid - is a big challenge. Smart grids involve replacement of aging infrastructure components, the integration of renewable energy sources and energy buffering solutions, widespread deployment of sensors and actuators, and automating grid management using distributed ICT systems. Researchers with expertise in optimisation, machine learning, control systems, distributed systems, performance evaluation and networking are coming together to develop technologies for smart grids. I believe multidisciplinary ICT research teams will play a critical role in addressing future complex infrastructure challenges.

Why NICTA?
NICTA provides a unique mix of research and business environments. The research teams cover major areas of ICT, have critical mass, and are of high quality. The business teams provide researchers with the opportunity to apply research to solve real-world problems, discover new challenges and commercialise research outcomes. This mix of research and business teams provides a uniquely appropriate environment for addressing big, real-world challenges.

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Computer Vision projects and activities

- Spectral Imaging
- Smart Transport and Roads
- Visual Processing for the Bionic Eye
- Automap
- Bionic Vision Australia
- Kernel Methods on Manifolds
- 3D Reconstruction of Reflective Methods

Computer Vision student wearing portable bionic vision simulator kit
Computer Vision

The Computer Vision Research Group undertakes fundamental research in computer vision with a focus on understanding the world through video. Our research builds on and develops the fundamentals of the mathematics of multiple-view geometry, optimisation, machine learning and statistical pattern recognition.

We conduct fundamental research to develop new computer vision techniques in areas such as object recognition and detection, the segmentation of the visual extent of objects from their surrounds, and recovering properties of materials present in a visual scene. Applications include vehicle-based data collection for in-car navigation devices and road asset management, developing technology to assist visually impaired individuals, and new multi-spectral camera technologies.

NICTA’s approach to computer vision research
Many challenges for computer vision research focus on objects, in particular detecting and recovering properties such as materials, segmentation from other objects, structure, motion and location. This focus is reflected in our key computer vision application areas.

- **Vision processing for the bionic eye**
  Our research in this area contributes to Bionic Vision Australia’s development of a retinal implant to aid the recovery of vision through electrical stimulation. We are working to restore functional vision such as face recognition and navigation. Our research approaches include multiple view geometry and segmentation to find hazards in a scene such as moving objects, so that the visually impaired person can avoid them. We are researching new algorithms to segment and present these hazards on phosphenes, which are small points of light at repeatable retinal locations, which are the perceptual artefacts that result from electrical stimulation of the retina.

- **Imaging spectroscopy (spectral imaging)**
  Matter absorbs, emits and reflects light at specific wavelengths. All objects have their own unique reflectance pattern, much like a fingerprint. We are using advanced statistical photometric techniques to automatically process spectral images in order to identify these signatures. This research can be applied to surveillance by permitting objects to be tracked based on material properties. In computational photography, image colours may be enhanced taking into account each specific material type in the scene. For food security, health and precision agriculture, the analysis of spectroscopic images can be the basis for the development of diagnostic, monitoring and surveying tools.

- **Large-scale data mining in road scene sensory data**
  Updating and maintaining digital maps and asset inventories is a big challenge for surveying and mapping companies. Images and other sensory data are currently gathered from the road scene and manually inspected to find the objects of interest. We develop algorithms that can automatically search such data to detect objects of interest, such as road signs and power poles on the roadside.

**Breakthrough results**
A critical step in automatic understanding of a picture or scene is detection of the contour or boundary of salient object surfaces within the picture. Extracting continuous and closed contours is hampered by noisy image information and occlusion by other object surfaces. We have demonstrated the efficacy of a new statistical model on benchmarked image datasets. The team also designed an approximate algorithm that exploits the structure of the edge model and can efficiently cope with the additional complexity in the model.

A key problem in low vision and prosthetic vision is reduction in an individual’s sensitivity to contrast. If printed text or a ground-based trip hazard have low contrast with respect to their surrounding background or floor, then it may be impossible to discern. We developed a new method for adaptive quantisation of an image that ensures that key contrast is preserved, while still retaining the overall visual appearance of the image.
What is your research area of specialty?
My research is focused on computer vision and machine learning, which aims to enable computers to find objects and understand natural scenes using cameras. I am currently interested in discovering efficient representation for object models, designing algorithms to build those models from large image datasets and applying them to real-world problems such as the creation of a bionic eye.

What do you see as the big research developments in your area?
The computer vision community has made significant progress in visual object recognition and scene-level image understanding. We are able to design better algorithms for object detection and recognition, for robust reconstruction of 3D scenes and for image interpretation in terms of objects inside and scene layout.

Why NICTA?
After I finished my post-doctorate, I was looking for a research institute where I could continue my academic research and investigate practical applications of computer vision. NICTA’s strong research groups and a variety of application-driven projects are what attracted me, as well as its ability to uniquely support my goals.

Selected Publications
McCarthy, C., Barnes, N., A Unified Strategy for Landing and Docking using Spherical Flow Divergence. IEEE Transactions on Pattern Analysis and Machine Intelligence, January, 2012. This paper describes a novel algorithm based on a visual cue that facilitates the control of autonomous systems with respect to looming surfaces inspired by behavioural models of insect flight for docking and landing.

Taghavi Namin, S., Petersson, L., Classification of Materials in Natural Scenes using Multi-Spectral Images, IEEE/RSJ International Conference on Intelligent Robots and Systems, Vila Moura Portugal, pp. 6, October, 2012. In this paper, a novel method was developed for roadside material classification using a camera with six visible sub-bands and one near infra-red sub-band. Key issues occurring in real-world outdoor data were considered which guided a choice of features robust to, in particular, varying lighting conditions.

