The Australian Computer Society

Annual Dennis Moore Oration Dinner

The University Club of Western Australia

Wednesday 10th October 2018

Quantum Computation

Professor Jingbo Wang

Annual Dennis Moore Oration

Since 2012, to commemorate fifty years of digital computing in Western Australia, the WA Branch of the ACS has invited a distinguished scholar and researcher with a connection to WA to present a lecture on the leading edge of an important and emerging area of information and computer technology.

In 2012, this was delivered by Professor Andrew Rohl on the subject of supercomputers.

In 2013, the oration was delivered by Professor Ian Reid and examined the subject of computer vision.

In 2014, it was delivered by Professor Craig Valli on the subject of cyber and network security.

In 2015, it was delivered by Professor Svetha Venkatesh on the question of “Where is that Data Utopia?”.

In 2016, it was delivered by Dr Adrian Boeing who addressed the question “Autonomous Mining: What’s Next?”.

In 2017, Professor Matthew Bellgard, gave the oration on “Embracing Digital Disruption to Advance Clinical Research”.

Prof Matthew Bellgard with Prof Dennis Moore at the 2016 Oration

1962 Prize

From a suggestion of Dennis Moore (and with his strong support) 2012 also saw the setting up of an annual prize for the best graduating student in ICT from a WA university. Although the primary criteria are based on academic performance, the candidates are also interviewed for their ability to promote their ideas in computing and contribution so far.

Previous winners of the 1962 Prize are:

2012 Kevin Adnan (Curtin University)
2013 Laurence Da Luz (ECU)
2014 Anthony Long (Curtin University)
2015 Michael Martis (UWA)
2016 Dalibor Borkovic (Murdoch University)
2017 Mark Shelton (UWA)

The 1962 Prize finalists who graduated in 2017 for consideration of the award in 2018 are:

Andrew Gozzard (UWA)
Taaqif Peck (Murdoch University)
Luke Phipps (Murdoch University)
Lewis Ari Tolonen (UWA)
Sabrina Young (ECU)

Mark Shelton receiving his certificate and prize from Prof Dennis Moore

The Australian Computer Society
presents
Annual Dennis Moore Oration Dinner

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Speaker: Professor Jingbo Wang

Proceedings

Opening and welcome by Arnold Wong, ACS National Treasurer
introducing Michelle Sandford, ACS WA Branch Chair.
Opening address by Parliamentary Secretary, Mr Chris Tallentire MLA,
on behalf of Hon Dave Kelly MLA, Minister for Water; Fisheries;
Forestry; Innovation and ICT; Science, representing the Premier.

Entrée served.

Introduction to the 1962 Prize and 2017 finalists by Dr Bob Cross.
Professor Dennis Moore to present certificates and the 1962 prize.

Main course served.

Introduction of the 2018 Orator by Professor Terry Woodings.
Distinguished Oration delivered by Professor Jingbo Wang.
Vote of thanks by Professor Tony Watson.

Dessert served.

Concluding comments by Arnold Wong.

We wish to thank our Gold Sponsors:

Curtin University

THE UNIVERSITY OF WESTERN AUSTRALIA

SEEK WISDOM

and Silver Sponsor:

Murdoch UNIVERSITY

SCHOOL OF ENGINEERING AND INFORMATION TECHNOLOGY

We wish to also thank the organizing committee:

Dr Vivienne Conway MACS,
Mr Rob Freeth FACS,
Prof Tony Watson FACS (Chair),
Mr Arnold Wong FACS and
Prof Terry Woodings FACS

Supported by
Sarah Newland ACS - WA State Manager
Alexandra Mollo ACS - WA Events Coordinator

Professor Jingbo Wang

BSc Sichuan., PhD Adel.

Professor of Physics , Head of Department,
Faculty of Engineering and Mathematical Sciences,
School of Physics, Mathematics & Computing

University of Western Australia

Professor Jingbo Wang received her PhD from the Department of Physics and Mathematical Physics in Adelaide University, and subsequently worked at Adelaide University, Murdoch University and the University of Western Australia.

She established and currently leads an active research group at UWA working in the area of quantum simulation, quantum walks, and quantum algorithm development.

Wang pioneered cutting edge research involving, in particular, single and multiple particle quantum walks. Her research team was the first to show the power of quantum walks in extracting local and global structural information of complex networks and in distinguishing a wide range of non-isomorphic graph classes.

The team also developed a general quantum compiler with an optimiser, which maps a given quantum algorithm to a quantum circuit consisting a sequential set of elementary quantum logic gates. It provides a powerful tool to assist the design of actual physical implementation of quantum algorithms in laboratories.

Professor Wang and her team have recently obtained some of the most efficient quantum circuits to implement a wide variety of quantum operators, which could underpin the utmost quantum supremacy.

Wang is also the Head of Physics Department and the chair of a newly formed cross-disciplinary research cluster named “Quantum information, simulation and algorithms” within the Faculty of Engineering and Mathematical Sciences at UWA.

Introduction

Quantum computation is a rapidly evolving interdisciplinary field, which has attracted researchers from physics, computer science, mathematics, and engineering. Instead of brute-force miniaturisation of basic electronic components, quantum computation utilises an entirely new design architecture and promises to solve problems that are intractable on conventional computers. Quantum computation offers the prospect of harnessing nature at a much deeper level than ever before, as well as a wealth of new possibilities for communication and data processing.

Briefly speaking, conventional computers are encoded with information called bits being either 0 or 1, while quantum computers are based on **qubits** that can be in a superposition of both 0 and 1 states. In this way, manipulating a single qubit allows one to process two bits of information simultaneously. A quantum register consisting of multiple qubits can also exhibit an unusual quantum property termed as **entanglement**, which connects n qubits in a special way to perform 2^n computations in quantum parallel all at the same time. A specific sequence of quantum logic gate operations on any single qubit or pair of qubits in the quantum register is called a **quantum circuit**. A quantum algorithm is considered exponentially efficient if its corresponding quantum circuit has a shallow depth, that is the number of quantum gate operations scales polynomially with the number of qubits in use in the register. An example quantum circuit for the best known quantum algorithm, Shor's factoring algorithm, is shown in Figure 1.

