AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

Research Report

ANNUAL
2018 –19

AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

ABOUT **AMSI**

AMSI is the collaborative enterprise of Australia's mathematical sciences. It exists to give independence to our disciplines and provide infrastructure so that we can take initiatives to the national and international stage.

These measures fall largely into three classes—research and higher education, school education and engagement with the industrial and commercial world. AMSI has built a record of achievement in these areas and is recognised by government and industry as a leading provider of services, activities and strategic initiatives.

The common aim we share with our partners is the radical improvement of levels of mathematical capacity and facility in the Australian community. It is AMSI's ability to pull together skills and experience at the highest levels across the spectrum of the mathematical sciences that underlies our impact.

We acknowledge the considerable support of both the Victorian and Commonwealth governments in the establishment of AMSI and some of its programs and we invite potential partners to join us in invigorating Australia's mathematical sciences in the 21st century.

AMSI MEMBERS

Full Members

La Trobe University
Monash University
Queensland University of Technology
RMIT University
The Australian National University
The University of Melbourne
The University of Newcastle
The University of Queensland
The University of Sydney
The University of Western Australia
The University of Adelaide
The University of New South Wales

AMSI and its members acknowledge the significant contribution of The University of Melbourne as our Lead Agent and host

Member list as of June 2019

Associate Members

Curtin University of Technology
Deakin University
Edith Cowan University
Federation University Australia
Flinders University
James Cook University
Macquarie University
Murdoch University
Swinburne University of Technology
University of New England
University of South Australia
University of Southern Queensland
University of Tasmania
University of Technology Sydney
University of Wollongong
Victoria University
Western Sydney University

Government Agencies

Australian Bureau of Statistics
Bureau of Meteorology
CSIRO
Defence Science & Technology Group
Reserve Bank of Australia

Societies

Australian Bioinformatics & Computational Biology Society (ABACBS)
Australian & New Zealand Industrial & Applied Mathematics (ANZIAM)
Australian Mathematical Society (AustMS)
Australian Mathematics Trust (AMT)
Mathematics Education Research Group of Australasia (MERGA)
Statistical Society of Australia (SSA)

Funding bodies and sponsors

Department of Education and Training (Australian Government)
BHP Foundation (as part of the Choose Maths project)

Cover image: *Torus Knot Fibration Visualization* image generated from code created by Jesse Bettencourt (jessebett.com)

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Design and layout: Michael Shaw

Disclaimer

Important

The following research workshop and event reports are not intended to be a comprehensive overview of research activities and events within the Australian mathematical sciences. These reports are developed in collaboration with event partners and may include views or recommendations from third parties that do not necessarily reflect those of the Australian Mathematical Sciences Institute. Links to event websites and contact information are not intended as endorsements of views or information but are provided for the convenience of the reader.

CHAMPIONING AUSTRALIA'S **MATHEMATICAL SCIENCES**

PHOTO: DREW ECHBERG

As the national champion of Australia's mathematical sciences, our membership across 43 Australian universities, scientific agencies and societies remains central to AMSI's mission and a lead focus of the work we do.

This year, over **1170** participants and **150** speakers attended the Institute's **15** workshops and five flagship training events spanning a wide range of pure and applied mathematics and statistics. Deepening global ties, almost **40%** of attendees were international. We also co-sponsored the AMSI-SSA Lecture Tour and the Mahler Lecture Tour.

Australia faces many challenges in building a workforce for the future which can compete to ensure the nation's prosperity and well-being. Understanding and skill in mathematical sciences are key tools for that workforce. Yet Australia lags well behind other countries in nurturing the talent of our school and tertiary students.

AMSI's flagship events in higher education and research secure our workforce by providing important opportunities for students and researchers to experience the best in the country, a best which compares well globally. Our events continue to attract students from across Australia. They are a powerful opportunity to build connections, knowledge, understanding and skills. The 2018-19 Vacation Research Scholarship program set records for enrolments.

Mathematical sciences in Australia have been diminished by the under-representation of women. To promote greater balance, AMSI has been actively encouraging women to attend and speak at AMSI-sponsored workshops, as well as to participate in its training programs and internships. I'm pleased to report that these efforts are returning positive results, particularly in the workshops program, where 27 per cent of participants and more than 30 per cent of speakers were women during 2018-2019.

Travel funding through AMSI's Choose Maths project has been instrumental in supporting female students and ECRs to attend our flagship training schools, with 57 grants awarded during the reporting period. As the program wraps up, we'd like to acknowledge the contribution of the BHP Foundation in supporting women in the mathematical sciences to further their careers by participating in these training events.

Our PhD Internship program APR.Intern continues to expand, placing 126 interns from 19 disciplines with 80 industry partners across 12 industry sectors during the year from July 2018 – June 2019. This was an increase of 50 per cent over the previous year.

I would like to thank the members of our Scientific Advisory Committee (SAC) and Research and Higher Education Committee (RHEC) for their leadership, diligence and support throughout the year. In particular, thank you to the former and current RHEC chairs, Markus Hegland and Mat Simpson, as well as the SAC chair Phil Broadbridge for their guidance.

I'd also like to thank the hardworking RHE team at AMSI, led by Chloe Pearse and including Angela Coughlin, Anna Muscara and Francesca Hoban Ryan, for the smooth delivery of these long-running AMSI programs.

Finally I would like to acknowledge the continuing support of our major funding partner, the Australian Government's Department of Education and Training, for our Research and Higher Education programs.

Professor Tim Brown
Director
November 2019

AMSI Milestones

2002

AMSI established through $1m grant from Victorian government's Science, Technology and Innovation infrastructure grants program

AMSI Winter and Summer Schools established

2003

AMSI is collaborating partner and a significant influence in the establishment of the Centre of Excellence for Mathematics & Statistics of Complex Systems (MASCOS). Out of an Australian government grant of $10.9m, $2.2m jointly administered by AMSI and MASCOS

2004

The International Centre of Excellence for Education in Mathematics (ICE-EM) is established with $7.8m from the Department of Education, Science and Training providing funding for AMSI's Schools and Higher Education programs

2005

$750,000 funding provided through ICE-EM to establish Access Grid Rooms in 11 member universities

100th Vacation Research Scholarship awarded

2006

AMSI supports the National Strategic Review of the Mathematical Sciences in Australia (Australian Academy of Science)

Annual AMSI Lecture Tour established

2007

AMSI awarded $2m Collaboration and Structural Reform grant to fund flagship programs in Higher Education, industry collaboration though workshops and the establishment of the AMSI Intern program

2008

AMSI sponsors 100th Scientific Workshop

2009

AMSI awarded $2m grant from the Department of Education, Employment and Workplace Relations for The Improving Mathematics in Schools (TIMES) project

2010

AMSI Intern program is expanded through $1.7m government grant

Group photo at AMSI Connect

PHOTO: ACARA PHOTOGRAPHY

2011

Research Training programs expanded through $2m government grant

2012

AMSI sponsors 150th scientific workshop

International Year of Mathematics of Planet Earth led by AMSI in Australia

2013

AMSI Intern program expanded through the establishment of a $6.7 co-investment partnership with eight NSW and Victorian member universities

2014

500th Vacation Research Scholarship awarded

10th Annual AMSI Lecture Tour is held

AMSI's Access Grid Network is replaced by Advanced Collaborative Environment (ACE)

Choose Maths launches with $22 million from BHP Foundation

2015

AMSI partners with AustMS to launch MathsFest, a three-week long multi-event including the AustMS conference flanked by two international workshops

AMSI awarded $2m government grant to expand research training programs

AMSI sponsors 200th scientific workshop

The Australian Academy of Sciences launches *The Mathematical Sciences in Australia, A Vision for 2025*, with AMSI's support

2016

AMSI Optimise launches in Melbourne

Australian Government awards $28 million to fund AMSI Intern program expansion

AMSI Intern relaunches as APR.Intern

AMSI places 200th intern

15th AMSI Summer School held

2017

AMSI sponsors 250th scientific workshop

AMSI places 300th intern

AMSI Director Prof. Geoff Prince retires

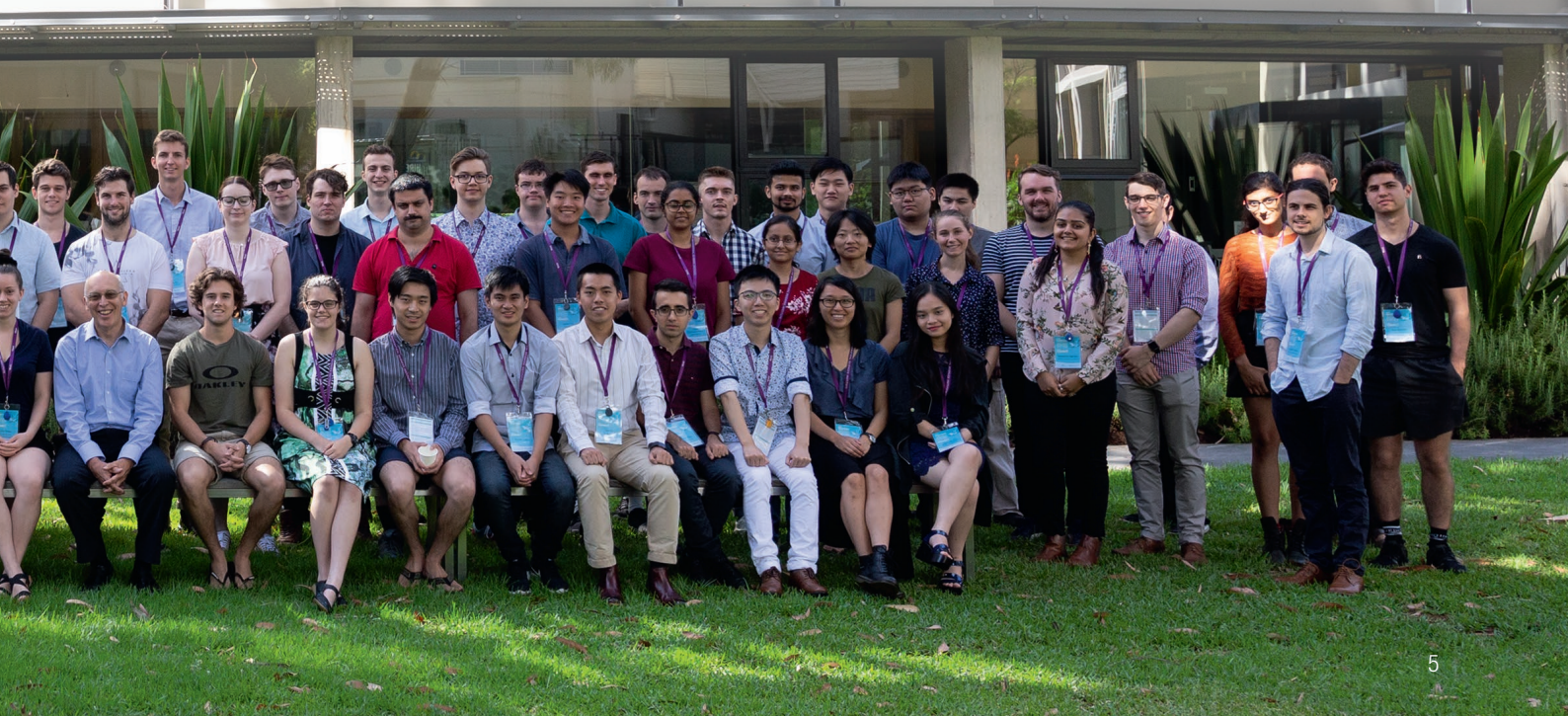
2018

Prof. Tim Brown joined AMSI as Director

AMSI places 400th intern

1169 mathematicians and statisticians attend AMSI-sponsored events in 2018/19

2019



ABOUT **AMSI RESEARCH**

AMSI Research has been supporting the advancement and communication of fundamental and applied mathematical sciences knowledge for 15 years.