Harandi, M., Sanderson, C., Hartley, R., and Lovell, B., Sparse Coding and Dictionary Learning for Symmetric Positive Definite Matrices: A Kernel Approach. European Conference on Computer Vision Florence, Italy, pp. 216-229, October, 2012. Natural images and videos can be efficiently described as a combination of a few primary signals (called visual words). Generally, these are learnt in Euclidean space (for example assuming parallel lines meet at infinity). However, Euclidean spaces may not be the ideal choice in many applications since space is curved (for example earth hour lines are parallel but intersect at poles not infinity). In this work, we learned visual words on Riemannian manifolds (curved spaces), leading to improved results.

Selected Awards and Achievements
Membership of program committees for top-level conferences, notably ECCV, ACCV, CVPR, and ICML. The delivery of keynote and invited talks and international collaborations continued to build the reputation and impact of the Computer Vision group.

The group chaired an invited special session at EMBC, Vision Processing for Prosthetic Vision. Invited speakers from University of Southern California (associated with Second Sight), Boston retinal implant group, and Monash Vision Group discussed their vision processing strategies and research. The first of its kind, the event brought together implant groups to give invaluable insight into progress in the field.

NICTA researcher Sandra Mau won the iLab Germinate Program Award at Tech23 for her facial recognition technology CeeQ, derived from work with the Advanced Surveillance Team.

PhD student, Lin Gu was presented with a Best Student Paper Award at the International Conference on Pattern Recognition 2012 for the paper entitled Shadow Detection via Rayleigh Scattering and Mie Theory.

Two invention disclosures on computer vision methods for bionic vision progressed to provisional patents with the support of Bionic Vision Australia. One of these provisional patents has the potential to be used in general consumer computing.
Researchers from Visual Processing for the Bionic Eye team.
What is your research area of specialty?
My research focuses on studying the interaction of machine learning and geometry to address computer vision problems. In particular, I am interested in 3D reconstruction from monocular images or video sequences.

What do you see as the big research developments in your area?
Machine learning approaches have become increasingly popular in computer vision. The resulting algorithms typically exploit existing datasets to infer some information about a new input image. As larger and larger amounts of data become available, it is crucial to focus on developing efficient computer vision algorithms that can effectively extract and leverage the information contained in this data.

Why NICTA?
The quality and size of the Computer Vision Group at NICTA make it extremely attractive and open the door to great collaborations. NICTA gives me the means to undertake the research that I want, by combining the advantages of an academic institution - such as the opportunity to supervise students - with the possibility for industrial collaboration via the NICTA business teams.
• Biomedical Text and Data Mining
• Graphical Models
• Human Computer Interaction and Cognitive Analytics
• Large-scale Machine Learning
• Learning Theory
• Structured Prediction
• Text Analysis and Language Technology
• Topic Modelling

3D point cloud of continental gravity readings coloured to reflect the Bouguer anomaly, a measure of the density and thickness of the Earth’s crust used with inversion methods to model subterranean structure.
Machine Learning

The Machine Learning Research Group develops and applies technologies that make sense of the ever-increasing amounts of data gathered in all areas of human endeavour.

NICTA’s approach to machine learning research

Our goal is to turn machine learning into an engineering discipline.

• We develop core machine-learning technologies in the form of new theories, techniques, algorithms, and models. Our particular expertise covers graphical models, Bayesian methods including Gaussian processes and decision-theoretic approaches.

• We build expertise with particular types of data (vision, text, structured and spatio-temporal). We have particular expertise in text and the allied technologies of natural-language processing.

• We implement the technologies, in collaboration with colleagues in the Software Systems research group.

• We work on end-use applications in the areas of geothermal energy exploration, photovoltaic energy prediction, enterprise-scale analytics, civil infrastructure management, groundwater modelling, and the navigation of the world’s patent literature.

• We study the role of human-computer interaction and how it can inform the design of machine-learning technologies. Past work has focused on the use of machine learning for cognitive load estimation which is useful in a wide range of areas.

Our key differentiator is that we endeavour to combine all these threads to make machine learning easier to use and more composable – in a nutshell, more like a traditional engineering discipline.

Breakthrough results 2012

A text-mining prototype has demonstrated almost 100 per cent recall in identifying patients diagnosed with an infection through biosurveillance of radiology records. Improvements continue to be made at the record level to increase the number of instances where the automated system identifies an at-risk patient earlier than through clinical methods. This in-hospital trial is also showcasing a NICTA initiative that addresses the challenges of data and resource dissemination and systematic benchmarking of methods within clinical-language processing.

Machine learning techniques for the structural health monitoring problem were investigated. A literature report, including proposed research approaches and a draft plan for 2013, has been created. The team has used supervised and unsupervised methods on collected bridge response data from the sensor system installed on the Sydney Harbour Bridge. The preliminary results are quite promising showing the potential of machine learning for the structural health monitoring problem.

Within the Water Pipe Prediction project, an efficient inference algorithm has been developed for sparse incident data based on a hierarchical beta process. For water pipe failure data, the observation period (about 10 years) is relatively short compared with the life cycle of water pipes, so that most (about 99 per cent) pipes do not fail or fail just once during the observation period. Such sparsity of the data could be utilised for approximation of the inference process to further reduce the computational complexity. Experimental results on water pipe data also indicate the effectiveness of the proposed approximate inference algorithm. A manuscript has been submitted to Machine Learning Journal, which reports the research contribution and interprets the outcomes in financial terms usable by water utilities. A patent application on infrastructure failure prediction has also been filed.

A method for water pipe condition assessment based on non-parametric beta process was developed. This study, carried out on the data from the Wollongong area, showed superior results to standard models such as the Weibull model. The proposed approach targets preventative repairs more effectively and produces better prioritisation of weak pipes, leading to savings on reactive repairs and maintenance. There is a potential saving of $2 million in capital expenditure per annum based on single factor (pipe age) impact.