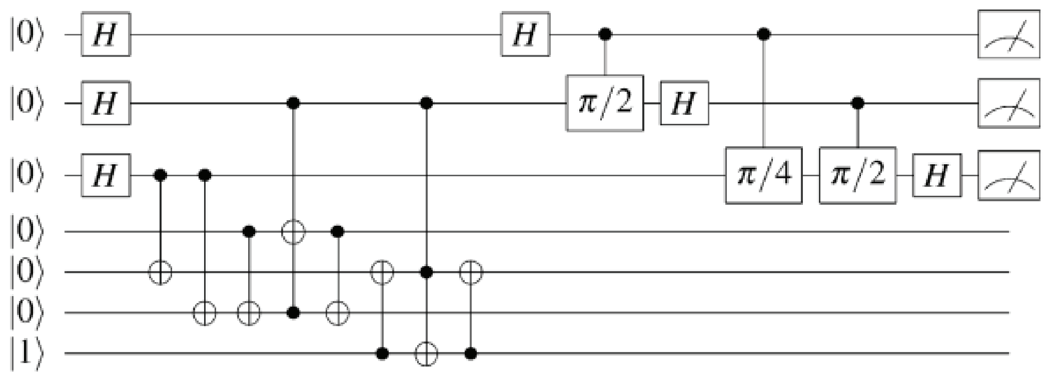


Figure 1. Quantum circuit for Shor's algorithm

In Figure 1, each qubit is represented by a single horizontal line, the various quantum gate operations are represented by boxes and circles, while the vertical lines indicate controlled operations. The final step is to measure the top three qubits, which then provides the sort-after factors of a composite number.

Quantum computation has come a long way since the discovery of Shor's factoring (1994)[1] and Grover's search (1996)[2] algorithms. We now have quantum algorithms that can solve exceedingly large set of linear equations[3], can simulate a wide range of Hamiltonians representing chemical and biological systems[4], can perform many linear transformations exponentially fast such as the Fourier and wavelet transforms, the cyclic permutation and circulant matrix transforms[5], and can efficiently evaluate inner products and distances in extremely high dimensional vector space[6], the last of which is particularly useful in data mining and machine learning.

In the field of quantum computation, we have pioneered cutting edge research involving single and multiple particle **quantum walks**, which are universal computational primitives in quantum information and computation. Our research team was the first to show the power of quantum walks in extracting local and global structural information of complex networks[7] and in distinguishing a wide range of non-isomorphic graph classes[8]. We also developed a general quantum compiler with an optimiser, which maps a given quantum algorithm to a quantum circuit consisting a sequential set of elementary quantum logic gates[9]. It provides a powerful tool to assist the design of actual physical implementation of quantum algorithms in laboratories. We have recently obtained some of the most efficient quantum circuits to implement a wide variety of quantum operators, which could underpin the utmost quantum supremacy[10].

Our current research includes (1) exploring fundamental structures and symmetries in nature such as the PT symmetry in quantum walks[11] and quantum field theory on regular and irregular lattices in curved space-time[12], (2) studying the implications of quantum stochastic, decoherence, and nonlinear processes[13], (3) quantum simulation of designer functional nano-structures, molecules and materials, (4) understanding chemical and biological kinetics and dynamics via quantum computation, (5) quantum image processing, quantum data mining, and quantum machine learning[14], and (6) quantum nested Monte Carlo simulation of financial options pricing and risk management.

In this paper I will provide a few example applications developed by our research team, which demonstrate the power and capability of a quantum computer, at least in theory. I will describe in particular the associated quantum algorithm development and quantum circuit design. I hope you will find them interesting, informative, and useful in your pursuit.

1. Efficient quantum circuits for circulant and circulant-like operators

[Sisi Zhou, Jingbo Wang]

A central research focus in quantum computation is to explore what kinds of linear transformations (either unitary or non-unitary) can be efficiently implemented on a quantum computer. Significant breakthroughs in the area include the development of efficient quantum algorithms for Hamiltonian simulation, which is fundamental to the studies of chemical and biological processes at the atomic and molecular level. Berry, Childs and Kothari[15] presented an quantum algorithm for sparse Hamiltonian simulation achieving near-linear scaling with the sparsity and sublogarithmic scaling with the inverse of the error.

However, as proven by Childs and Kothari[16], it is impossible to perform a generic simulation of an arbitrary dense Hamiltonian H in $\mathbb{C}^{N\times N}$ in time $O(\mathrm{poly}(|H|, \log N))$, where $|H|$ is the spectral norm. It is then natural to ask under what conditions we can extend the sparse Hamiltonian simulation algorithm to the realm of non-trivial classes of dense matrices.

Circulant matrices are an important family of linear operators, which have a wide range of applications in science, mathematics, computing, and engineering related fields. Since a circulant matrix can be decomposed into a linear combination of permutation matrices

$$C = \begin{pmatrix} c_0 & c_1 & \cdots & c_{N-1} \\ c_{N-1} & c_0 & \cdots & c_{N-2} \\ \vdots & \vdots & \ddots & \vdots \\ c_1 & c_2 & \cdots & c_0 \end{pmatrix} = c_0 \begin{pmatrix} 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{pmatrix} + c_1 \begin{pmatrix} 0 & 1 & \cdots & 0 \\ 0 & 0 & \cdots & \vdots \\ \vdots & \vdots & \ddots & 1 \\ 1 & 0 & \cdots & 0 \end{pmatrix} + \cdots = \sum_{j=0}^{N-1} c_j V_j$$

where $V_j = \sum_{k=0}^{N-1} |(k-j) \mod N\rangle\langle k|$, we are able to implement this operation efficiently by the following quantum circuit:

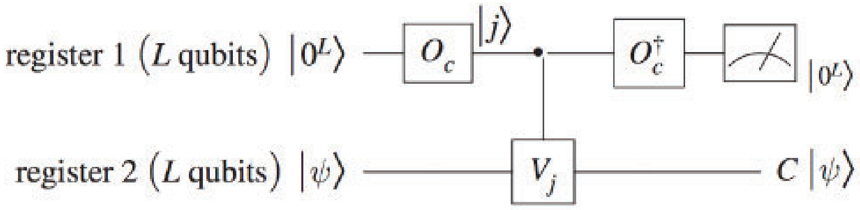


Figure 2. Quantum circuit to implement a circulant matrix

By similar arguments, we can also efficiently implement the operations of Toeplitz, Hankel, block circulant matrices, as well as the inverse and the exponential of circulant matrices[5].

2. Visual motion tracking by quantum machine learning

[Chaohua Yu, Fei Gao, CH Liu, Du Huynh, Mark Reynolds, Jingbo Wang]

Visual motion tracking is the task of locating a moving object of interest in sequential frames of a video. It is a key problem in computer vision, which has wide application across human-computer interaction, security and surveillance, robot perception, traffic control, and medical imaging. In this work, we developed a quantum algorithm which can track translational motion of an object in a sequence of video frames. The algorithm comprises two phases, quantum training and quantum detection, as shown in Figure 3.