Building critical links between universities, government agencies and industry, our programs foster cross-disciplinary collaboration and industry engagement to grow mathematical sciences capability and equip Australia as a STEM leader for the future.

Our research training schools, scholarships and graduate courses have enhanced learning outcomes and networking opportunities for students and early career researchers, helping grow the supply of emerging mathematical talent to support public and private sector innovation.

Research Committees

Reporting directly to the AMSI Board, the Scientific Advisory and Research & Higher Education committees are responsible for governance of all AMSI Research programs.

Research and Higher Education Committee (RHEC) 2018–2019

The RHEC monitors mathematical sciences research across Australia and provides strategic advice to the AMSI Board and Executive.

Prof. Markus Hegland, Mathematical Sciences Institute , The Australian National University (Chair until 14 December 2018)
Prof. Mat Simpson, Queensland University of Technology (Chair, from 14 December 2018)
Dr Nicola Armstrong, Murdoch University
Prof. Nigel Bean, The University of Adelaide (from July 2017)
Prof. Philip Broadbridge, La Trobe University (from March 2019)
Tom Dyer, University of Wollongong (student representative) (until December 2018)
Prof. Andreas Ernst, Monash University
Prof. Anthony Henderson, The University of Sydney (until December 2018)
Dr Phil Isaac, The University of Queensland
Assoc. Prof. Inge Koch, Executive Director, Choose Maths (until January 2019)
Chloe Pearse, AMSI Research and Higher Education Program Manager
Prof. Geoff Prince, AMSI Director (until 31 December 2018)
Prof. Aidan Sims, University of Wollongong
Prof. Scott Sisson, The University of New South Wales
Prof. Kate Smith-Miles, The University of Melbourne (until December 2018)
Prof. Ngamta Thamwattana, The University of Newcastle (from March 2019)
Maaike Wienk, ACE Network, AMSI (until July 2018)

Scientific Advisory Committee (SAC) 2018–2019

The SAC provides scientific advice for AMSI Research activities and reviews, as well as AMSI-funded scientific workshops.

Prof. Philip Broadbridge, La Trobe University (Chair)
Prof. Ben Andrews, The Australian National University (until 31 December 2018)
Prof. Andrew Barbour, University of Zurich
Prof. Tim Brown, AMSI Director (from January 2019)
Prof. Darren Crowdy, Imperial College London
Prof. Ezra Getzler, Northwestern University
Prof. Elizabeth Mansfield, University of Kent
Prof. Mary Myerscough, The University of Sydney
Prof. Geoff Prince, AMSI Director (until 31 December 2018)
Prof. Terry Tao, UCLA; Clay Mathematics Institute, USA
Assoc. Prof. Lesley Ward, University of South Australia
Prof. Ole Warnaar, The University of Queensland

Standing Committees

AMSI's Research and Higher Education programs are supported by a number of standing committees including:

ACE Network Standing Committee
BioInfoSummer Standing Committee
Optimise Standing Committee
Summer School Standing Committee
Vacation Research Scholarships Academic Panel
Winter School Standing Committee

Research and Higher Education Staff 2018-2019

Chloe Pearse, AMSI Research and Higher Education Program Manager
Angela Coughlin, Project Coordinator
Anna Muscara, Project Coordinator
Francesca Hoban Ryan, Administrative Assistant
Liam Williamson, Administration Support

CONTENTS

Research Workshops 1

Participants at the Applications of Nonlinear Diffusion Equations 2019 workshop

PHOTO: SUPPLIED

1 RESEARCH WORKSHOPS

AMSI's internationally recognised program of sponsored scientific workshops nurtures the collaboration and knowledge-sharing critical to mathematical discovery. The events attract participants at every level, from students to leading researchers and from academia to industry and government.

In 2018–19 AMSI sponsored **15 workshops and conferences** through the Scientific Workshops Program

AMSI-sponsored workshops and conferences attracted **666 participants** from academia, industry and government. This total was comprised of:

47% International visitors
27% Female mathematical scientists
16% Postgraduate students
19% Early career researchers (ECRs)

AMSI sponsored **59 speakers**
31% of sponsored speakers were **female**
88% of sponsored speakers were **international**

30 AMSI Travel Grants were awarded to **16 students, 5 early career researchers** and **5 academics** to attend research workshops (several individuals received multiple grants)

1.01 VIRTUAL TISSUES: PROGRESS AND CHALLENGES IN MULTICELLULAR SYSTEMS BIOLOGY

MATRIX, Creswick, 1–7 July 2018

Australia is emerging as a hub for the development of virtual multicellular models. Attended by a diverse community of global and national researchers, this workshop aimed to identify the main challenges and establish research directions using multicellular approaches.

With experimental techniques in biomedicine continuing to advance in sophistication, new datasets spanning bio-visualisation to detailed cellular and molecular information are being generated at an accelerating rate. Tools to analyse these data are, however, lagging behind. At the same time, computational power is becoming ever cheaper. This has led to the increased adoption of computational models of multicellular tissues and organs, where cells are considered as discrete entities, which interact both spatially and over time. To expedite data integration and model simulation, state-of-the-art mathematical, numerical and computational analyses are required. A significant challenge in the field is that there are many different ways to construct models of this type, and as a result, it's very difficult to compare them and/or establish what behaviours are generic and what behaviours are specific to a particular model representation.

As part of MATRIX's *Month of Mathematical Biology,* the *Virtual Tissues* workshop brought together world-leading mathematical modellers, systems biologists, experimentalists and clinicians to discuss the future of multicellular modelling in biology and its application to drug discovery and improved therapies. A set of 'grand challenges' for the future use of multicellular modelling was defined and investigated through the five-day workshop promoting multicellular modelling approaches, especially those being developed and applied in Australia, as an important and growing field of scientific research.

The focus of the workshop on grand challenges in multicellular modelling and the resulting collaborative position paper and model repository, which are still being worked on, will help establish Australia as a hub for this emerging interdisciplinary field.

Featuring both keynote and contributed talks from experimentalists and theoreticians along with extensive discussion sessions, each day was on a particular theme (systems biology, cancer and development) with similar talks grouped together. Topics included multicellular modelling of tissues, the integration of experimental data, and modelling and reproducibility of computational simulations. Speaker highlights included:

- James Glazier gave an overview of his open-source Virtual Tissue model building environment CompuCell3D, which was developed using Python and XML to simplify the construction of sophisticated virtual tissue models, facilitating initial model development and submodel reuse and extension.
- Sandy Anderson, from the Moffitt Cancer Center, discussed the eco-evolutionary view of cancer and tumour metabolism, providing a sound biological platform for model development.
- Paul Macklin discussed the challenges of building a virtual tissue laboratory using multiscale computational models to help detangle, understand and control complex biological systems like those found in cancer. He noted that building such systems is difficult, particularly while maintaining cross-platform compatibility on Linux, OSX, Windows and other architectures.
- Melissa Knothe-Tate presented the computational modelling approach used by her mechanobiology team at the University of New South Wales to understand mechanisms underpinning the response of biological tissues to stimuli, and potential applications in engineering and manufacturing.
- Guillermo Gomez, from the Centre for Cancer Biology in Adelaide, gave a talk about using computational modelling in combination with experiments to develop an understanding of the process of cell extrusion in the epithelium.

WORKSHOP PARTICIPATION

26	attendees
6	postgraduate students
6	ECRs
6	women
11	international participants

The high quality of talks at the workshop was complemented by both small and large group discussion sessions, encouraging participants to work together on interdisciplinary problems.

The main outcomes of the workshop were two projects, a position paper on model specification in multicellular modelling and a repository of benchmark multicellular problems along with a paper to release the repository. Work continues on both the papers and repositories.

Note: *AMSI sponsored this workshop, held as part of a longer Month of Mathematical Biology program at MATRIX.*

"I had some good discussions with various people, and it was interesting to get some insight into some of the cool new approaches / challenges facing the modelling community."

Dr Kynan Lawlor, Murdoch Children's Research Institute

Organisers

Prof. Helen Byrne, University of Oxford, UK
Prof. Edmund Crampin, The University of Melbourne
Dr Alexander Fletcher, Sheffield University, UK
Dr Edward Green, The University of Adelaide
Dr James Osborne, The University of Melbourne

Special Presenters

Prof. James Glazier, Indiana University, USA
Research Interests: chaos in fluids, biophysics, turbulence, bioinformatics
Dr Sandy Anderson, Moffitt Cancer Center, Florida, USA
Research Interests: integrated mathematical oncology, diagnostic imaging and interventional radiology, radiation oncology, cancer biology and evolution
Assoc. Prof. Paul Macklin, Indiana University, USA
Research Interests: bioinformatics and computational biology, bioengineering, multicellular systems biology
Prof. Melissa Knothe-Tate, The University of New South Wales
Research Interests: multiscale, experimental and computational mechanobiology, regenerative medicine, next generation implants and advanced materials
Dr Guillermo Gomez, Centre for Cancer Biology, University of South Australia
Research Interests: cancer biology, mechanobiology, image analysis

MathSciNet Classification

92 Biology and Other Natural Sciences 08
92 Biology and Other Natural Sciences C15
92 Biology and Other Natural Sciences D37
92 Biology and Other Natural Sciences C42

Web Links

matrix-inst.org.au/events/virtual-tissues-progress-and-challenges-in-multicellular-systems-biology/

Other Sponsors

AustMS, Computational Biology Research Initiative (The University of Melbourne), MATRIX, The University of Melbourne

Key Contact

Dr James Osborne, The University of Melbourne, jmosborne@unimelb.edu.au

Participants at the Virtual Tissues: Progress and Challenges in Multicellular Systems Biology workshop at MATRIX, Creswick PHOTO: SUPPLIED

1.02 AMSI–CARMA WORKSHOP ON MATHEMATICAL THINKING

Newcastle, 14–16 November 2018

Bringing together an unusually diverse group of international and Australian experts from a range of disciplines, this workshop explored mathematical thinking and its application to mathematics education, critical thinking, neuroscience, machine learning and more, from different perspectives.