Selected publications

Noel, J., Sanner, S., Tran, K., Christen, P., Xie, L., Bonilla, E., Abbasnejad, E., and Della Penna, N., New Objective Functions for Social Collaborative Filtering. International World Wide Web Conference, Lyon, France, pp. 1–10, April, 2012. This paper reports very exciting results on how to substantially improve the performance of collaborative filtering algorithms by simple adjustments to the objective function. The results are compelling because of the large-scale experiments carried out using Facebook.

van Erven, T., Reid, M., and Williamson, R., Mixability is Bayes Risk Curvature Relative to Log Loss, Journal of Machine Learning Research, pp. 1639–1663, May, 2012. This paper provides a new, geometrical characterisation of when it is possible to learn quickly from expert advice in
What is your research area of specialty?
My research background is in physics, but I am currently completing my PhD in machine learning, specialising in non-parametric Bayesian inference.

What do you see as the big research developments in your area?
Should we drill for oil here? Is this water too polluted to drink? Such important decisions rely on creating geo-spatial models. However, both government and industry almost exclusively treat these models as being infallible when in fact they can contain significant uncertainty. Having the ability to generate models with quantified uncertainty would allow explicit, risk-based planning and fundamentally change the decision-making process. This is the big research development we are pursuing at NICTA which, if successful, would have significant impact in Australia both environmentally and economically.

Why NICTA?
NICTA is in a unique position to introduce quantitative analysis of risk and uncertainty to organisations and government in Australia. NICTA’s combination of world-class machine learning research and close ties to both these communities means that we can not only develop the techniques, but also bring about the change in thinking required to see them implemented.
in cognitive load in user behaviour (such as speech, eye movement and digital pen input) during system interaction. The benefit of using this approach to determine the user’s cognitive load in real time is that the data can be collected implicitly and thus overcomes problems of intrusiveness and increases applicability in real-world environments.

**Selected awards and achievements**
Professor Bob Williamson, Machine Learning Research Group Leader, was elected as a Fellow of the Australian Academy of Science in recognition of his research in developing powerful new methods and theoretical arguments for analysing data.

The Cognitive Load Measurement group received a US Air Force Asian Office of Research and Development grant of $120,000 for *Robust Multimodal Cognitive Load Measurement*. This funding will allow research into novel fusion methods for integrating cognitive load information from multiple sources in a manner that optimises their collective use. The key aim is to establish accuracy, reliability and limitations of speech-based and eye activity-based cognitive load measurement and their combination as the groundwork for real-time, non-invasive, automatic workload assessment for real-life applications.

Quoc Le, ANU/NICTA honours graduate, made *The New York Times* with his ground breaking research on simulation of the human brain to learn about images. Principal Researcher Wray Buntine talked to *ABC World Today* on this development in his interview *Artificial Intelligence recognises faces and cats*.

Scott Sanner, senior researcher gave an invited talk at Google, Sydney, on his paper *New Objectives for Social Collaborative Filtering*. International World Wide Web Conference (WWW), Lyon, France, pp. 1-10, April. He also received a Top Supervisor Award from ANU.

Dr Mark Reid, Researcher, won a three year Discovery Early Career Researcher Award for a project titled “Composing Machine Learning via Market Mechanisms”. This project aims to better understand connections between learning algorithms and markets as aggregators of information and develop new, principled techniques for combining predictions. This will improve our ability to construct systems that make predictions based on multiple, complex and structured sources of data.

Lexing Xie, Researcher, and her team won first prize in the “Multimodal Grand Challenge” category at the ACM Multimedia conference held in Nara, Japan.

PhD student Wei Liu received a “Best Paper Award” at the AI 2012 Conference for his paper *Efficient Adversarial Learning Strategy for Constructing Robust Classification Boundaries*. This paper is a joint work with Sanjay Chawla, James Bailey, Christopher Leckie and Rao Kotagiri. The award was received at the conference in early December.
**What is your research area of specialty?**

I build intelligent decision-making systems that can learn from past experience. My research in this area ranges from learning efficiently with large quantities of heterogeneous data through to end-user applications such as personalised content recommendation systems on social media platforms like Facebook.

**What do you see as the big research developments in your area?**

With the explosion of social media content, data has transformed into a rich network of social interactions and viral content, which is dynamically changing over time. This has led to a data-driven revolution that is developing continuously, adapting distributed learning and decision-making algorithms to exploit the wisdom of the crowd.

**Why NICTA?**

NICTA allows researchers to focus on what they do best – research! I supervise some of the world’s best PhD students, consult daily with top researchers in a variety of fields, work in an environment that emphasises a long-term research vision and have access to stellar business teams that connect research to industry.
Machine Learning researchers have developed a method for water pipe condition assessment based on a non-parametric beta process.
• Real-time management of renewable energy
• Intelligent Decision Theory
• Future Energy Systems
• Logistics Research for Ports, Roads, Public Transport
• Raising the IQ of the Smart Meter
• Managing the Cascade of Alarms Generated by the Grid
• Resupplying 90% of Customers in 1 min after a major power outage
• Disaster Management
• Smart Scheduling for the Smart Grid
• Improving Canberra’s Bus Service
Optimisation

The Optimisation Research Group at NICTA carries out fundamental and applied research that addresses grand challenges faced by our society in disaster management, future energy systems, logistics, and supply chains. Our mission is to contribute pioneering scientific results and innovative optimisation systems and to work with our partners in deploying our contributions for the benefits of our society.