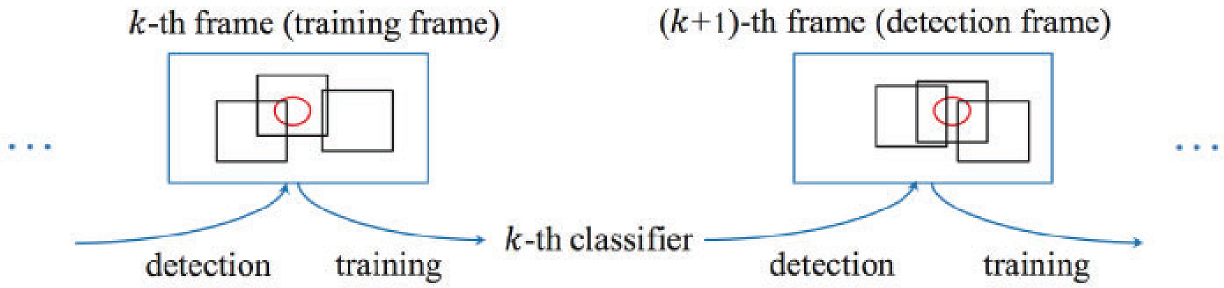


Figure 3. Schematic diagram of the visual tracking scheme

The algorithm first trains a ridge regression classifier using a quantum register, where the optimal fitting parameters of ridge regression are encoded in the quantum state amplitudes. The classifier is then employed to generate a quantum state whose amplitudes encode the translation position of the moving object.

This algorithm is based on a classical computation scheme proposed by Henriques et al[17]. In the training phase, we take the original sample image patch with n pixels represented by $\mathbf{x} = \{x_1, x_2, \cdots, x_n\}$ and generate n virtual images through cyclic shifting, represented by the circulant matrix

$$C(\mathbf{x}) = \begin{bmatrix} x_1 & x_2 & x_3 & \cdots & x_n \\ x_n & x_1 & x_2 & \cdots & x_{n-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_2 & x_3 & x_4 & \cdots & x_1 \end{bmatrix}$$

It then trains a linear function $f(\mathbf{x}) = \mathbf{w}^T\mathbf{x}$ by ridge regression, which minimises its difference from a Gaussian like response distribution y, i.e.

$$\min_{\mathbf{w}} \sum^{n} |f(\mathbf{x}_i) - y_i|^2 + \alpha \|\mathbf{w}\|^2$$

The below quantum circuit performs the training procedure, which requires the implementation of the exponential of circulant matrices, as shown. The goal is to construct the classifier quantum state $|\mathbf{w}\rangle$.

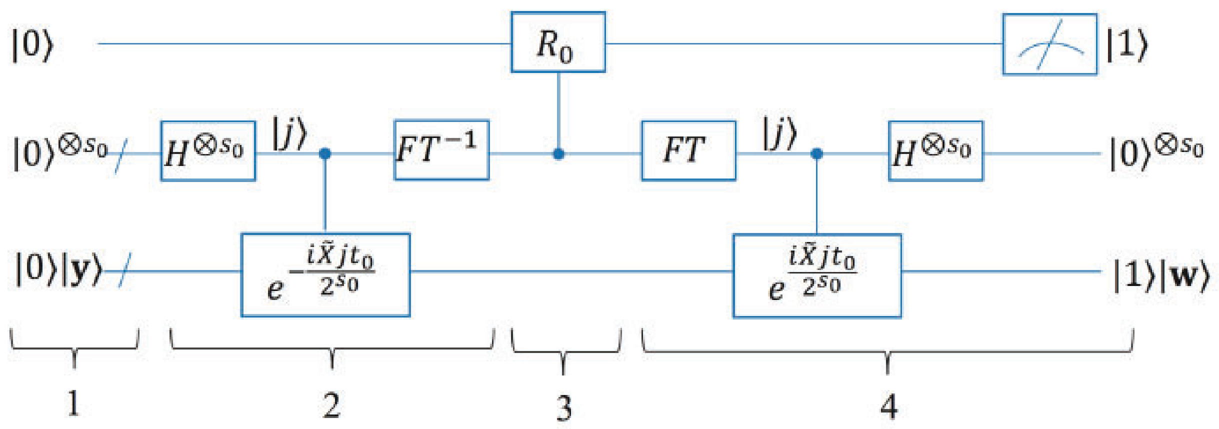


Figure 4. Quantum circuit for the training phase

In the detection phase we take a subsequent image patch from the video, represented by $\mathbf{z} = \{z_1, z_2, \cdots, z_n\}$, and generate n virtual images using again a circulant matrix $Z = C(\mathbf{z})$. The response function $\hat{\mathbf{y}} = Z\mathbf{w}$ can then predict the translational position of the candidate object. The below quantum circuit performs the detection procedure. The goal is to produce the response quantum state $|\hat{\mathbf{y}}\rangle$, which contains the information of the object's position.

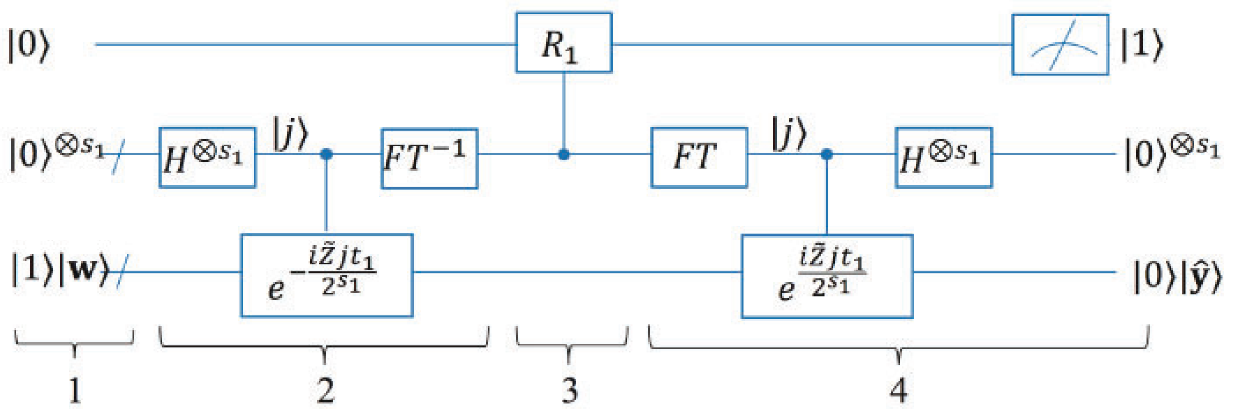


Figure 5. Quantum circuit for the detection phase

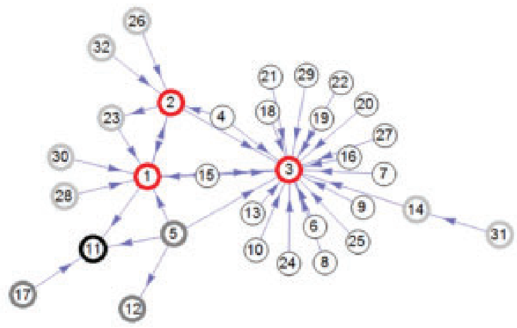
As described in the previous section, we can efficiently implement the exponential of circulant matrices. The above proposed quantum algorithm for visual motion tracking is therefore also efficient.