Mathematics underpins much of the scientific and technological progress of modernity, and as such, mathematical thinking is one of the most important tools available to humanity. On the one hand, it deserves to be studied in its own right, since any improvements would be vastly valuable, and insights from mathematical thinking are applied to many other domains. On the other hand, many people remain woefully underinformed, and thus unappreciative of the power of mathematical thinking, which is dangerous since the research is ultimately funded by the public and the next generation of researchers needs to be recruited and effectively educated.

The primary goal of this workshop was to bring together international experts in a diverse range of areas on Australian soil to discuss and share insights on mathematical thinking from as wide a range of viewpoints as possible. This exceeded expectations and participants, both domestic and international, came away with broader horizons and plenty of new ideas.

The secondary goal was public outreach. Keith Devlin gave a presentation at a local school. Furthermore, Erik Stern and Rachel Bachman presented a workshop of mathematics and dance at another local school, as well as a public lecture. There was also some industry participation in the form of MapleSoft as well as Lynz Education. A WIMSIG lunch was also held, with several women in mathematics recounting their experiences.

A key outcome of the workshop was the establishment of new linkages between very diverse research areas, with the potential for future collaboration, for example between the Critical Thinking Project at UQ and various experts in mathematics education, as well as between the neuroscience group at UNSW and various pure mathematicians concerning mathematical visualisation ability. One of the highlights was the dance workshop of Erik Stern and Rachel Bachman, which opened participants' eyes to how mathematical ideas can be effectively conveyed via participation in dance. This is directly relevant to mathematics education, but also broadened everybody's horizons.

Another highlight was the research presented by Joel Pearson on aphantasia—the inability to produce mental images—and the counter-intuitive result that mathematicians with this condition can nevertheless be successful even in highly visual areas like geometry. Brailey Sims, a successful geometer and functional analyst with aphantasia, backed this up by describing his personal experience.

The workshop concluded with a well-attended and lively discussion session and plans to organise a similar workshop on the theme "Computer-Aided Proof" in 2019.

WORKSHOP PARTICIPATION

33	attendees
6	postgraduate students
3	ECRs
13	women
7	international participants

Organisers

Prof. Florian Breuer, The University of Newcastle (chair)
Prof. Ljiljana Brankovic, The University of Newcastle
Dr Judy-anne Osborn, The University of Newcastle
Dr Timothy Trudgian, UNSW Canberra

Special Presenters

Dr Rachel Bachman, Weber State University, USA
Research Interests: mathematics education, mathematics and dance, historical mathematical representation
Dr Keith Devlin, Stanford University, USA
Research Interests: mathematics education and communication, information systems for intelligence analysis, theory of information, models of reasoning, mathematical cognition
Dr Peter Ellerton, University of Queensland
Research Interests: development of teacher pedagogical expertise in teaching for thinking, public understanding of science, group and individual decision-making, critical thinking in politics
Prof. Veselin Jungic,
Simon Fraser University, Canada
Research Interests: Ramsey theory, mathematics education
Prof. Rafael Núñez, University of California, San Diego, USA
Research Interests: mathematical cognition, the empirical study of spontaneous gestures, cognitive linguistics, psychological experiments, neuroimaging, and field research with isolated groups
Prof. Joel Pearson, University of New South Wales
Research Interests: cognitive neuroscience, specifically the mechanisms and application of mental imagery, hallucinations, decision-making, the science of intuition, memory, metacognition, visual perception, learning, attention, awareness innovation and entrepreneurship, by using behavioural, human brain imaging and brain stimulation techniques
Prof. Erik Stern, Weber State University, USA
Research Interests: professional dancer/choreographer, mathematics and dance

MathSciNet Classification

03 Mathematical Logic and Foundations
68 Computer Science
97 Mathematics Education

Web Links

carma.newcastle.edu.au/meetings/thinkingworkshop/

Other Sponsors

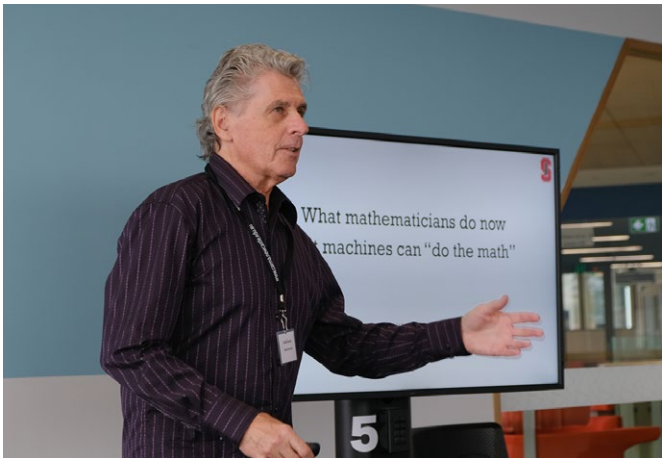
AustMS, Maplesoft, ASES, CARMA (Priority Research Centre for Computer-Assisted Research Mathematics and its Applications)

Key Contact

Prof. Florian Breuer, The University of Newcastle, florian.breuer@newcastle.edu.au

"I have never attended a conference that celebrated such a diversity of modalities of thinking and areas of expertise. How remarkable to examine mathematical thinking from many different angles and from true experiments in their fields. A magic space was created in X803 and I am so blessed to be there."

Dr Rachel Bachman, Weber State University, USA



Participants at the AMSI–CARMA Workshop on Mathematical Thinking workshop held in Newcastle

PHOTOS: SUPPLIED

1.03 WORKSHOP ON NONLINEAR WAVES IN OCEANOGRAPHY AND BEYOND

University of Southern Queensland (Toowoomba), 26–30 November 2018

Dedicated to the celebration of Professor Roger Grimshaw's 80th birthday, global and Australian research leaders explored contemporary nonlinear oceanic waves research to identify emerging opportunities for new interdisciplinary collaboration.

Nonlinear wave theory is an interdisciplinary field of fluid dynamics research with applications to practical problems of physical oceanography. This workshop, which was dedicated to Professor Roger Grimshaw—one of Australia's foremost applied mathematicians and a Fellow of the Australian Academy of Science—brought together Australian and international experts in applied mathematics to discuss their achievement in nonlinear wave theory with application to practical problems of physical oceanography, perspectives of further research and applications, world trends in the development of wave theory, numerical techniques, and laboratory and field experiments.

A major goal of the conference was to promote interdisciplinary collaboration between Australian research teams and their international counterparts, in particular in the fields of applied mathematics, nonlinear wave theory and physical oceanography. The lack of large-scale experimental facilities in Australia, like the Coriolis platform in Grenoble, France and the water canal in Hamburg, Germany, hampers Australian researchers in validation of their results through comparisons of the theoretical and experimental data. In addition, there is a wide range of topical practical problems that have applicability in Australia, in particular in coastal zone oceanography where results of nonlinear wave theory can be applied, including protection of gas and oil near-shore platforms and pipelines, as well as harbours and marine engineering constructions against wind and internal wave impacts; erosion of beaches; wave transport of sediments; tsunami warning and marine navigation. The workshop focused on several key research themes including:

- Wind wave theory and comparison of the results obtained with field and laboratory data
- The development of solitary wave theory for surface and internal waves in spatially inhomogeneous media
- The inverse scattering method for the solution of vector equations
- Further development of extreme wave theory for the analysis of hazardous impact on marine engineering construction and ship navigation

WORKSHOP PARTICIPATION

38 attendees
5 postgraduate students
5 ECRs
6 women
18 international participants

In addition to the program of plenary lectures and presentations, three public lectures on contemporary mathematical sciences were delivered, and a TV interview was taped with several of the workshop participants, including Simon Clarke (Monash University), Karl Helfrich (Woods Hole Oceanographic Institution, USA), Edward Johnson (University College London), Karima Khusnutdinova (Loughborough University, UK) and Anthony Roberts (The University of Adelaide). Edward, Karima and Anthony, along with Boris Malomed (Tel Aviv University, Israel) and several local school teachers, also participated in a round-table discussion facilitated by Linda Galligan, Head of School at USQ, on world trends in mathematics education.

The conference provided Australian researchers, particularly postgraduate students and ECRs, with the opportunity to discuss their research with some of the leading researchers in the field and has led to several collaborative projects between the participants.

Unfortunately, due to ill-health, Prof. Roger Grimshaw was unable to attend the workshop as planned, however he presented his lecture over Skype and had few Skype conversations from London with the workshop participants.

"Yury, I would like to congratulate you for a most successful and fruitful workshop. I was most impressed by the quality of the event and exchanges during the workshop. I know that you did a lot of work to make this event possible. Well done."

Prof. Hubert Chanson, The University of Queensland

Organisers

Prof. Alexander Babanin, The University of Melbourne
Prof. Hubert Chanson, The University of Queensland
Dr Simon Clarke, Monash University
Prof. Georg Gottwald, The University of Sydney
Prof. Nalini Joshi, The University of Sydney
Prof. Timothy Marchant, University of Wollongong
Prof. Anthony Roberts, The University of Adelaide
Prof. Yury Stepanyants, University of Southern Queensland

Special Presenters

Prof. Jerry Bona, University of Illinois, Chicago, USA
Research Interests: fluid mechanics, PDEs, computational mathematics, numerical analysis, oceanography, coastal engineering, mathematical economics
Prof. Roger Grimshaw, Loughborough University, UK
Research Interests: linear and nonlinear waves, solitary waves in fluids, fluid dynamics, geophysical fluid dynamics, theoretical physical oceanography, internal solitary waves
Prof. Edward Johnson, University College London, UK
Research Interests: theory of nonlinear dispersive waves, integral equations, boundary layers and highly accurate spectral integrations in the propagation and scattering of finite-amplitude waves and eddies in the oceans and atmosphere
Dr Karima Khusnutdinova, Loughborough University, UK
Research Interests: nonlinear waves in inhomogeneous media and complex systems, PDEs, fluid and solid mechanics, physical and geophysical applications
Prof. Boris Malomed, Tel Aviv University, Israel
Research Interests: pattern formation in nonlinear dissipative media, Ginzburg–Landau equations, nonlinear optics, optical solitons, optical communications, dynamics of Bose-Einstein condensates and matter waves, nonlinear dynamical lattices, dynamics of long Josephson junctions
Prof. Lev Ostrovsky, University of Colorado, Boulder, USA
Research Interests: theory of nonlinear phenomena, fluid dynamics and oceanography, nonlinear acoustics and biomedical acoustics
Prof. Efim Pelinovsky, Institute of Applied Physics, Russian Academy of Sciences, Russia
Research Interests: applied mathematics, geophysics, fluid dynamics, physical oceanography
Prof. Anthony Roberts, The University of Adelaide
Research Interests: modelling of complex multiscale dynamical systems, stochastic differential equations, centre manifold theory and applications, free-surface hydrodynamics, thin film flows, turbulent floods, multifractal geometry, scientific computing, computer algebra algorithms, multiscale modelling of emergent dynamics in complex systems
Prof. Victor Shrira, Keele University, UK
Research Interests: nonlinear waves, 3-d patterns, wave instabilities, Hamiltonian and "almost" Hamiltonian systems, wave interactions with shear currents and turbulence, fundamental problems of statistical description of random wave field, formation of wave groups and Langmuir circulations, EM scattering by wind wave patterns, physical oceanography, fluid mechanics

MathSciNet Classification

76 Fluid Mechanics
86 Geophysics

Web Links

usq.edu.au/nonlinear-waves-workshop

Other Sponsors

Monash University, Australasian Fluid Mechanics Society, AustMS, ANZIAM, University of Southern Queensland

Key Contact

Prof. Yury Stepanyants, University of Southern Queensland, yury.stepanyants@usq.edu.au

Participants at the workshop on Nonlinear Waves in Oceanography and Beyond workshop in Toowoomba

PHOTO: SUPPLIED

1.04 AUTHENTICATION FOR THE FUTURE INTERNET OF THINGS

Deakin University, 28–30 November 2018

Focusing on the identification of low-resource methods for authentication of communications between devices in current use in the Internet of Things, attendees at this conference had the practical goal of coming up with feasible ideas on testing and implementation for current and future use.