**NICTA’s approach to optimisation research**
Our projects push the frontier of optimisation to meet the modelling and computational requirements underlying these challenges. We develop the decision support to prepare, mitigate, respond, and recover from natural disasters and security threats. We study how to plan and operate the smart grid in order to integrate renewable energies and support large-scale distributed generation. We explore how to build the next generation of logistics and supply-chain software, striving toward holistic optimisation in multi-modal environments.

**Technology**
Our research is multi-disciplinary and integrates technologies from artificial intelligence, operations research, and theoretical computer science. We make scientific advances in constraint and mathematical programming, local search and approximation algorithms, planning and diagnosis, simulation and forecasting, computational social choices, and stochastic optimisation. We develop an optimisation platform that integrates these technologies and will transform the design and implementation of complex optimisation applications. We aim to develop optimisation systems that interoperate naturally with other components in comprehensive software solutions and to pursue a holistic approach to our grand challenges.

**Collaborations**
We deeply value collaborations and technology transfers. We have significant engagements with the business teams. In particular these include Infrastructure, Transportation, and Logistics (ITL) and Security and Environment (SE), stakeholders such as Port Botany, the US Air Force, and the ACT Government, and numerous international research partners in Australia, Europe, and the United States. We have joint projects with researchers in the Networks, Machine Learning, and Control and Signal Processing Groups.

**Breakthrough results 2012**
Significant progress was made in the area of energy systems (provisional patents were lodged in both cases): NICTA researcher Dr Carleton Coffrin and Research Group Leader Professor Pascal Van Hentenryck, showed that linear approximations of the AC power flow equations can capture voltage magnitude and reactive power accurately in their paper *Linear-Programming Approximations of AC Power Flow Equations*. This work opened a new scientific research direction that consists of finding accurate convex approximations of the power flow equations, now a central topic in the future energy systems project.

**Senior researcher Dr Menkes van den Briel introduced, in his paper *Randomised Load Control*, a simple but effective way to control demand at power grid scale, whilst respecting consumer privacy and constraints.**

**Selected publications**


Keyder, E., Hoffmann, J., and Haslum, P., *Semi-Relaxed Plan Heuristics*, International Conference on Automated Planning and Scheduling (ICAPS), June, 2012. This paper won Best Paper Award and is described below.

Davies, J., Naroditska, N., and Walsh, T., *Eliminating the Weakest Link: Making Manipulation Intractable?*, Association for the Advancement of Artificial Intelligence (AAAI), July, 2012. This paper showed that it is NP-hard to compute how a single voter can manipulate the result of the elimination version of veto voting, of the closely related Coombs’ rule, and of the elimination versions of a general class of scoring rules.

Walsh, T., *Symmetry-Breaking Constraints: Recent Results*, Association for the Advancement of Artificial Intelligence (AAAI), July, 2012. This was an invited publication and talk at the premier AI conference surveying recent work, much of it undertaken at NICTA, on dealing with symmetry, an important feature of many combinatorial problems.
Dr Manuel Cebrian

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Senior Researcher
PhD in Computer Science
Universidad Autonoma de Madrid (Spain)

What is your research area of specialty?
My research lies at the intersection of the computer and social sciences. My primary interests include social and financial networks, crowdsourcing, urban economics, behavioral game theory and evolutionary dynamics.

What do you see as the big research developments in your area?
The key research developments in my field are a result of the growth of the digital world. The sheer volume and complexity of data in this new world forces us to think about the design of information systems where massive computational and social feedback effects are simultaneously at work. The data generated by digital systems which record how hundreds of thousands - or even millions - of participants create content, link information and communicate has made it possible to theories of interaction and propose new ones. What is now emerging is a far higher level of interaction between computing and the social sciences. This in turn is deepening and enriching both fields.

Why NICTA?
I had been trying to formalise the concept of the “resilience of a city”: is there an index for how different cities withstand natural or man-made disasters? NICTA’s Optimisation Group had a long-term goal to develop a comprehensive disaster-management platform. I saw this platform as the “microscope” under which I could measure the resiliency of cities, and help design them better.

Selected awards and achievement
The group had an extremely successful year with two best papers and two best thesis awards at CP12 and ICAPS 2012 - two of the top conferences for this research group. The group is dominating these fields and is now branching into other fields.

Senior NICTA researcher, Dr Patrik Haslum, won Best Paper Award at ICAPS 2012 for his co-authored paper, Semi-Relaxed Plan Heuristics. This paper breaks new grounds by providing accurate estimation of the quality of heuristic planners.

Recent NICTA PhD graduate Dr Geoffrey Chu and Professor Peter Stuckey won Best Paper Award at CP12 for their paper, A Generic Method for Identifying and Exploiting Dominance Relations. This paper presents a general methodology for exploiting dominances, often producing massive computational benefits.

Dr Chu also received the 2012 Best Thesis Award at CP12, for his PhD thesis Improving Combinatorial Optimization. He was also awarded a Discovery Early Career Researcher Fellowship through the ARC. Nina Narodytska received an Honorable Mention at CP12 for her PhD thesis Reformulation of Global Constraints.

PhD graduate Silvia Richter won the ICAPS 2012 Best Thesis Award, for her thesis Landmark-Based Heuristics and Search Control for Automated Planning.

Research Group Leader Professor Pascal Van Hentenryck, was a Ulam Fellow at the Centre of Nonlinear Studies at Los Alamos National Laboratories.

Optimisation Research Group researchers held 51 committee membership roles, most of these in top-tier conferences. Our researchers were also singled out as outstanding reviewers: Patrik Haslum received the ICAPS 2012 Outstanding Reviewer Award and postdoctoral researcher Nina Narodytska received Outstanding Program Committee Member Award from the Australasian Joint Conference on Artificial Intelligence.