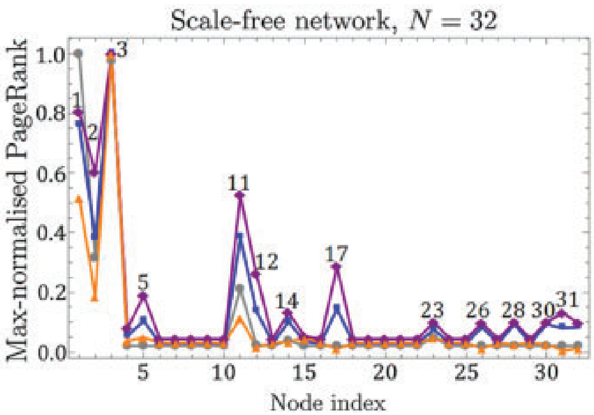
3. Quantum walk based centrality and PageRank

[Tania Loke, Scott Berry, Jingwei Tang, Jeremy Rodriguez, Michael Small, Jingbo Wang]

Characterising the relative importance of nodes in a graph is a key element in network analysis. A ubiquitous application of such centrality measures is Google's PageRank algorithm, whereby the World-Wide Web is considered as a network of webpages connected by hyperlinks between them. By ranking each webpage according to its PageRank centrality, the search engine's results are ordered based on their approximated quality. Since the intuition behind Google's PageRank is a classical "random surfer" crawling the web, a quantum walker traversing the associated network along multiple paths simultaneously is expected to provide an analogous measure of network centrality and PageRanks, but much more efficiently.

We explored such possibilities by employing three different quantum walking schemes: (1) discrete-time coin-based quantum walks involving alternating coin and shift operations, (2) continuous-time open-system quantum walks governed by the Linblad-von Neumann equation, and (3) discrete-time Szegedy quantum walks which quantise classical random walks described by transition matrices. Our results, as shown in Figure 6, demonstrated that the quantum PageRank measures are able to distinguish nodes of importance for outer-planar hierarchical, scale-free, and Erdos–Renyi directed networks, as per classical PageRank (plotted in grey). The quantum measures also pick out more secondary hubs and resolve ranking degeneracy among peripheral nodes.





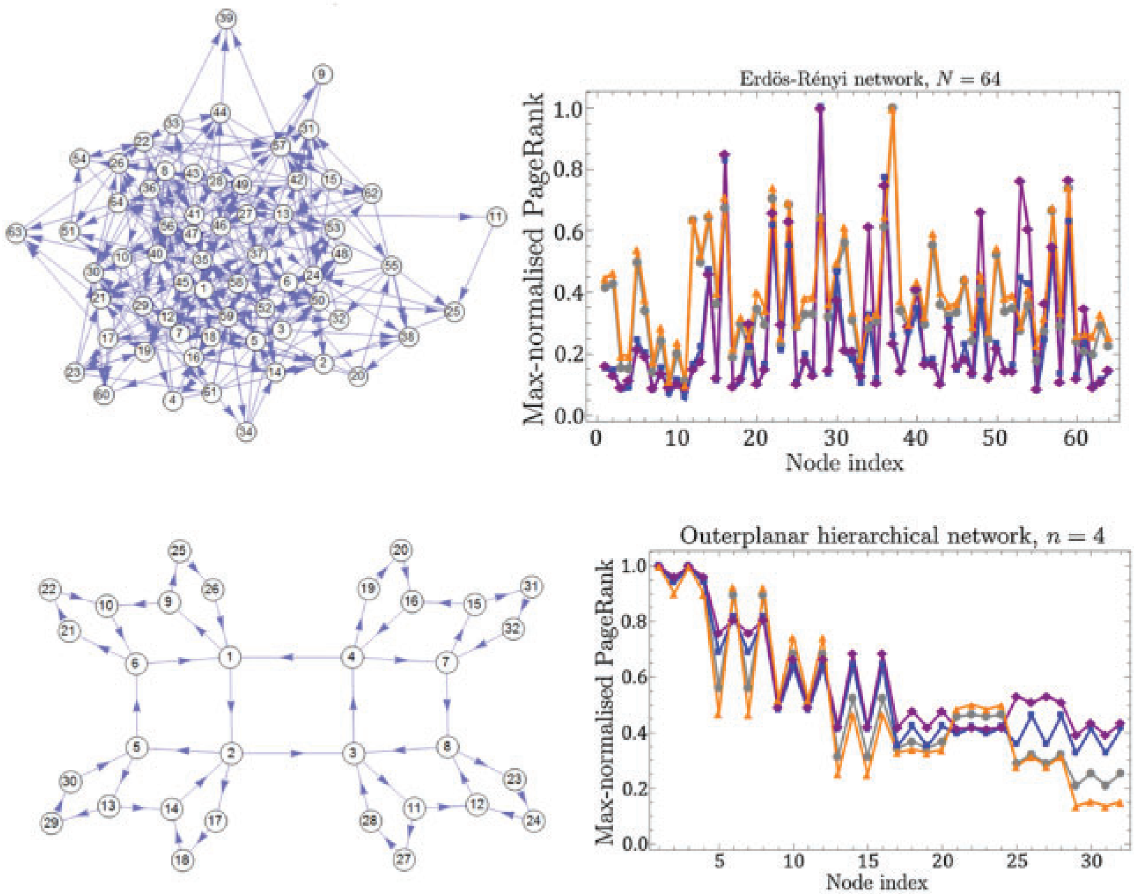


Figure 6. PagerRanks on three different families of graphs by classical method (grey) and quantum methods (other colours)

4. Graph isomorphism and graph similarity via quantum walk

[Callum Schofield, Brendan Douglas, Yuying Li, Jingbo Wang]

Graph isomorphism (GI) is of considerable theoretical importance due to its computational complexity and its relationship to the concepts of *P* vs *NP*. Moreover, a whole set of problems is referred to as GI-complete, such as finding the actual isomorphism mapping, graph isomorphism for directed graphs, graph automorphism, and graph automorphism mapping, which are proven to be Turing equivalent to GI. This means these and many other combinatorial problems can be considered as special cases of the graph isomorphism problem.