The current Internet of Things is inherently limited in that it requires special-purpose computing as opposed to general-purpose computing and because it focuses on high-value applications; we argued that developing contextual relationships from metadata is critical to the success of the Future Internet of Things (FIoT). This event was significant in being the first workshop on the topic to bring in experts from overseas and Australia to develop a strategy for proceeding at all levels, from mathematical to regulatory, to ensure that the FIoT will be secure from major failures.

The workshop brought together mathematicians, computer scientists and engineers with wide-ranging knowledge and capabilities to discuss ideas and plan future work. Over the course of the conference, attendees participated in one of four work-streams based on key research themes (see below). Each stream was led by an Australian researcher with members from outside Victoria as well as outside Australia:

- *Mathematical problems related to cryptographic authentication in low-resource environments*, led by Diane Donovan (The University of Queensland) and Lynn Batten (Deakin University)
- *Cryptographic algorithms for authenticated encryption with associated data*, led by Leonie Simpson (Queensland University of Technology)
- *Secure implementation of authenticated encryption algorithms with associated data*, led by Damith Ranasinghe (The University of Adelaide)
- *Legal and regulatory aspects of authentication in the IoT*, led by Ghassan Beydoun (University of Technology Sydney)

Two keynotes and a series of invited presentations accompanied the discussions in the work-streams. Hugh Williams discussed the role of number theory in authentication in his keynote lecture, while Bart Preneel's keynote on technological and regulatory challenges was complemented by a panel discussion on security compliance moderated by Ghassen Beydoun.

In addition, Ray Hunt (University of Canterbury, NZ) provided a hands-on demonstration of how insecure authentication is when communicating with small, low-powered devices.

On the final day the work-streams each reported to the full group, identifying major issues needing further work. Workshop participants agreed to continue to work over the next few months with the aim of producing journal papers, in particular for special issues of the two journals *Cryptography* and *Sensors* (both to be co-edited by Leonie Simpson), and ultimately grant applications for future research collaborations.

"I enjoyed the workshop immensely more than I have enjoyed anything else recently. And the speakers contributed a lot to this, they were great. So thanks for organising everything and inviting me to be part of it."

Prof. Diane Donovan, The University of Queensland

WORKSHOP PARTICIPATION

44 attendees
7 postgraduate students
3 ECRs
19 women
8 international participants

Organisers

Prof. Lynn Batten, Centre for Cyber Security Research and Innovation, Deakin University
Dr Leonie Simpson, Queensland University of Technology

Keynote Presenters

E/Prof. Hugh Williams, University of Calgary, Canada
Research Interests: computational number theory, cryptography and the design and development of special-purpose hardware devices, history of mathematics and computation
Prof. Bart Preneel, KU Leuven, Belgium
Research Interests: information security, cryptographic algorithms and protocols, applications to computer and network security, and mobile communications

MathSciNet Classification

11 Number theory T 01
12 Field theory and polynomials F
14 Algebraic geometry H
11 Number theory A 51
11 Number theory T 14
94 Information and communication, circuits A 03

Web Links

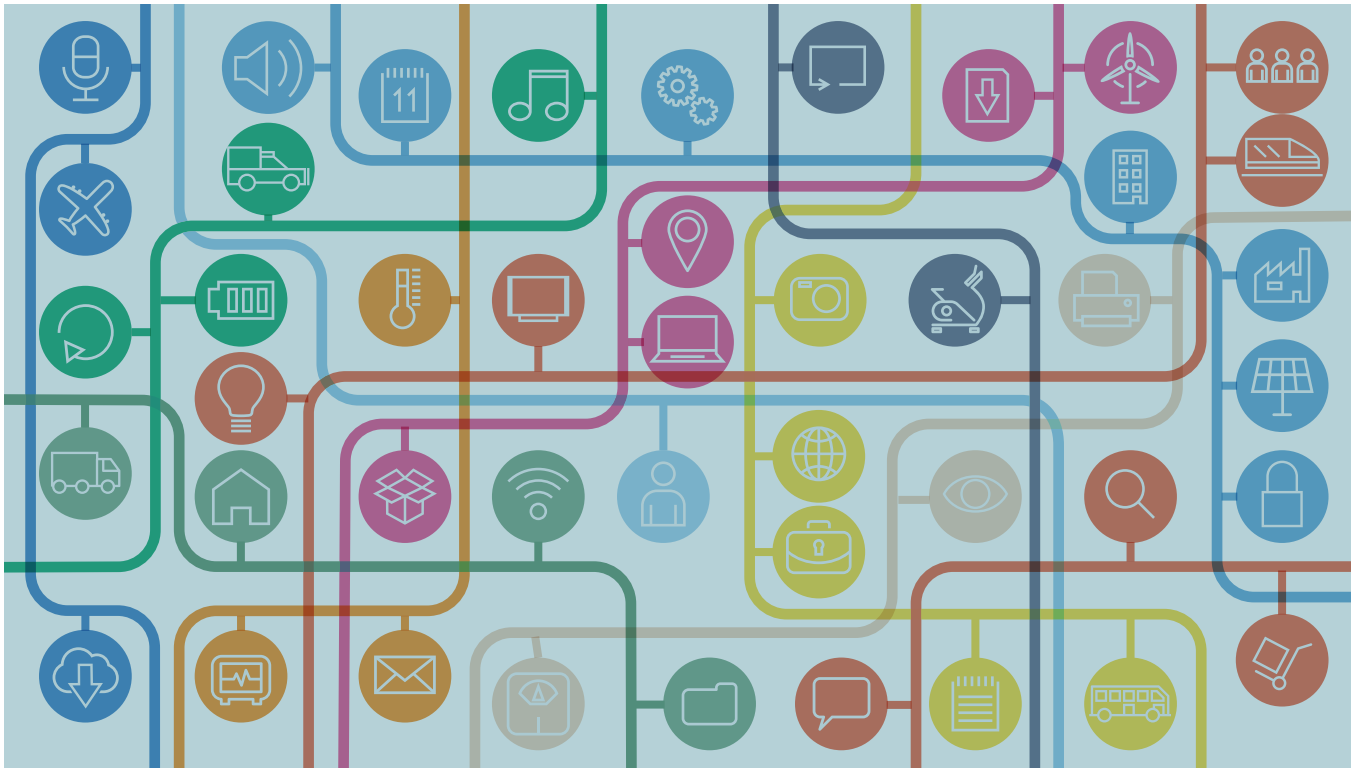
authiot2018.conferences.academy/

Other Sponsors

Senetas, AustMS, Centre for Cyber Security Research and Innovation, IT Security Research, Deakin University, Queensland University of Technology, IBM, the TULIP Research Laboratory, MDPI Cryptography, MDPI Sensors

Key Contact

Prof. Lynn Batten, Centre for Cyber Security Research and Innovation, Deakin University, lynn.batten@deakin.edu.au



AUTHENTICATION FOR THE FUTURE **INTERNET OF THINGS**

By Professor Lynn Batten and Dr Leonie Simpson

MOTIVATION AND GLOBAL BENEFIT

In developing this workshop, the organisers argued that the current Internet of Things (IoT) is inherently limited in that it requires computing designed for a specific purpose, such as that of automatic teller machines or blockchain computations, as opposed to general-purpose computing, which is able to perform many tasks, as does a laptop computer. As we move into the future, 'general purpose' devices will be required to undertake more and more 'specific purpose' tasks as part of a natural evolution, and it is anticipated that these distinctions will disappear.

With everything connected to the Internet, every device becomes a sensor in a global network of the future, and reams of data, much of it sensitive, are recovered and sent around the globe. This scenario is a drawcard for attackers. Authenticating the sender of data, the data itself, as well as the intended location are all critical to maintaining the safety and security of the Future Internet of Things (FIoT).

Understanding cryptographic algorithms and data transmission for networks of devices involves the application of many branches of mathematics, including finite mathematics, graph theory, number theory, probability and statistics.

Therefore, the workshop was divided into four streams, outlined below, which permitted each participant to interact with keynote and invited speakers in discussing the gaps in authentication of multitudes of small devices produced by various companies, aligned to numerous guidelines and standards and designed for many functionalities. In particular, authentication of multiple communicating devices based on different hardware, firmware and software and equipped with limited resources was viewed as being a major challenge to the success of the FIoT and its global economic impact.

INTRODUCTION

FROM: [SNCC2018] Sfar, A.R., Natalizio, E., Challal, Y. and Chtourou, Z., 2018. A roadmap for security challenges in the Internet of Things. *Digital Communications and Networks*, 4(2), pp.118-137.

- According to [1], "in 2011, the number of interconnected systems exceeded the number of human beings. In 2012, nine billion devices were interconnected; this number is expected to reach 24 billion devices in 2020."
- "…previous security models should be applicable to IoT to guarantee basic security services including authentication, confidentiality, integrity, nonrepudiation, access control and availability. However, the IoT is constrained by many new factors.
  - numerous devices and objects may interact together in a complex manner, through many security techniques and according to different policy requirements [2].
  - IoT devices can have different operational environments and, usually, limited computational power.
  - some IoT devices have the potential for interaction with a huge number of nodes leading to serious security problems.
- Security challenges became more difficult to address as it is difficult to develop a generic "one size fits all" security strategy or model.

Figure 1. Size of the IoT and Security Challenges

This workshop was intended to be a learning experience for all parties. It brought together people with wide-ranging experience and capabilities to discuss ideas and plan papers. Each stream was led by an Australian and had members from outside Victoria as well as outside Australia. The organisers anticipated that this would lead to joint work initiated by Australians with other Australians as well as with overseas researchers, resulting in high quality publications and grant applications.