Senior researcher, Dr Manuel Cebrian gave a keynote speech entitled Using Friends as Sensors to Detect Global-Scale...
Contagious Outbreaks, at the International Workshop on Multimodal Crowd Sensing in Maui, USA and gave an invited lecture series talk at George Washington University on the reliability of crowdsourcing. Manuel obtained a series of very visible results in crowd sourcing and social networks, which he is looking at applying to the area of disaster management.

Pascal Van Hentenryck visited the Los Alamos National Laboratory, giving three invited talks in hybrid optimisation, disaster management, and power systems. A regular inter-laboratory discussion group on power systems has since been established. Pascal also gave an invited tutorial at CP12 and an invited talk at the CLNS Smart Grid conference in Santa Fe.

Pascal Van Hentenryck and Research Leaders Professor Toby Walsh and Dr Phil Kilby were invited by the US Air Force to investigate further research opportunities in supply chain and logistics. This is in addition to their three-year basic research grant of $291,000, for the Lifelong Optimisation project. Prof. Van Hentenryck and Dr Kilby subsequently received a “Window of Science” grant to return to Scott Air Force Base, St Louis, USA to strengthen the current collaboration.
Dr Haris Aziz
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Researcher
PhD Computer Science, University of Warwick; MSc Mathematics & Foundations of Computer Science, University of Oxford.

What is your research area of specialty?
My research focus is on the algorithmic and game-theoretic foundations of multi-agent systems. In particular, I work in two young and rapidly growing fields called algorithmic game theory and computational social choice.

What do you see as the big research developments in your area?
With the increase in distributed environments such as the internet, tools from AI and mathematical social sciences will play a crucial role in designing better systems, markets and protocols. The challenge will be to match the scale of these problems with innovative algorithmic and market design.

Why NICTA?
NICTA provides an ideal opportunity to learn from leading researchers, work on intellectually challenging research problems and to make real-world impact.
Control and Signal Processing projects and activities

- Assistive and Adaptive Bionics
- Future Grid
- Power System Modelling and Fault Detection
- Computational Approaches to Immunology
- Distributed Control and Estimation in Networked Environments
- Large-Scale Genetic Network Modelling
Control and Signal Processing

The Control and Signal Processing (CSP) Research Group develops new tools and methodologies for computational life sciences and large-scale interconnected systems.

In 2012, our Systems Biology project was enhanced by the appointment of Professor Edmund Crampin, a world-leading expert in the area of computational systems biology, as a leader of this project.

CSP is building research capacity in the area of future power grid technology. Our work in the area of precision agriculture has expanded into China, and the CSP FarmNet project has received attention in the Legislative Council Daily Hansard with Minister for Technology Gordon Rich-Phillips mentioning that “FarmNet software platform ... is an important piece of software which will lead to better land and water use in the agricultural sector”. We are pleased to have had two papers published in the prestigious journal Science in 2012.

A key research challenge for our group is to develop tools for the design and analysis of very large-scale, distributed dynamical systems with network-connected sensors and actuators. This takes applications in urban transport, power systems, urban and rural water-distribution systems, defence and surveillance systems consisting of large swarms of possibly mobile sensors, and many areas of biology, including cell signalling and protein interactions.

Industrial projects

The Smart Farming project is developing an online platform that will utilise the Commonwealth’s National Broadband Network to bring together data and information from myriad sources with widely different formats to transform decision making in farm management. The Future Grid project is undertaking fundamental and applied research into new modelling, optimisation and control techniques for future electricity networks and associated energy markets. The Distributed Control and Estimation in Networked Environments (DICE) project is partnered with the Australian Defence Science and Technology Organisation to develop a range of new tools for design and analysis of large networks of sensors.

Life Sciences projects

The Life Sciences projects focus on the areas of bioinformatics, computational and systems biology, biomedical devices and biomedical informatics. The common application theme for all of these project areas is translational medicine; the commitment to translate fundamental research into useful health outcomes. For example, at the genomics level, the research challenges centre on the development of efficient string encoding and storage methods, genomic feature extraction and classification as well as new work in gene regulation pathway models. Such work involves combining aspects of graph theory, dynamic systems and statistical modelling. At the cellular level, researchers investigate techniques for the modelling and measurement of biological phenomena with a specific focus on the interactions between different levels of biological organisation. New formulations of life-death processes have emerged along with tracking and path analysis for the analysis of the immune response to diseases. The biomedical informatics work applies a consortium of textual features, clustering and classification methods to detect, query and retrieve information relevant to drug design and clinical treatments. Key to this work is a deep understanding of computational linguistics, clustering and classification methods along with data fusion and decision-support modelling. The biomedical devices research develops cheap, wearable devices capable of accurately recording patient actions. This requires the development of microelectronic devices, new robust algorithms for drift compensation, and the use of stochastic computational geometry to encode actions invariant to their position, orientation and, in some cases, temporal warping.

Breakthrough results

Researchers from the Faculty of Veterinary Science at The University of Melbourne in collaboration with John Markham from the NICTA CSP-Life Sciences research group discovered that two different vaccine viruses used for control of the avian pathogen infectious laryngotracheitis were able to recombine and generate more virulent viruses. The findings of this study suggest that regulation of live attenuated vaccines needs to take into account the real potential for recombination and measures to ameliorate the likelihood and/or the consequences of recombination between different vaccines, or potentially between vaccines and field viruses, will need to be implemented. They have significance not only for vaccines in poultry, but also for any live viral vaccine where the parental viruses are capable of recombination, including those in use in humans.

CSP researchers have been working with collaborators from a number of Melbourne hospitals to develop a low-
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ARC DECRA Fellow, ANU
PhD (Electrical Engineering) Deakin University

What is your research area of specialty?
My research interests concern the distributed control of large-scale systems.