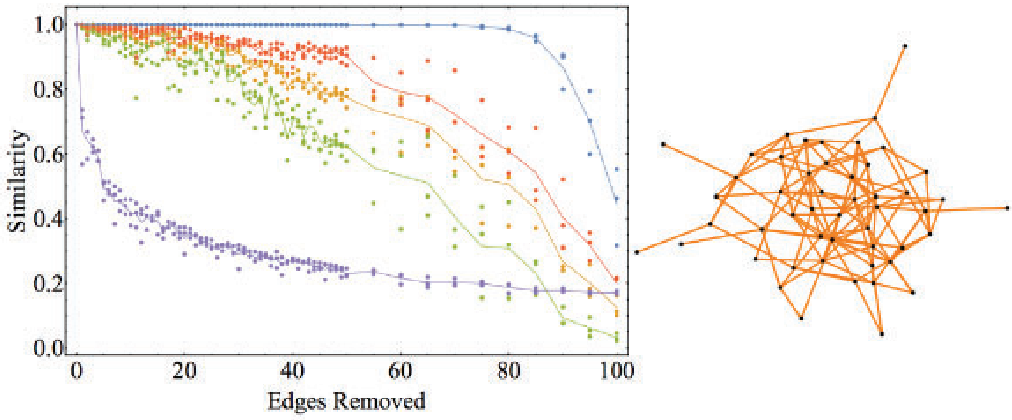
Graph isomorphism is also of considerable importance in solving a wide range of practical problems. For instance, it is often critically important in chemistry and molecular biology that we know if two molecules have topologically the same structure, a generalisation of which is a graph with specified nodes and connectivity. Graph isomorphism identification provides an efficient tool for protein structure comparison and classification. It can also be used for structural analysis of kinematic chains, oil pipelines, roads and subways, scheduling problems, network management, communication systems, pattern recognition, data retrieval and management.

A naive approach to identify graph isomorphism is to generate all n!permutations and test each in turn. The solution then scales in $O(n!)$. The best-known algorithm for general graphs scales with $O(\exp(n^{1/2+O(1)}))$, which is based on a canonical labelling scheme after a set of transformations[18]. An important question arises: can we identify graph isomorphism from the amplitude distributions of quantum walks considering its potentially superior efficiency? For example, quantum walks were proven to provide an exponential algorithmic speedup for traversing a randomised glued-tree graph over classical random walks[19].

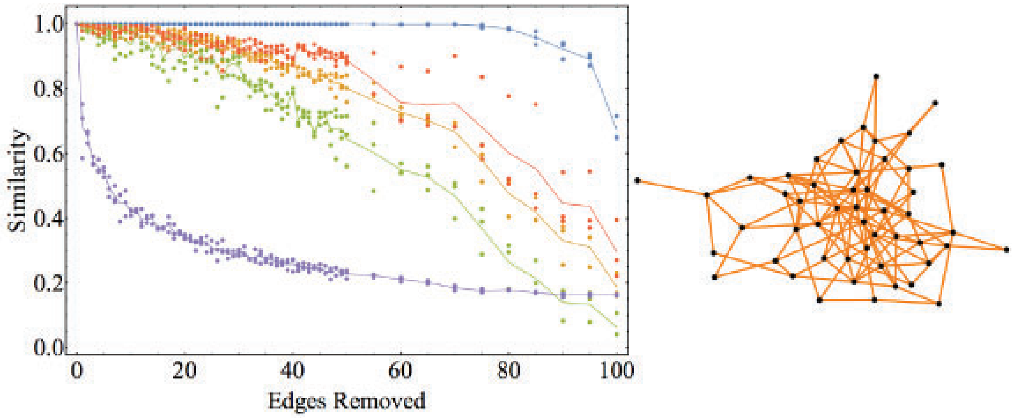
We have carried out extensive tests on using single and multiple particle quantum walks to identify graph isomorphism for trees, planar graphs, projective planes, Eulerian graphs, Hypohamiltonian graphs, vertex critical graphs, edge critical graphs, vertex-transitive graphs, regular graphs, strongly regular graphs, and strongly regular graphs that are also distance-transitive. All graphs in each category with the same parameters are compared pair-wise and this algorithm has successfully identified all isomorphic and non-isomorphic pairs. Particularly worth mentioning is the set of strongly regular graphs with parameters (36,15,6,6), of which all 529,669,878 pairs were tested and distinguished. This quantum-walk-based GI algorithm scales as $O(n^9)$.

Furthermore, this algorithm can also be used to quantitatively compare unlabelled pair of graphs, which is another computationally hard problem. Algorithms for making comparisons between graphs with known labelling typically have linear or polynomial complexity, such as the *DeltaCon* algorithm which has complexity $O(n^2)$[20]. However, in many applications we do not have the luxury of knowing how to match up the nodes and consequently the nodes cannot be labelled. The unlabelled sub-graph matching problem is NP-Complete, and the best known algorithm scales exponentially[21,22]. These methods include the techniques developed to find the maximum common subgraph, such as detecting the maximum clique which has complexity $O((nm)^n)$ and a decision tree based algorithm with $O(2^n n^3)$.

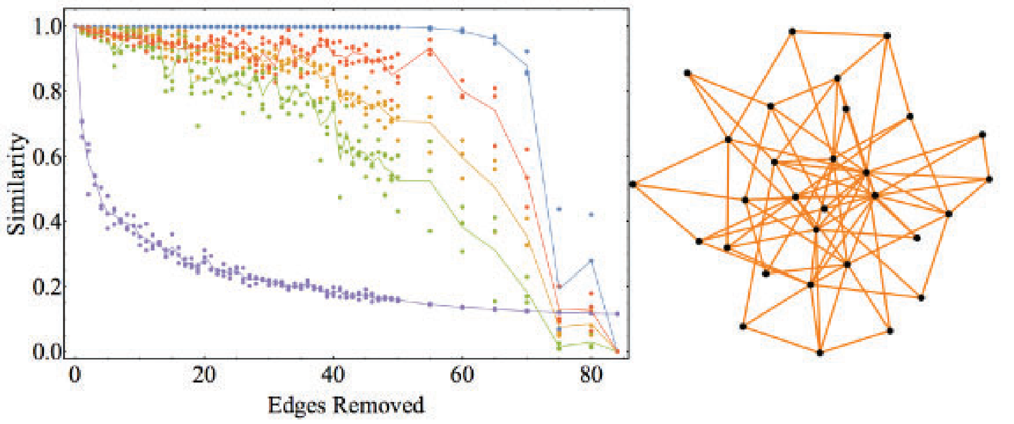
We developed a graph similarity metric based on the quantum-walk-base GI scheme described above that scales as $O(n^9)$. We made comparisons between an input graph and a modified copy of this graph. Changes are made by randomly removing edges from the original graph. The graph similarity score is expected to decrease as edges are removed. This trend is clearly demonstrated in Figure 7 for a variety of input graphs. For each number of edges removed, a statistical ensemble of graphs were generated for comparison. The comparison score for each set is averaged, given by the solid lines in the plots. As each graph is generated with respect to the original graph, we can match the nodes between the graphs. This allows us to compare the quantum algorithm with a classical graph similarity technique, such as DeltaCon (plotted in purple in Figure 7).