KEY RESEARCH THEMES

Mathematical problems related to cryptographic authentication in low-resource environments, led by Professors Diane Donovan (The University of Queensland) and Lynn Batten (Deakin University). This theme was also supported by the keynote speech of Professor Hugh Williams.

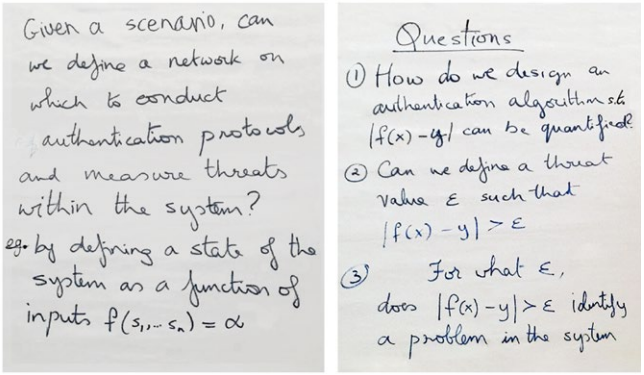


Figure 2. Theoretical Questions Concerning Authentication

The mathematical problems stream explored theoretical aspects of authentication in IoT, studying the drivers for such systems, developing a mathematical framework for protocols and the subsequent analysis of these protocols.

To place the theory in context it focused on representative examples, for instance the authentication aspects of automated tractors or fire sensors in a forest. Within this context, the salient features were studied as networks or graphs, where individual sensors or activators formed nodes and communication was represented as weighted edges between nodes. The group studied the concept of nodes or sensors being assigned states to accurately record information on risk levels, but also to account for failure detection, intrusion detection and malicious assault detection. For example, in the fire scenario the deployment of sensors for risk detection could lead to an alert once a threshold was reached, where information is aggregated over changes in the state for temperature, wind speed, smoke density, tinder levels, oxygen levels and/or humidity. But such systems should also account for false readings, animal and hiking activity or even flashovers. To accurately capture this information, networks would need to operate in both local and global environments with nodes changing states over time and intercommunicating, where analysis of results was executed in real time and all information was accurately communicated to a central overarching node.

By studying these systems as a time series of graphs embedding in topological spaces, the stream members tapped into rigorous mathematical theory and developed frameworks for the study of their authentication.

Cryptographic algorithms for authenticated encryption with associated data, led by Dr Leonie Simpson (Queensland University of Technology) and supported by the invited speaker Dr Damith Ranasinghe (The University of Adelaide) whose talk title was *Can physical unclonable functions be used to realise lightweight dynamic authentication for IoT devices?* and by Matt Tett (Managing Director of Enex TestLab) who spoke on *Why authentication is critical to security in an IoT world*.

Workstream members discussed the IoT as an ecosystem of connected heterogeneous devices with corresponding issues of trust in knowing the identity of devices that connect and exchange information, and requirements to protect the data transmissions. In the example of IoT deployment on a farm, where sensors send data to a central aggregator providing input to a decision management tool that determines the required commands to be transmitted to actuators which trigger irrigation, it is important that the sensors as well as their data be authenticated by the actuators.

Understanding the context is important in determining appropriate algorithm choices, as crop damage can result from erroneous transmissions, and commercial espionage may occur. Issues to be considered include:

- The value and currency of the data transmitted between devices
- The range of threats to information security, including data leakage, data corruption and availability; linked to actions of a threat actor in intercepting communication and/or physical tampering with devices
- IoT device constraints, such as available power and memory to support cryptographic algorithms in addition to other device operations
- Key management requirements of particular algorithms
- Network topology

Lightweight cryptography may be used in parts of a network, and standardised algorithms be used where components have the capacity. Further, crypto-agility for systems is required so that algorithms can be updated or replaced if required. In some systems automated cryptographic updates may be desirable, but assurances of authenticity are required to enable this to occur in a trusted way.

The IoT is rapidly changing the way many industries operate, but the connection to the Internet also increases the potential threat sources. Lightweight cryptography is currently a major research topic, as evidenced by the current US NIST Lightweight Cryptography competition. The additional challenges of the varying capacities of heterogenous devices makes this a complex security issue.

In a knowledge economy, data has value. As the IoT continues to expand, the range and volume of data transmitted also increases. The security of transmissions against an evolving range of threats is an area requiring constant attention. This is an area that will continue to grow and evolve.

Legal and regulatory aspects of authentication in the IoT was led by Professor Ghassan Beydoun (University of Technology Sydney) and supported by keynote speaker Professor Bart Preneel who spoke on *Technology and regulatory challenges for the IoT*, and by the *Panel security compliance and regulations in IoT age* with members Bart Preneel, Dr Jürg von Kaenel (IBM), Julian Fay (Senetas) and Helaine Leggat, a partner of the law firm Sladen Legal. The panel was moderated by Ghassan Beydoun.

Secure implementation of authenticated encryption algorithms with associated data, led by Dr Damith Ranasinghe (The University of Adelaide) and supported by invited speaker Professor Margreta Kuijper (The University of Melbourne) who spoke on *Resilient linear systems under attack*.

Professor Margreta Kuijper, The University of Melbourne and Dr Trent Marbach (ECR), Nankai University PHOTO: SUPPLIED

CONCLUDING REMARKS

In the opinion of the organisers, the highlight of the event was the work-stream concept in which every participant was able to be part of and contribute to a small group focused on a specific component of the overall topic.

PUBLICATIONS:

Several publications were generated by the workshop, some in the two Special Issues produced by our sponsor MDPI in the journals *Cryptography* (mdpi.com/journal/cryptography) and *Sensors* (mdpi.com/journal/sensors), and some elsewhere. This work is ongoing; however, it includes:

Martínez-Peláez, R., Toral-Cruz, H., Parra-Michel, J., García, V., Mena, L., Félix, V., Ochoa-Brust, A. (2019). An Enhanced Lightweight IoT-based Authentication Scheme in Cloud Computing Circumstances. *Sensors* 19(9), 2098. doi.org/10.3390/s19092098

Venkatraman, S and Overmars, A. (2019). New Method of Prime Factorisation Based Attacks on RSA Authentication in IoT. *Cryptography*, 3(3), 20. doi.org/10.3390/cryptography3030020

Batten, L.M. and Williams, H. C. (2019). Unique Rabin-Williams Scheme Decryption. *Cryptology ePrint Archive*, Report 2019/915. eprint.iacr.org/2019/915

Kihara, M and Iriyama, S. (2-19). New Authentication Algorithm Based on Verifiable Encryption with Digital Identity. *Cryptography* 3(3), 19; doi.org/10.3390/cryptography3030019

Mohammed, A. and Yassin, A. Efficient and Flexible Multi-Factor Authentication Protocol Based on Fuzzy Extractor of Administrator's Fingerprint and Smart Mobile Device. *Cryptography* 3(3), 24; doi.org/10.3390/cryptography3030024

Hall, J., Tang, Z. and Kuijper, M. Protecting an autonomous tractor from sensor spoofing, in progress.

Emeritus Professor Lynn Batten *is the Director of the Information Security Group at Deakin University and a member of the Centre for Cyber Security Research and Innovation, also at Deakin. She is a former member of AMSI's Board of Directors.*

Dr Leonie Simpson *is a Senior Lecturer in the School of Electrical Engineering and Computer Science at Queensland University of Technology.*

Drs Simpson and Batten *were co-investigators on ARC Discovery grant 'Efficient and secure word-based stream ciphers for wireless communications' from 2006 to 2009.*

1.05 CLASSICAL AND QUANTUM THREE-MANIFOLD TOPOLOGY

Monash University, 17–21 December 2018

Over four decades connections between topological quantum field theory (TQFT), low-dimensional topology, and geometric structures on manifolds, particularly hyperbolic geometry, have deepened. Strengthening and building on these findings, this conference drew a distinguished group of international field leaders.

A flurry of activity in low-dimensional topology research, which is ongoing, was unleashed by Thurston with his late 1970s work on the Geometrisation Conjecture, which postulated that every 3-manifold can be cut into pieces that are locally isometric to one of eight homogeneous "model geometries", and proved it for certain 3-manifolds. In particular, his theorem applied to the complements of knots and links. In 2003, Perelman established the Geometrisation Conjecture in full generality.

Deep relationships have also been revealed between low-dimensional topology, representation theory, and topological quantum field theory (TQFT) and quantum groups, leading to powerful and subtle invariants of knots and 3-manifolds. This began with Jones' unexpected discovery of the Jones polynomial for knots and links while working with representations of von Neumann algebras. Following this, an interpretation of the Jones polynomial within the framework of a SU(2)-Chern-Simons TQFT was formalised by Reshetikhin and Turaev using the representation theory of the quantum group. In particular, the theory gave rise to the Witten-Reshetikhin-Turaev quantum invariants for 3-manifolds. The manner in which the invariants came about is perhaps more important than the definitions themselves, with striking reliance on so many areas seemingly unrelated to low-dimensional topology.

These "dual revolutions" of Thurston's geometrisation and the development of quantum topology provide the once isolated area of low-dimensional topology with the potential to explode into new areas of research.

With a focus on interactions in low-dimensional topology, hyperbolic geometry and geometric structures, representations and Teichmuller theory, and quantum topology, this conference aimed to foster the sharing of new tools and ideas between the participants. Showcasing current domestic and international research, the conference addressed the question of which geometric invariants are encoded by quantum ones. It featured four invited speakers each day, with ample time built into the program for discussion and collaboration.

WORKSHOP PARTICIPATION

61 attendees
21 postgraduate students
13 ECRs
18 women
37 international participants

Participants were introduced to new and ongoing work in the closely-related fields, allowing for cross-fertilisation of ideas. Highlights among the 16 invited talks included:

- Emerging connections between classical topology and quantum topology, such as Sakie Suzuki's talk illustrating how triangulations of 3-manifolds connect with quantum invariants, Thang Le's presentation on skein algebras and TQFTs, and Christine Lee's talk connecting Khovanov homology with embedded surfaces
- New information on cutting-edge tools in computing, including Benjamin Burton's talk describing the knot enumeration, Anastasiia Tsvietkova's talk on the computational complexity of problems in knot theory, Roland Van der Veen's presentation of new knot invariants computable in polynomial time, and William Worden's discussion on new tools to compute 3-manifold invariants
- Applications of geometry to problems in topology and quantum topology, such as Eiko Kin's talk on virtual fibering, Makoto Sakuma's discussion of Kleinian groups generated by two parabolics, and talks by Efstratia Kalfagianni and Tian Yang on volumes and quantum invariants

Ample opportunities were provided for discussions and networking, and breakout rooms for further discussions proved popular and were fully occupied during program breaks. These discussions facilitated some new collaborations, including between Jessica Purcell and Christine Lee, and between Efstratia Kalfagianni and Eiko Kin.

A two-day student workshop preceded the conference, enabling students and early career researchers attending the conference to share their work.

"The Monash conference was very high quality all around: excellent organisation [sic], great time balance of activities: lectures and time for discussions. Myself and my two students got a lot out of it [sic]."