What do you see as the big research developments in your area?
I expect big breakthroughs in control as we gain a better understanding of how we can design control algorithms for large-scale distributed systems such as the water network. Information available for control algorithms to make decisions in such systems is distributed along with the individual controllers and sensors. At the moment, how that information should be shared between a collection of distributed controllers and how to design each individual controller so that the global system behaviour is controllable and the desired behaviour emerges is not well understood. However, this field is progressing and I expect important developments in the future will change the way modern large-scale systems are designed and, as a result, advance the achievable performance.

Why NICTA?
NICTA is a great organisation in which to conduct research, as it fosters and strives to achieve high-impact fundamental research outputs while also encouraging, supporting and developing key commercial applications. At NICTA I am lucky enough to work with some of the world’s top researchers in control and signal processing from labs all across Australia.
the past 12 months. The paper demonstrated a method for de novo genome assembly that could be utilised on desktop computers. Recent citations suggest that the paper is driving a whole new direction in the genome assembly literature.

Hamish Meffin et al., paper Modeling extracellular electrical stimulation: I. Derivation and interpretation of neurite equations, J. Neural Eng. 9:065005, 2012, has been chosen as one of the Journal of Neural Engineering Highlights of 2012. The Journal of Neural Engineering Highlights is a collection of papers that represent the breadth and excellence of the work published in the journal in 2012; selected for their presentation of outstanding new research, receipt of the highest praise from our international referees, and the highest number of downloads last year.

Kandeepan Sithamparanathan is a co-author of the book Cognitive Radio Techniques: Spectrum Sensing, Interference, Mitigation, and Localization published by Artechhouse. This textbook is an overview of intelligent radios that could dynamically adopt themselves to optimise usage of scarce radio resources.

A central goal of medical genetics is to accurately predict complex disease from genotypes. In the recently published paper by NICTA-funded PhD student Gad Abraham and co-authors, a comprehensive analysis of genome-wide SNP profiles across eight complex diseases within cross-validation is presented. The findings show that the methodology is robust across different disease architectures and produces as good or better phenotype predictions than other methods to date. This has fundamental ramifications for the selection and future development of methods to genetically predict human disease. Abraham, G., Kowalczyk, A., Zobel, J., and Inouye, M., SparSNP: Fast and memory-efficient analysis of all SNPs for phenotype prediction, BMC Bioinformatics 2012.

Nick Opie, NICTA-funded PhD student, is the first author of the paper Retinal prosthesis safety: Alterations in microglia morphology due to thermal damage and retinal implant, published in the Journal of Investigative Ophthalmology and Vision Sciences. The paper investigates important aspects of damage to the neural tissue by the heat that the electrical circuits generate. The paper is an example of successful collaboration between ICT researchers and clinical scientists.

Selected awards and achievements

Graduate Researchers Jeffrey Zhang and Baoqi Huang have both received Chinese Government Awards for Outstanding Self-financed Students Abroad. These awards are given for the academic excellence to self-financed Chinese students studying overseas, with 49 awarded in Australia this year. Samantha Lichter, NICTA PhD student, won second place in the University of Melbourne Three Minute Thesis competition. CSP student Sachintha Karunaratne received a travel award and had his paper recognised as one of the Top 10 student papers at the 15th international Conference on Information Fusion held in Singapore.

Adam Kowalcyzk was invited to submit a short testimony on performance of the group’s GWIS algorithm on the NVIDIA web page. This is a recognition from NVIDIA, the leader in GPU technology, that we are achieving impressive results in term of innovative usage using our GWIS technology for applications in the personalised medicine area.

Rob Evans was invited to present an IEEE Distinguished Lecture on New Frontiers in RADAR at the Adelaide Convention Centre. Rob Evans was invited to serve as a TPC member on the technical program committee for 2012 International Conference on Connected Vehicles & Expo. Rob Evans was invited to chair the Expert Working Group on one of multi- and interdisciplinary research projects under an overarching program Securing Australia’s Future: New Technologies and Their Role in Our Security, Cultural, Democratic, Social and Economic Systems. Brian Anderson was appointed Chair of the University of Technology, Sydney, Faculty of Engineering Research Advisory Board.
Dr Adam Kowalczyk

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Principal Researcher
PhD Mathematics
Warsaw University of Technology

What is your research area of specialty?:
I specialise in bioinformatics, more precisely genomics and genomic epidemiology.

What do you see as the big research developments in your area?
The biggest development is an emergence of genomic technologies capable of profiling human DNA genome on a wide scale, quickly and affordably. This can be used for personalised, precision medicine, where disease can be diagnosed and prognosis made, taking into account the specific predispositions of the patient. Drugs and treatments can be selected optimally, to suit the patient’s genomic predispositions, potential susceptibility to side effects and actual disease subtype. Recent breakthroughs in computational hardware and algorithms make it possible to develop practical decision-making systems, based on this complex, high-dimensional data.