(a) Similarity comparison while removing edges in $ER_A(50, 0.1)$, with 118 edges.



(b) Similarity comparison while removing edges in $ER_B(50, 0.1)$, with 118 edges.



(c) Similarity comparison while removing edges in $SF_A(30, 3)$, with 84 edges.

Figure 7. Similarity score after removing edges from an input graph; solid lines denote average score from a statistical ensemble

5. Quantum Approximate Optimisation Algorithm (QAOA)

[Sam Marsh, Jingbo Wang]

Combinatorial optimization is to find an optimal solution over an ordering of a finite discrete set of objects. For many such problems, exhaustive search is not feasible due to the exponentially large number of possible orderings. A well-known combinatorial optimization problem is the traveling salesperson problem, which is NP-hard. The intrinsic parallelism offered by quantum computing provides a simultaneous evaluation of all possible combinations and permutations, which may lead to powerful quantum algorithms capable of solving classically intractable problems. Below is an illustration of a hybrid quantum-classical variational method for finding the optimal parameters β and γ which would then provide the optimal solution. The dashed region is the quantum component.

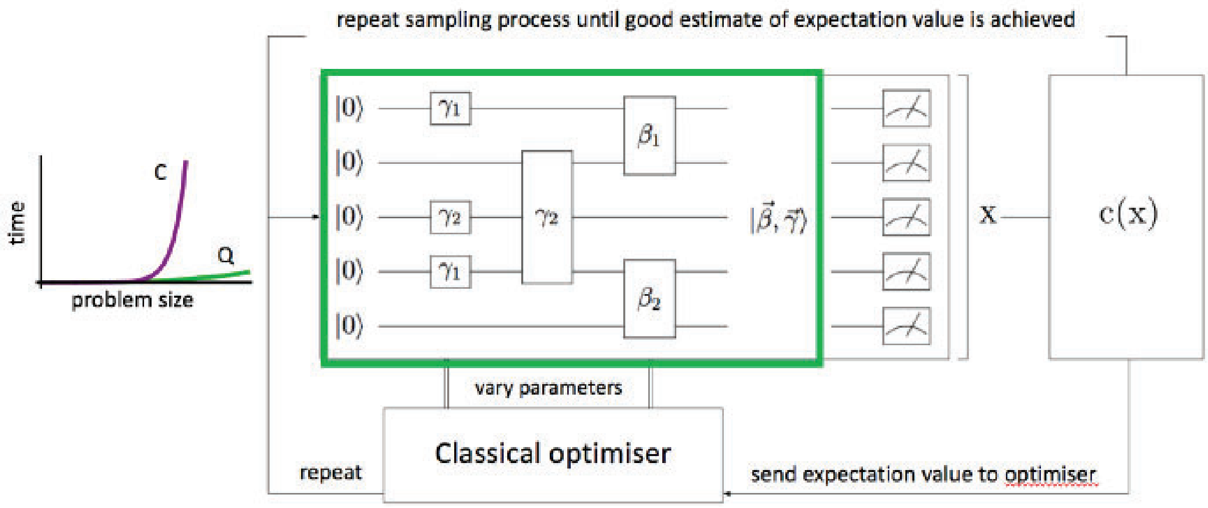


Figure 8. Illustration of the hybrid quantum-classical variational method for finding the optimal QAOA parameters β and γ

In this work, we developed an algorithm for finding approximate solutions to NP optimisation problems with polynomially bounded measure (NPO PB) using QAOA. We shown that the constraints involved with NP optimisation problems can be incorporated into the QAOA state evolution. This is done by interpreting the state evolution as a series of quantum walks, and then restricting the quantum walks to the region of feasible solutions. We demonstrated that the recent concept of a hybrid quantum-classical variational algorithm suits for this purpose, and is efficient for NP optimisation problems that have polynomially bounded measure. This algorithm provided better approximate quality than the known classical method when applied to the minimum vertex cover problem on cycle graphs, as shown in Figure 9.

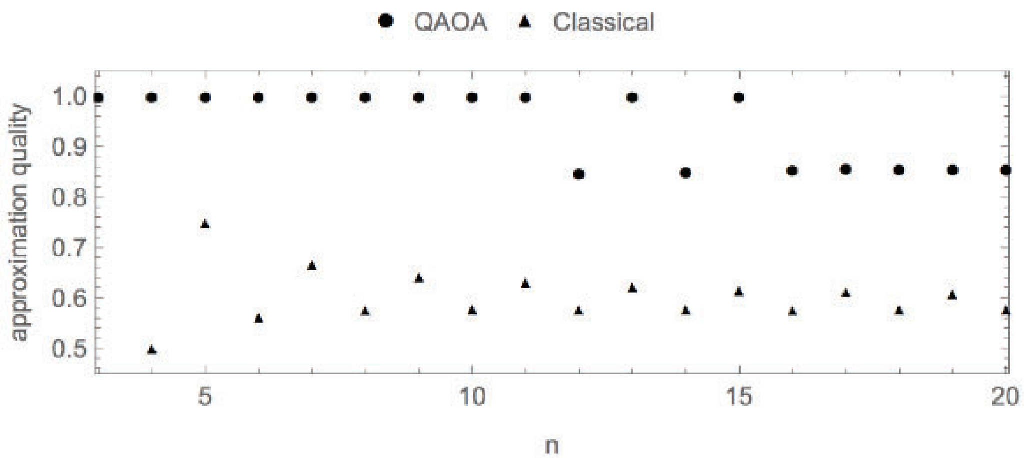


Figure 9. Performance of quantum algorithm on cycle graphs, with comparison to the classical 2-approximation algorithm.

Conclusion

Consider wandering, blindly, in a land of perplexing objects and barriers. We bump into things and bounce off, and we get to learn a small part of that land at each bounce. This is how we perceive the classical world, which we experience on a daily basis. In a quantum world, we do not simply 'bounce' off objects or barriers one after another. In this strange quantum world, we can simultaneously bounce and traverse the whole territory in which we wander. Part of us is everywhere at once and so we can explore everything all at the same time. Knowledge of this quantum wonderland can be used to speed up computing, crack codes, walk through mazes, and solve otherwise intractable mathematical problems. Exploring this quantum wonderland offers exciting prospects for science and practical applications.