Prof. Efstratia Kalfagianni, Michigan State University, USA

Organisers

Assoc. Prof. David Futer, Temple University, USA
Dr Stavros Garoufalidis, Max Planck Institute for Mathematics, Germany
Dr Craig Hodgson, The University of Melbourne
Prof. Jessica Purcell, Monash University
Prof. Hyam Rubinstein, The University of Melbourne
Dr Saul Schleimer, University of Warwick, UK
Dr Paul Wedrich, The Australian National University

Special Presenters

Prof. Benjamin Burton, The University of Queensland
Research Interests: computational geometry and topology
Dr François Guéritaud, CNRS Lille, France
Research Interests: geometry and topology
Dr Ingrid Irmer, Technion—Israel Institute of Technology, Israel
Research Interests: low-dimensional topology, mapping class groups, fibrations of 3- and 4-manifolds, Morse theory and Lorentzian geometry
Prof. Efstratia Kalfagianni, Michigan State University, USA
Research Interests: low-dimensional topology, classical and quantum 3-dimensional topology, knot theory, hyperbolic geometry, braid groups, combinatorics
Assoc. Prof. Eiko Kin, Osaka University, Japan
Research Interests: topology, geometry, dynamical systems
Prof. Thang Le, Georgia Institute of Technology, USA
Research Interests: differential topology, 3-manifolds, knot theory, quasicrystals
Dr Christine Lee, University of South Alabama, USA
Research Interests: quantum topology, hyperbolic geometry, 3-manifolds
Dr Joan Licata, The Australian National University
Research Interests: low-dimensional topology, contact geometry
Prof. Makoto Sakuma, Hiroshima University, Japan
Research Interests: geometry and topology
Assoc. Prof. Henry Segerman, Oklahoma State University, USA
Research Interests: 3-dimensional geometry, topology, ideal triangulations
Dr Sakie Suzuki, Kyoto University, Japan
Research Interests: topology, knot theory
Assoc. Prof. Stephan Tillmann, The University of Sydney
Research Interests: low-dimensional topology, hyperbolic geometry, group theory, computational algebraic geometry, tropical geometry
A/Prof. Anastasiia Tsvietkova, Rutgers University, USA/Okinawa Institute of Science and Technology, Japan
Research Interests: low-dimensional topology, geometry, knot theory, computational topology, differential geometry, quantum topology
A/Prof. Roland Van der Veen, Leiden University, The Netherlands
Research Interests: knot theory, low-dimensional topology, representation theory, geometry and physics
Dr William Worden, Rice University, USA
Research Interests: hyperbolic 3-manifolds & their triangulations, commensurability of 3-manifolds, experimental mathematics
A/Prof. Tian Yang, Texas A&M University, USA
Research Interests: quantum topology, geometric topology

MathSciNet Classification

57 Manifolds and cell complexes
81 Quantum theory

Web Links

sites.google.com/view/cq3dt/home

Other Sponsors

Monash University, The University of Melbourne, National Science Foundation (USA), AustMS

Key Contact

Prof. Jessica Purcell, Monash University, jessica.purcell@monash.edu

Participants at the Classical and Quantum Three-Manifold Topology workshop at Monash University PHOTO: SUPPLIED

1.06 TOPOLOGY OF MANIFOLDS: INTERACTIONS BETWEEN HIGH AND LOW DIMENSIONS

MATRIX, Creswick, 7–18 January 2019

Positioning Australia at the frontier of the exchange between high and low-dimensional topology research communities, this conference has already shown international impact.

Low-dimensional spaces, those of dimension at most four, appear naturally in physics, for example as our universe and space-time, and exhibit unique phenomena. Higher-dimensional spaces, those of dimension at least five, arise as the parameters spaces of complex systems. The areas of low-dimensional topology and high-dimensional topology have developed rather independently since the days of Milnor and Smale, reflecting the differing nature of problems in dimensions 3 and 4 and in higher dimensions.

In dimension 3, Thurston's geometrisation program led to the possibility of a complete classification of 3-manifolds. Dimension 4 is marked by the failure of the Whitney trick and is intermediate between high and low dimensions. Surgery theory and smoothing theory provide powerful tools for analysing manifolds of dimensions 5 and higher.

Revealing exciting new connections, this two-week workshop explored the study of manifolds in low and high dimensions, via the comparison of phenomena and methods across dimensions and analysis of higher-dimensional spaces in terms of lower-dimensional subspaces.

The summer school in Week One featured three lecture series, one by Wolfgang Lück, one by András Stipsicz, and one by Diarmuid Crowley, Jim Davis and Kent Orr. The afternoons were devoted to exercise sessions. This was followed by a week of invited talks and collaborative problem-solving sessions. This structure allowed participants to learn introductory material during the first week, building a foundation for the research talks and working on research problems in the second week.

Highlights included:

- Sylvain Cappell's insights into the use of Atiyah-Bott classes to produce polynomial invariants of 3-manifolds
- An in-depth overview of Daniel Kasprowski's joint work with Mark Powell and Peter Teichner, showing how classification of 4-manifolds up to CP2-stable diffeomorphism is determined by the homotopy 2-type for many fundamental groups
- Insights into Peter Lambert-Cole's new proof of the Thom conjecture that combines contact geometry with the novel theory of bridge trisections of knotted surfaces
- A talk from Ana Lecuona addressing the question of which integer surgeries on torus knots result in 3-manifolds-bound rational homology balls, drawing on work with P. Aceto, M. Golla and K. Larson
- Lisa Piccirillo's overview of her resolution of question 1.41 on the Kirby problem list, showing the existence of knot traces where the minimal genus smooth surface-generating second homology is not of the canonical type
- A presentation by Jessica Purcell on combinatorial criteria to determine whether a state surface is a fibre
- An exciting report from Hyam Rubinstein outlining his joint work with Stephan Tillmann on the construction of multisections of manifolds
- Abigail Thompson's presentation on outcomes of her collaboration with Rob Kirby investigating trisections and surgery questions on links in 3-manifolds

Collaborative work by participants during the problem sessions has resulted in a number of new collaborations between mathematicians who first met at the workshop, which is witnessed by papers submitted for publication in the 2019 *MATRIX Annals*.

With around half of the participants being postgrad students and early career researchers, the workshop provided valuable opportunities for collaboration and networking between the high and low topology communities.

Participants at the Topology of Manifolds: Interactions Between High and Low Dimensions workshop at MATRIX, Creswick PHOTO: SUPPLIED

"This conference was one of the most satisfying that I have attended. It was an excellent idea to bring together the two communities (low and high) and the details worked well. The problem sessions were particularly fruitful for me."

Dr Jonathan Hillman, The University of Sydney

WORKSHOP PARTICIPATION

48 attendees
9 postgraduate students
16 ECRs
13 women
33 international participants

Organisers

Dr Jonathan Bowden, Monash University
Assoc. Prof. Diarmuid Crowley, The University of Melbourne
Prof. Jim Davis, Indiana University, USA
Prof. Stefan Friedl, University of Regensburg, Germany
Dr Carmen Rovi, Indiana University, USA
Assoc. Prof. Stephan Tillmann, The University of Sydney

Special Presenters

Dr Bea Bleile, University of New England
Research Interests: manifolds, algebraic topology, Poincaré duality complexes
Prof. Sylvain Cappell, Courant Institute of Mathematical Sciences, New York University, USA
Research Interests: algebraic and geometric topology, symplectic and algebraic geometry
Prof. Jae Choon Cha, Postech, Korea
Research Interests: geometric topology, topology of dimensions 3 and 4, knot theory, related algebra, homotopy theory, $L2$-invariants
Assoc. Prof. Diarmuid Crowley, The University of Melbourne
Research Interests: differential topology, algebraic topology, surgery classification of manifolds
Prof. Jim Davis, Indiana University, USA
Research Interests: algebraic topology, geometric topology, surgery theory
Assoc. Prof. Jen Hom, Georgia Institute of Technology, USA
Research Interests: low-dimensional topology, knot theory, concordance and Heegaard Floer homology
Assist. Prof. Qayum Khan, Saint Louis University, USA
Research Interests: geometric topology, algebraic K- and L-theory
Dr Daniel Kasprowski, University of Bonn, Germany
Research Interests: algebraic K- and L-theory, Farrell-Jones conjecture, 4-manifold topology
Assist. Prof. Peter Lambert-Cole, Georgia Institute of Technology, USA
Research Interests: low-dimensional topology, contact and symplectic topology
Dr Ana Lecuona, University of Glasgow, UK
Research Interests: knot theory, low-dimensional topology, contact and symplectic topology
Assist. Prof. Adam S. Levine, Duke University, USA
Research Interests: low-dimensional topology, concordance, surfaces in 3- and 4-manifolds, Heegaard Floer homology and its applications to knot theory
Prof. Wolfgang Lück, University of Bonn, Germany
Research Interests: topology, K-theory, non-commutative geometry, global analysis
Prof. Kent Orr, Indiana University, USA
Research Interests: geometric topology, algebraic topology, homological algebra
Prof. Jessica Purcell, Monash University
Research Interests: low-dimensional topology, 3-manifolds, hyperbolic geometry
Dr Lisa Piccirillo, University of Texas, Austin, USA
Research Interests: low-dimensional topology, 3- and 4-manifolds, knot concordance
Prof. Hyam Rubinstein, The University of Melbourne
Research Interests: low-dimensional topology, minimal surfaces (combinatorial and smooth), differential geometry and shortest network design, especially applied to underground mining
Prof. András Stipsicz, Alfréd Rényi Institute of Mathematics, Hungarian Academy of Sciences, Hungary
Research Interests: symplectic topology, Lefschetz fibrations, contact topology, Stein fillings of contact 3-manifolds, Seiberg-Witten and Heegaard Floer homologies, Legendrian and transverse knot theory
Prof. Abigail Thompson, University of California, Davis, USA
Research Interests: knot theory, 3-manifolds

MathSciNet Classification

57 Manifolds and cell complexes N13
57 Manifolds and cell complexes N15
57 Manifolds and cell complexes M50

Web Links

matrix-inst.org.au/events/interactions-between-topology-in-high-and-low-dimensions/

Other Sponsors

MATRIX, NSF, ERC, ARC, AustMS

Key Contact

Assoc. Prof. Stephan Tillmann, The University of Sydney, stephan.tillmann@sydney.edu.au

1.07 GEOMETRIC EVOLUTION PROBLEMS AND RELATED TOPICS

Newcastle, 15–18 January 2019

An important area of modern mathematical research, geometric evolution problems have far-reaching applications. Encouraging a robust exchange of ideas between Australian and international experts, ECRs and students, this event opened new avenues of investigation.

Geometric evolution problems form an important area of modern mathematical research with far-reaching applications within mathematics and beyond. This workshop gathered together many leading Australian researchers and some key international guests to discuss the latest developments, build on existing collaborations and initiate new ones.