Why NICTA?
Prior to joining NICTA I spent time at Peter MacCallum Cancer Centre, the leading cancer research institute in the country. However, it became clear that I would need a talented, multi-disciplinary team capable of cutting-edge bioinformatics algorithms. This is what NICTA offers. Over the years we have created collaborations with wet labs, while preserving the ability to concentrate on the technical aspects of developing algorithms and their efficient computer implementations. It is very rewarding to have surgeons come to the lab and debate aspects of novel systems we jointly develop, to address acute issues faced while treating cancer patients.
NICTA’s John Markham, in collaboration with researchers from the Faculty of Veterinary Science at the University of Melbourne, discovered that two different vaccine viruses used for control of the avian pathogen infectious laryngotracheitis were able to recombine and generate more virulent viruses.
Optics and Nanoelectronics projects and activities

- Nano-devices for Biological Sensing
- Radar on a Chip (ROACH)
- Stereoscopics Imaging and Binaural Scene Encoding
- Engineering Nanometre-Scale Photodetector
- Silicene-enhanced 3D Optical Imager System on a Chip
This group brings together NICTA’s expertise in optics and nanoelectronics, which draws on the organisation’s longstanding experience in advanced sensor networks and CMOS research. We conduct fundamental research and also apply this research to build systems and products. We work closely with the Centre for Neural Engineering at the University of Melbourne, clinicians, and with NICTA’s Health Business Team.

NICTA’s approach to Optics and Nanoelectronics research
We use our advanced modelling and analysis capabilities to design and build functional systems. We draw on deep experience in embedded systems research and the development of sophisticated sensor networks. At present, we are working on five projects:

- **100TB/s Optical System**: developing technology to enable 100TB/s fast optical connections between cities
- **100GS/s Analog-to-Digital Converters**
- **Radar on a chip (77GHz Automotive Applications)**: developing automotive applications to make cars more intelligent
- **60GHz and 120GHz wireless communication**: these are the wireless technologies supporting the development of Australia’s future ‘bionic eye’
- **Nanopores and nanowires**: We have developed advanced DNA sequencing techniques to support the detection of personalised medicine and real time monitoring of the blood brain barrier.

Breakthrough results
The Bionic Eye project achieved the first successful surgical implantation of the diamond electrode arrays in cats. The electrode array was then electrically stimulated and visual cortical responses were successfully recorded. The required levels of electrical stimulation were under the three volt limit required for voltage compliance of the second-generation chip. They were also under or at the limit of safe charge injection for doped-diamond electrodes. Further studies are required to confirm these results. Histological assessment of the eyes is underway to assess the safety of the current design.

The electronics team working on the Bionic Eye project are proceeding with the tapeout of the second-generation chip and have achieved clean design rule checks and layout versus semantic checks. This is a key milestone that is the culmination of 12 month’s work.

Publications
Garret, D., Ganesan, K., Stacey, A., Fox, K., Meffin, H., and Prawer, S., *Ultra-nanocrystalline Diamond Electrodes: Optimisation for Neural Stimulation*, Journal of Neural Engineering, vol 9, pp 1-10, 2012. This paper demonstrates that ultra-nanocrystalline diamond can stimulate neurons up to the same charge capacity as platinum (which is the current “gold standard” in neuroprosthetics). Ultra-nanocrystalline diamond has a number of advantages over platinum, including the ability to modulate its conductivity so as to form hermetic feedthroughs. Such feedthroughs are a key component in any neuroprosthetic system. The hermeticity of the feedthrough was demonstrated for the first time in the past quarter and was a key milestone for the Bionic Eye project. Zhu, C., Tran, A., Chen, S., Du, L., Do, C., Anderson, T., Lowery, A., and Skafidas, E., “Statistical Moments-Based OSNR Monitoring for Coherent Optical Systems”, Optics Express, vol. 20, no. 16, pp. 17711-17721, July 30, 2012.


Selected awards and achievements
David Ng, Senior Researcher, gave an invited talk on *Wireless Power delivery for Retinal Prosthesis* as part of his visit to the Malaysia-Japan International Institute of Technology at Universiti Teknologi Malaysia.

Members of Optics and Nanoelectronics were invited to present on NICTA’s research in *Ultra-Broadband Optical Wireless Communications for Short-Haul Applications* at Intel Research Labs, Santa Clara, USA.

Graduate Researcher Desmond (Ke) Wang was awarded the IEEE Photonics Society Japan Young Scientist Award for the most outstanding student paper at the Asia-Pacific Microwave Photonics Conference held in Kyoto in April. Desmond’s paper on a high-speed, full-duplex, indoor optical wireless
What is your research area of specialty?
My research area is in nano-scale biological and chemical sensors. It is the study, design and fabrication of fast and cost-effective sensing devices for disease diagnosis, detection of harmful bacteria in food and drink, and sequencing of the human genome.

What do you see as the big research developments in your area?
The Nobel Prize winning experiments on the discovery of the groundbreaking material graphene in 2004, and the availability of the powerful imaging and lithography tool SHIM (scanning helium ion microscope) in 2007 have generated great promise for developing innovative sensing devices. The project I work on at NICTA is now patenting graphene-based DNA sequencing inventions with single nucleobase resolution.

Why NICTA?
After obtaining my PhD and working for nearly a decade with Motorola, Bandspeed and NEC, I found that NICTA provided me with unique opportunities to leverage my industry experience and academic expertise to focus on cutting-edge research that could make big impact.
NICTA is part of the Bionic Vision Consortium providing the ICT expertise to enable the development of an implantable bionic eye for retinitis pigmentosa and macular degeneration.
Implant Systems projects and activities

- Systems architectures
- Device packaging
- Tissue packaging
Implant Systems

The Implant Systems team develops small, sophisticated and low-cost implantable therapies to help relieve chronic pain. The work is significant in light of the large numbers of people who will suffer the debilitating effects of chronic pain in their lifetime.

This team’s work promises to result in the creation of medical devices that can monitor and stimulate many sites across the body. This capability stands in stark contrast to currently available device architectures which cannot emulate the complex biological behaviours of the human body.