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Curtin University

Curtin University is truly an International university with campuses in Perth, Kalgoorlie, Malaysia, Singapore, Dubai and Mauritius. Curtin has risen significantly in the prestigious Academic Ranking of World Universities Curtin in recent times and was ranked in the top one per cent of universities worldwide in 2017. Curtin is also WA's largest and most multicultural university, welcoming more than 52,000 students, around a third of whom come from a country other than Australia.

Curtin's computing courses cover a range of areas essential to the growing IT industry. In addition to training, Curtin also has extensive research expertise in areas of critical importance to the region including minerals and energy, the prevention and management of chronic health conditions, sustainable development, space & defence related research and computational science and is firmly focused on solving real-world problems.

Curtin leads the recently established ARC Industrial Transformation Training Centre for Transforming Maintenance through Data Science, which is a collaborative industry embedded research centre involving significant investments from three major mining operators. Curtin is also the host for the recently announced WA Data Science Innovation Hub, which will connect government, industry, researchers and SMEs to promote and facilitate transformation of business, government and the community through increasing Data Science capability.

Underpinning Curtin's high impact research lies strong partnerships with industry, business and government, which result in outcomes that greatly benefit the broader community locally, nationally and globally. Computation now fundamentally underpins the majority of internationally competitive research across all fields and disciplines. As the demand for computational skills has grown, so too has the need for a dedicated institute that can support the research community.

The Curtin Institute for Computation (CIC) was established to meet this increasing demand for computational modelling, data analytics, and visualisation. The CIC initiates and fosters collaborative, interdisciplinary research and education programs with researchers. The CIC, led by Professor Andrew Rohl, a previous Dennis Moore orator, builds on the major investments made by the University and its partners in the Square Kilometre Array project and the Pawsey Supercomputing Centre, and will ensure the computation and data analytics capability being built in WA is effectively deployed.

The recently rebranded Innovation Central Perth (ICP) at Curtin's Bentley campus is a partnership between Cisco, Curtin University, Woodside and Data 61. ICP is a state-of-the-art collaborative community developing ingenious solutions for cloud, analytics and Internet of Things (IoT) network platforms. By creating an environment that fosters collaboration, small-to-medium enterprises, industry experts and researchers can develop original and inventive solutions through rapid prototyping and proofs-of-concept to solve real business problems.

Curtin is proud to partner with forward looking organisations and is embracing the next digital wave of disruption. Curtin is committed to its vision to Make tomorrow better.

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University of Western Australia

The University of Western Australia is a world-top 100 university and is the only Western Australian university to belong to the Group of Eight – a coalition of the best research universities in Australia.

One of UWA's founding faculties, The Faculty of Engineering and Mathematical Sciences has a rich heritage of over 100 years of achievement and an international reputation for excellent research. As a hub for world leading technology, computing and engineering expertise, our researchers are currently working to solve some of the key challenges of today and tomorrow.

The Department of Computer Science and Software Engineering was the State's first Computer Science department and has produced many successful graduates with sought after expertise. Attracting the highest quality of students, the school has produced three World Final teams for the ACM Intercollegiate Programming Competition in multiple years.

The department offers the first Master of Data Science in Western Australia and the sought after Computer Science major. Postgraduate students can undertake the accredited Master of Professional Engineering: Software Engineering specialisation, or pursue the Master of Information Technology, or the highly sought after Master of Data Science. There is also the opportunity to pursue PhD research in image processing, data science, wireless networks, adaptive systems, formal methods and software engineering.

This is an exciting time for the Department of Computer Science and Software Engineering as its research capability strengthens to bring the school to the forefront of cutting edge of modern technology. The department has a growing number of researchers dedicated to interdisciplinary research including Virtual Reality, Augmented Reality, Vision and Image Processing, Data Analytics, Artificial Intelligence, Modelling, Logic and Networks.

Master of Data Science at UWA

UWA's Master of Data Science is ideal for students and professionals who wish to gain the skills to tackle big data challenges and compete in the digital realm. The Master of Data Science provides students with the knowledge and skills to understand and apply appropriate analytical methodologies to transform the way an organisation achieves its objectives, to deal effectively with large data management tasks, to master the statistical and machine learning foundations on which data analytics is built, and to evaluate and communicate the effectiveness of new technologies.

Master of Professional Engineering at UWA

Specialise in the Software Engineering discipline in UWA's Master of Professional Engineering and become a professionally accredited engineer who is highly sought after by industry. This course unlocks a wide range of career opportunities as you will be very employable both in engineering sectors and in industries that require a high degree of numeracy and problem-solving skills, including finance and consulting.

Find out more at **www.ecm.uwa.edu.au**

SILVER SPONSOR

Murdoch University

The School of Engineering and Information Technology at Murdoch University recognises that for ICT graduates to succeed, they require a skill set that integrates technical, organisational and communication skills.

The School has established innovative, dynamic and industry-relevant ICT curricula. It enjoys the benefits of leading-edge and word-class research, and strives, in collaboration with its industry partners, to design and deliver world class courses.

Information Technology students at Murdoch University, will enjoy state-of-the-art teaching facilities, including the newly established IT Innovation Hub, a highly flexible hands-on learning environment, offering specialised High-Performance Computing (HPC) capabilities to keep pace with the IT industry and with the developing trends in computer science, networking and network security, and cyber security.

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Dennis Moore AM MA *(Cantab)* FACS

Dennis Moore was born in NSW in 1937. He was educated on scholarships at The King's School, Parramatta where he was captain and dux of the school, and at Queens' College Cambridge where he graduated in 1958 in mathematics.

After a period with commerce and industry in computing and operations research in NSW, he pioneered computing in Western Australia, installing the first computer at UWA in 1962. He introduced WA's first computing qualification – the DipNAAC – at UWA. In 1965, he was responsible for the purchase and installation of the DEC PDP-6. This was the world's first commercial installation of a time-shared computer and Australia's first high precision graphics device.

He was foundation president of the WA Computer Society, which later merged with the Australian Computer Society, becoming the first WA Branch Chairman. He was Director of the Western Australian Regional Computing Centre in the sixties and seventies. This provided computing services to CSIRO and State Government Departments as well as the University.

He was executive director of Government Computing for WA from 1978 to 1984. During this period he promoted the development of inter-departmental systems and was closely associated with the development of the WA Land Information System and the WA Technology Park. This was followed by a two year stint managing a computer company in Malaysia, including a consultancy to the Sarawak Government.

He then undertook research in RAN DATA, an encryption company which he had helped establish, and was appointed foundation Head of School of Computing at Curtin University of Technology in 1987. From 1998 to 2002 he was Director of Academic Planning at Curtin. From 1995 to 1999 he was Chair of the State Government's Information Policy Council.