The exchange of ideas and methods coming from analysis of different geometric flows has been extremely fruitful in the past—for example, the notion of non-collapsedness was first introduced by Perelman for the Ricci flow and was a major ingredient in the Hamilton/Perelman proof of the Thurston conjecture. A geometric notion of non-collapsedness was subsequently obtained for mean curvature flow by Ben Andrews, which has proved a very useful analytical tool for this flow, leading to many new results in geometry and topology.

Conference topics included the theory of geometric evolution problems including existence, regularity and singularities, hypersurface flows and metric flows, and related numerical modelling. The daily schedule included five presentations by invited speakers as well as plenty of discussion breaks and a daily collaboration session. The latter was very successful and in particular facilitated a number of groups working on ARC Discovery Project applications and joint research programs, including James McCoy (The University of Newcastle), Glen Wheeler (University of Wollongong) and Yann Bernard (Monash University), as well as Daniel Hauer (The University of Sydney) and Julie Clutterbuck (Monash University).

The workshop provided a unique opportunity for attendees, particularly ECRs, to see talks by Miles Simon and, in his first visit to Australia, Reto Buzano.

"Thank you again for organising this wonderful conference in Newcastle. It was really very productive and had many interesting talks"

Dr Daniel Hauer, The University of Sydney

WORKSHOP PARTICIPATION

27 attendees
2 postgraduate students
12 ECRs
6 women
7 international participants

Organisers

Assoc. Prof. James McCoy, The University of Newcastle
Laureate Prof. Ben Andrews, The Australian National University
Dr Glen Wheeler, The University of Wollongong
Prof. Miles Simon, OVGU Magdeburg, Germany
Dr Julie Clutterbuck, Monash University
Dr Ting-Ying Chang, Monash University

Special Presenters

Prof. Miles Simon, Madgeburg University, Germany
Research Interests: Ricci flow, singular metric spaces, mean curvature flow, singularities of Ricci and mean-curvature flow, geometric flows, geometric flows with surgery, parabolic and elliptic differential equations, global geometry, compactness theorems in geometry
Assoc. Prof. Reto Buzano, Torino University, Italy/Queen Mary University of London, UK
Research Interests: geometric analysis, geometric heat flows, critical points of geometric functionals

MathSciNet Classification

53 Differential Geometry C 44
35 Partial differential equations K 55

Web Links

carma.newcastle.edu.au/meetings/gepart/

Other Sponsors

CARMA, AustMS

Key Contact

Assoc. Prof. James McCoy, The University of Newcastle, James.McCoy@newcastle.edu.au

1.08 ASIA-AUSTRALIA ALGEBRA CONFERENCE

Western Sydney University, 21–25 January 2019

A first for Australia, the Asia-Australia Algebra conference was wide-ranging in its exploration of the field, with deepened connections opening avenues to build on current research.

There is no doubt the last decade has cemented Asia, particularly China, as a major node in mathematical research. Underscoring this jump in prominence is the region's influx of emerging mathematical talent, a workforce benefiting from the return of prominent mathematical expertise from the West. Fostering ties between the Asian and Australian research communities, this conference attracted some of the region's leading algebra talents to Sydney.

A broad program included topics such as universal algebras, algebraic K-theory, algebraic geometry, C*-algebras, representation theory of algebras and their interactions—all areas where ideas from algebra and discrete mathematics play important role. With around 60 invited talks plus a further 20 talks from postgraduate students and ECRs, the conference showcased some of the most recent Australian and international research in pure mathematics.

A series of keynote presentations from four Australian field leaders proved an event highlight. The University of Western Australia's Cheryl Praeger provided an overview of the recent advances in the structure of permutation groups. George Willis (The University of Newcastle) gave a survey talk on his program on compact groups. Geordie Williamson (The University of Sydney) talked about his breakthrough on representation theory of algebras and Monash University's Ian Wanless gave an accessible talk about Latin squares and their many connections to other areas of mathematics.

As well as boosting the profile of Western Sydney University's emerging mathematics group, the event strengthened links between young and established researchers.

"The Asia-Australia Algebra Conference was a stimulating and excellently executed event... I particularly liked the fact that this conference had researchers with interests in many different aspects of algebra gathered together and exchanging ideas. I found this particularly inspiring."

Prof. Lia Vas, University of the Sciences, USA

WORKSHOP PARTICIPATION

111 attendees
8 postgraduate students
20 ECRs
32 women
65 international participants

Organisers

Dr Changhao Chen, The University of New South Wales
Prof. Jie Due, The University of New South Wales
Dr James East, Western Sydney University
Prof. Roozbeh Hazrat, Western Sydney University
Dr Huanhuan Li, Western Sydney University
Prof. Cheryl Praeger, The University of Western Australia

Special Presenters

Prof. Cheryl Praeger, The University of Western Australia
Research Interests: group theory, algebraic graph theory, combinatorial designs
Prof. George Willis, The University of Newcastle
Research Interests: algebra, topology, functional analysis, totally disconnected locally compact groups
Prof. Ian Wanless, Monash University
Research Interests: Latin squares, combinatorial designs, combinatorial enumeration, matrix permanents, graph theory
Prof. Geordie Williamson, The University of Sydney
Research Interests: algebra, geometry, representation theory, geometric representation of group theory

MathSciNet Classification

19 K-theory D 55
16 Associative rings and algebras G 20
46 Functional analysis L 80

Web Links

sydneyalgebra.scem.westernsydney.edu.au

Other Sponsors

AustMS, WSU, Australian Algebra Group

Key Contact

Prof. Roozbeh Hazrat, Western Sydney University, r.hazrat@westernsydney.edu.au

1.09 AUSTRALIAN-GERMAN WORKSHOP ON DIFFERENTIAL GEOMETRY IN THE LARGE—CONFERENCE

MATRIX, Creswick, 4–8 February 2019

Promoting the research relationship between Australia and Germany, this international conference and research symposium brought together international and national field leaders to explore recent advances and future directions in geometry, topology and geometric analysis.

Differential geometry is one of the most research-intensive areas of mathematics in recent decades, with a long tradition that traces its development back well over a century. Its prominence stems from its nexus with active fields including topology, metric geometry, analysis, partial differential equations and Lie group theory. Its influence spreads beyond the confines of pure mathematics to interact with theoretical physics and applications as diverse as engineering, robotics and computer vision. This conference formed part of a longer workshop, and was the first Australian-German friendship workshop in differential geometry to be held in Australia.

A showcase of Australian geometric analysis expertise, the event highlighted the seminal work of Neil Trudinger and budding geometric analyst Valentina Wheeler (University of Wollongong). German field leaders were also well represented by, among others, Christoph Boehm and Burkhard Wilking. Invited speakers included distinguished international mathematicians Robert Bryant, Karsten Grove, Claude LeBrun, Peter Petersen and Guofang Wei from the USA, Fuquan Fang and Tom Farrell from China and Dame Francis Kirwan from the United Kingdom.

As well as encompassing global differential geometry in its entirety, themes included geometric evolution equations and curvature flow, structures on manifolds and mathematical physics, recent developments in non-negative sectional curvature, and higher invariants and positive scalar curvature.

Highlights included:

- Christoph Boehm, who talked about his work on immortal homogeneous Ricci flows with Ramiro Lafuente (The University of Queensland), showing that for an immortal homogeneous Ricci flow solution any sequence of parabolic blow-downs sub-converges to a homogeneous expanding Ricci soliton. This was established by constructing a new Lyapunov function based on curvature estimates which come from real geometric invariant theory.
- Robert Bryant, who presented results about the local structure of solitons for the Laplacian flow on closed G2-structures, in particular their local generality.
- Peter Petersen addressed whether one can estimate from above the volume of the boundary of an Alexandrov space in terms of curvature of the space and convexity of the boundary and what spaces allow for maximal volume boundary.
- Guofang Wei presented work that gave an optimal estimate for the volume entropy in terms of integral Ricci curvature, substantially improves an earlier estimate of Aubry, and provided an application on the algebraic entropy of its fundamental group. She also discussed extending the quantitative almost maximal volume entropy rigidity of Chen-Rong-Xu and almost minimal volume rigidity of Bessières-Besson-Courtois-Gallot to integral Ricci curvature, in research she has collaborated on with Lina Chen.

WORKSHOP PARTICIPATION

63	attendees
5	postgraduate students
14	ECRs
12	women
43	international participants

The conference concluded with a problem session focusing on known geometric problems as well as new problems arising from conference discussions. Several new collaborations between Australian and overseas participants were established during the conference and the subsequent symposium, and new projects were initiated.

Note: *AMSI sponsored the conference held during the first week of this 12-day MATRIX event.*

"Wonderful and exciting conference with the leading experts in Differential Geometry [sic] present, on a top international level."

Dr Xianfeng Wang, Australian National University

Participants at the Australian-German Workshop on Differential Geometry in the Large—Conference at MATRIX, Creswick PHOTO: SUPPLIED

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Assoc. Prof. Diarmuid Crowley, The University of Melbourne
Dr Yuri Nikolayevsky, La Trobe University
Dr Thomas Leistner, The University of Adelaide
Prof. Wilderich Tuschmann, Karlsruhe Institute of Technology, Germany

Special Presenters

Prof. Ben Andrews, Australian National University
Research Interests: differential geometry, PDE, and their applications
Prof. Dr Christoph Boehm, University of Muenster, Germany
Research Interests: differential geometry, Ricci flow, homogeneous and cohomogeneity one Einstein manifolds, positive Ricci curvature
Prof. Robert Bryant, Duke University, USA
Research Interests: geometric theory of PDEs, conservation laws for PDE, Finsler geometry, projective geometry, and Riemannian geometry, including calibrations and the theory of holonomy
Prof. Fuquan Fang, Capital Normal University, China
Research Interests: geometry, topology
Prof. Thomas Farrell, Tsinghua University, China
Research Interests: differential topology, in particular on classifying manifolds of a given homotopy type, geometry, algebra, discrete subgroups of Lie groups, algebraic K-theory
Prof. Rod Gover, University of Auckland, New Zealand
Research Interests: differential geometry, representation theory, analysis on manifolds, PDE theory, mathematical physics
Prof. Karsten Grove, University of Notre Dame, USA
Research Interests: metric and differential geometry, topology and geometric analysis
Prof. Dame Frances Kirwan DBE FRS, University of Oxford, UK
Research Interests: algebraic and symplectic geometry, moduli spaces in algebraic geometry, geometric invariant theory
Prof. Claude LeBrun, Stony Brook University, USA
Research Interests: Riemannian geometry, complex and differential geometry
Prof. Peter Petersen, University of California Los Angeles, USA
Research Interests: Riemannian geometry
Prof. Neil Trudinger, Australian National University
Research Interests: nonlinear elliptic PDEs, applied and nonlinear analysis
Prof. Guofang Wei, University of California Santa Barbara, USA
Research Interests: differential geometry, topology of manifolds
Prof. Burkhard Wilking, University of Muenster, Germany
Differential geometry, Riemannian geometry, Geometric evolution equations, particularly the Ricci Flow

MathSciNet Classification

53 Differential Geometry C Close

Web Links

matrix-inst.org.au/events/australian-german-workshop-on-differential-geometry-in-the-large-conference/

Other Sponsors

MATRIX, SPP2026 'Geometry at Infinity', National Science Foundation (USA), University of Melbourne International Research and Research Training Fund, AustMS, Ian Potter Foundation, La Trobe University

Key Contact

Dr Owen Dearricott, The University of Melbourne, owen.dearricott@gmail.com

1.10 SUBFACTORS IN SYDNEY

The University of New South Wales, 4–8 February 2019

Attended by prominent researchers within the subfactors community including two Fields Medallists, this Australian first resulted in several new collaborations between attendees.