NICTA's approach to Implant Systems research

Implant Systems is a multidisciplinary team of engineers, scientists and neurophysiologists. We work closely with clinicians to develop neuromodulation therapies. Our relationship with the Pain Management Research Institute – a joint initiative of the University of Sydney and Royal North Shore Hospital - has allowed us to test our technology in humans very early in the development process. We have developed a unique neural response recording system which lets us measure the electrical activity in the spinal cord. Our basic science is revealing the mechanisms of neuromodulation for pain relief. We translate this immediately into clinical application through design of new algorithms and techniques and test these in models and humans. Our engineering has allowed us to build the world’s first bidirectional interface to the nervous system. With this we can simulate and continuously adjust to provide closed-loop therapy.

Breakthrough results 2012

• Tissue Interface - product: Progress in the development of microtextile leads was focussed on addressing the issue of tissue ingrowth that was highlighted in the in vivo trials in Q4 2011. A coating that is porous to electrolyte but not tissue.
• A second trial, later in the year, tested four kinds of electrolyte permeable/tissue impermeable coverings on the knitted lead structure. These were two different braided structures using multi-filament Dyneema yarns and two different Dynene non-woven membranes. All four coverings were able to resist tissue ingrowth and this trial suggests that the membrane covered leads provoked a minimal fibrous tissue capsule development.
• Tissue interface - process: the design for the integration of the knitting and wrapping processes for the textile lead development was completed.
• Work began on a method of altering the impedance of the tissue interface. An electrochemical method of increasing the electrode surface area has been investigated and promising results were gathered. The tissue interface has complex (resistive and capacitive) impedance and the process works to increase the capacitance.
• A major issue for the measurement of compound action potential recording is the so-called electrode artefact caused by loading the tissue around the electrode with charge during a stimulation cycle. This is quite variable, depending on patient posture and stimulation parameters. A method for Artefact Characterisation was developed and has been applied to the human trials data. A method for automating the collection of data for this characterisation has been developed and this will be applied to all future results.
• Trials Program - Eight animal trials were conducted. The NICTA-developed MCS lab software was deployed for these trials and provided much improved resolution. MCS trials provided further opportunity to develop the NICTA stimulation feedback algorithms

Experiments conducted include:

• Measurement of an impedance matrix to test the understanding of electrode orientation, after insertion, without the use of a fluoroscope. This now needs to be analysed.
• Acute neurological measurements to improve understanding of the effect of different stimulation patterns on neurological response.
• Two animal trials were completed at Royal North Shore Hospital Kolling Institute during Q3. The standout trial for the quarter tested the feasibility of using the NICTA MCS-2 system for measuring the evoked action potentials in the brain.
• Nine human trials were conducted. These trials collected more information to help tune the feedback loop therapy and also gave interesting insight into the mechanisms of operation of some competitive approaches that are based on high frequency stimulation.

Human trials included:

• The use of NICTA technology in an intraoperative procedure. The measured neural response was provided to the surgeon while a trial lead was being implanted to assist the surgeon to optimise the placement of the lead. Significant improvements in lead placement were achieved using this method which should result in
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Software Engineer
Masters in Radio-Physics and Electronics
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What is your research area of specialty?
My research area of specialty is in embedded software engineering. I specialise in designing and building reliable and maintainable safety-critical software for biomedical applications. My interests are also concentrated on the construction of optimised and well-balanced software development projects for the fast and efficient design and development of high-quality embedded software.

What do you see as the big research developments in your area?
Developing embedded software for high availability, safety-critical systems within budget and on time is always a great challenge. Serious efforts have been taken in the past to develop efficient and flexible embedded software development practices for safety-critical, bio-medical systems. Adaptive agile practices are widely recognised by institutions and major medical industry players as very efficient and powerful for the development of high-availability software systems. I have no doubt that agile practices will continue to improve and better integrate with the needs of the medical industry, incorporating best practices of risks management and defensive software development techniques.

Why NICTA?
NICTA has a great group of highly motivated, enthusiastic and extremely professional people. Working collaboratively in such a saturated and multi-disciplinary environment is a rare and amazing opportunity for me. NICTA has given me the chance to add value to Australian science and technology while utilising my previous experience in commercial software engineering.

improved patient comfort and reduced power consumption. This was a “world first” and was mentioned in the 7.30 Report on ABC.

• The first demonstration of filtering mode performing feedback control at all postures in a patient was trialled using the NICITA Multi-channel system for spinal cord stimulation and recording.
• Analysis of the effect of signal averaging on feedback loop performance. The first use of the Body Worn System (BWS). The BWS performed as required, delivering feedback control in a package that allowed the patient to walk freely around the clinic. This is the first time real-time closed-loop control of stimulation has been used in an ambulatory mode.

Selected awards and achievements
John Parker, Chief Technology Officer and Group Leader, attended the 14th World Congress on Pain in Milan on 27 August, 2012. John presented two posters at the conference, Spinal cord potentials during neuromodulation for pain relief, Neural feedback neuromodulation.

John Parker delivered two keynote presentations at the North American Neuromodulation Society’s (NANS) annual meeting, December 2012.

Publications
Parker, J., Compound action potentials recorded in the human spinal cord during neurostimulation for pain relief, Pain, March 2012. This journal is consistently the highest ranking journal in the field of anaesthesiology.
Novel ‘knitting’ machine
Values

Our Vision
NICTA’s ICT research drives Australia’s future.

Our Mission
NICTA undertakes breakthrough, internationally recognised research in partnership with industry, government and researchers, to create value for Australia.

Our Values
NICTA’s values represent our culture and the way we do things:

INVENT
We create new ideas, seize business opportunities and take risks

INSPIRE
We energise and motivate people to be entrepreneurs

COLLABORATE
We work together and partner to tackle big problems

MAKE IT HAPPEN
We focus, commit and deliver

EXCEL
We are excellent in everything we do
Engaging with NICTA

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