Dennis Moore was elected a Fellow of the Australian Computer Society in 1970 and was made a Member of the Order of Australia for services to Information Technology in 1997. He retired in 2002 and was made an Honorary Life Member of the ACS in 2014.

A young Dennis Moore demonstrates the IBM 1620 at UWA in 1967.
Photo by Wayne McKenzie, WA Newspapers.

Australia's Digital Pulse 2018

The ACS Australia's Digital Pulse 2018 report was launched in Perth on Thursday 27 September by Hon. Michaelia Cash, Minister for Small and Family Business, Skills and Vocational Education and Deloitte Partner, Giles Nunis, who were joined by ACS President Yohan Ramasundara and ACS CEO, Andrew Johnson.

Prepared by Deloitte Access Economics, ACS Australia's Digital Pulse 2018 investigates the digital policy environment in Australia and looks at the potential levers to encourage businesses to invest in new technologies, innovation and skills development. It reveals how we can accelerate digitally led economic growth and improve Australia's overall international ICT competitiveness.

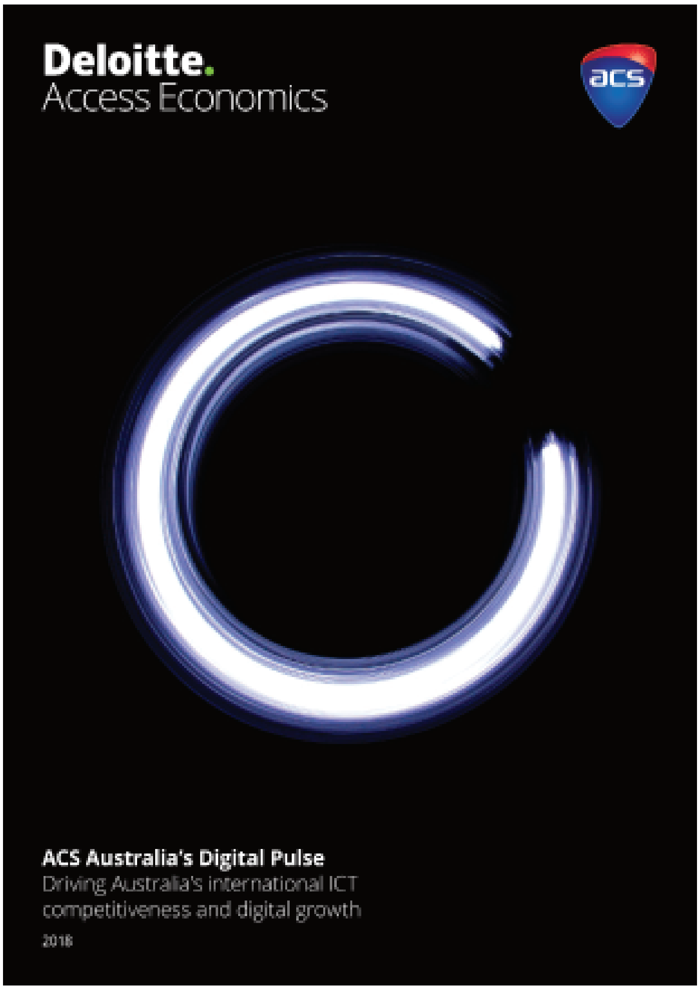
The report investigates Australia's international competitiveness in ICT, finding that Australia is in the middle of the pack without any movement over the last five years. It highlights that Australia's ICT workforce grew from 640,800 workers in 2016 to 663,100 workers in 2017, an increase of 3.5%.

The report also forecasts demand for ICT workers is set to grow with the Australian economy requiring an additional 100,000 workers (to 758,700) by 2023.

According to ACS President Yohan Ramasundara, "The demand for digital skills in our economy is exploding, the growth of artificial intelligence, automation and the internet of things is driving significant disruption across all industries, and highly trained ICT professionals are in more demand than ever before."

"If we want to be competitive in the world economy, we need to invigorate the education and training sectors to increase Australia's ICT talent pool.", he concluded.

To read the full report visit https://www.acs.org.au/content/dam/acs/acs-publications/aadp2018.pdf

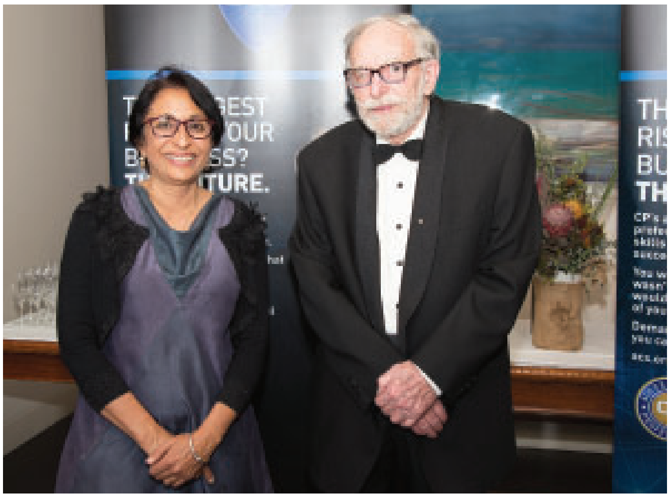


Dennis Moore with ACS Distinguished Orators

In 2012 with Professor Andrew Rohl.

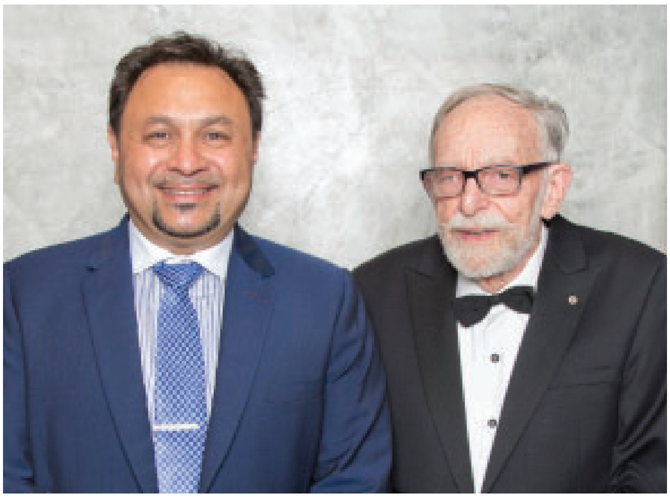
In 2013 with Professor Ian Reid.

In 2014 with Professor Craig Valli



In 2015 with Professor Svetha Venkatesh.

In 2016 with Dr Adrian Boeing



In 2017 with Professor Matthew Bellgard