Originating from the study of von Neumann algebras, subfactor theory has developed into a major area of mathematical research. Over the past three decades the field's evolution has been closely tied to research areas including operator algebras, quantum topology, representation theory and more recently conformal field theory.

Exploring major open problems in subfactor theory, including the question of realisation of subfactors by conformal theory and the relationship between Thompson's group and planar algebras, the workshop brought together researchers from nine different countries in addition to Australia.

Major themes included the mathematical foundations of topological quantum computing and quantum information theory, discussed in the talks of Freedman, Delaney, Musat, and Kawahigashi; and the relationship of conformal field theory to mathematical structures such as vertex operator algebras (VOAs), modular tensor categories, and subfactors, as discussed by Ridout, Tener, Gannon and Ram in their presentations.

The talks addressed cutting-edge areas of mathematical research, such as the relationship between fusion categories and topological phases of matter; and discussed major open problems, such as the realisation of exotic subfactors by conformal field theories. The schedule of talks was kept light to provide ample time for discussions and collaboration among the participants and included presentations by local and international mathematicians as well as several early career researchers.

Program highlights included:

- A presentation by Fields Medallist Vaughan Jones providing a new perspective on the long-standing mystery of the relation between the Hecke groups and the index of subfactors. The key challenge being to find a direct connection which links the discreteness of these groups to the admissibility of the index value. While this problem has been open for 30 years, Jones indicated a new approach to the problem using recent developments in the theory of planar algebras.
- A discussion exploring the linearity of the GNVW index in high dimensions lead by fellow Fields Medallist Michael Freedman. Introduced to measure net transport of quantum information, Freedman explained how topological tricks can be used to show that the index is additive for codimension one cycles.

WORKSHOP PARTICIPATION

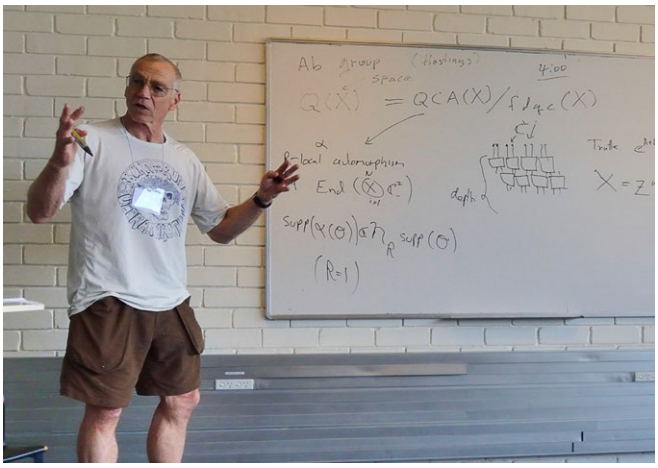
39	attendees
5	postgraduate students
10	ECRs
26	women
13	international participants

- Magdalena Musat's presentation on the recently developed relationship between von Neumann algebras and quantum information theory. Attendees benefited from her description of new infinite-dimensional phenomena in quantum information theory, arising from recent joint work with M. Bordam.
- Insights into a new operator algebraic approach to modular tensor categories appearing in studies of topological phases of matter presented by Yasuyuki Kawahigsahi. He offered new perspectives on a relative Verlinde formula in the context of a relative version of the boundary-bulk duality and the relative Drinfeld commutants of a fusion subcategory.
- The opportunity to join Terry Gannon in discussion on a hypothetical new construction, smashed-sum. This combines modular tensor categories into larger ones, a construction he conjectured may also exist in the VOA world, and in fact this may be its natural home. An example of such a VOA would be the mythical Haagerup VOA.

Participants took advantage of breaks in the program to develop and extend collaborations. James Tener and Terry Gannon had extremely successful meetings outlining an ambitious research plan to classify 'small' conformal field theories well beyond the scope of current knowledge, which they expect to guide research endeavours in the short- and medium-term future, while Andrew Schopieray and Terry Gannon continued their collaboration on Frobenius-Perron dimension of objects in fusion categories. In particular, they fleshed out the details of the proof of a claim they made in Banff that 'the centre of Haagerup cannot be realised by arbitrary extensions of the WZW VOA's' (can't be realised as local modules over a connected étale algebra in the quantum group modular tensor categories, or a modular subcategory thereof).

"I knew the workshop 'Subfactors in Sydney' would be very interesting, indeed I came to participate from almost the most distant point in the world! Scientifically, we could exchange important new ideas and make the point on different but related subjects [sic]."

Prof. Roberto Longo, University of Rome, Tor Vergata, Italy



Professor Sir Vaughan Jones (left) and Professor Michael Freedman (right) speaking at the Subfactors in Sydney workshop PHOTO: SUPPLIED

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Dr Pinhas Grossman, The University of New South Wales
Assoc. Prof. Scott Morrison, The Australian National University
A/Prof. Julia Plavnik, Indiana University, USA
Dr Andrew Schopieray, The University of New South Wales
Dr James Tener, The Australian National University

Special Presenters

Dr Daniel Barter, The Australian National University
Research Interests: category theory, representation theory, quantum algebra
Prof. Dietmar Bisch, Vanderbilt University, USA
Research Interests: von Neumann algebras, subfactors, quantum information theory, quantum physics
Dr Zsuzsanna Dancso, The University of Sydney
Research Interests: low-dimensional topology, quantum algebra, categorification
Colleen Delaney, University of California Santa Barbara, USA
Research Interests: topological quantum computation
Prof. Michael Freedman, Microsoft Quantum, Santa Barbara, USA
Research Interests: quantum computation, solid state physics, quantum topology
Prof. Terry Gannon, University of Alberta, Canada
Research Interests: conformal field theory, algebra, number theory, mathematical physics
Dr Iva Halacheva, The University of Melbourne
Research Interests: quantum algebra, geometric and combinatorial representation theory, knot theory, low-dimensional topology
Prof. Sir Vaughan Jones, Vanderbilt University, USA
Research Interests: von Neumann algebras, knot polynomials, conformal field theory
Prof. Yasuyuki Kawahigashi, University of Tokyo, Japan
Research Interests: operator algebras, Jones theory of subfactors, algebraic quantum field theory, conformal field theory, exactly solvable lattice models, quantum groups, quantum invariants in low-dimensional topology and vertex (operator) algebras
Prof. Gus Lehrer, The University of Sydney
Research Interests: algebraic and geometric aspects of representation theory, reductive algebraic groups, particularly over finite fields, algebraic geometry, spaces of configurations in algebraic varieties, Hecke and other algebras, cohomological group actions, knot-theoretic algebra, including diagram algebras and braid groups
Dr Galina Levitina, The University of New South Wales
Research Interests: operator theory, noncommutative analysis, noncommutative geometry, scattering theory
Prof. Roberto Longo, University of Rome, Tor Vergata, Italy
Research Interests: operator algebras, quantum field theory
Assoc. Prof. Magdalena Musat, University of Copenhagen, Denmark
Research Interests: functional analysis and operator algebras, analytic, geometric and probabilistic aspects of group theory, noncommutative probability theory, analysis in quantum information theory
Prof. Arun Ram, The University of Melbourne
Research Interests: combinatorial representation theory
Dr David Ridout, The University of Melbourne
Research Interests: mathematical physics, vertex operator algebras, conformal field theory
Dr Andrew Schopieray, The University of New South Wales
Research Interests: fusion categories, quantum algebra and tensor categories
Dr Alexander Stottmeister, University of Münster, Germany
Research Interests: quantum field theory, theoretical physics, mathematical physics, operator algebras, symplectic geometry,
Dr James Tener, The Australian National University
Research Interests: quantum field theory, conformal field theory, operator algebras, subfactors, geometric field theories, quantum algebra and tensor categories, vertex operator algebras, complex function theory
Assoc. Prof. Makoto Yamashita, University of Oslo, Norway
Research Interests: operator algebras, quantum groups, noncommutative geometry
Prof. Andrzej Zuk, University of Paris Diderot, France
Research Interests: analysis, geometry, probability on groups

MathSciNet Classification

46 Functional analysis L 37
46 Functional analysis N 50
18 Category theory; homological algebra

Web Links

https://sites.google.com/site/arnaudbrothier/organized-conferences-and-talks/subfactors-in-sydney-2019

Other Sponsors

AustMS, School of Mathematics and Statistics (UNSW), ARC

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SUBFACTORS IN SYDNEY

OPERATOR ALGEBRAS, REPRESENTATION THEORY, QUANTUM FIELD THEORY

By Dr Arnaud Brothier, Dr Pinhas Grossman, Associate Professor Scott Morrison, Assistant Professor Julia Plavnik, Dr Andrew Schopieray and Dr James Tener

INTRODUCTION TO SUBFACTORS

In the nineteenth century, scientists conducting physical experiments began noticing a number of strange phenomena which could not be explained by the laws of classical physics. In particular, the energy levels of certain physical systems seemed to take on only a discrete set of values, rather than covering a continuous spectrum as was expected. To explain this mysterious discovery, quantum mechanics was born. Two seemingly different theories emerged in the 1920's: Heisenberg's matrix mechanics and Schrödinger's wave mechanics.

It was soon realised that the Heisenberg and Schrödinger theories were equivalent. The underlying common mathematical structure is Hilbert space, an infinite-dimensional geometric analogue of Euclidean space. Abstractly, an "observable" in quantum mechanics corresponds to a linear operator on a Hilbert space associated to the physical system. One can also consider a collection of observables for a system, which leads to the mathematical notion of a ring, or an algebra, of operators. In the 1930s and 40s, Murray and von Neumann wrote a series of influential papers on what they called "rings of operators", now known as von Neumann algebras.

Classically, symmetry can often be expressed using the mathematical concept of a group. A key technique for understanding the structure of a group is to look for smaller symmetries, or subgroups, and then study how these subgroups are embedded in the larger group. Subfactor theory aims to follow a similar approach for von Neumann algebras. A "factor" is a type of relatively simple von Neumann algebra, and a subfactor is a smaller factor embedded inside a larger one. The embedding of the subfactor can be thought as a "quantum symmetry".

In the early 1980s, Vaughan Jones introduced the notion of index for a subfactor. Modelled after the index of a subgroup inside a group, the index is a number which measures the relative size of the subfactor. Jones proved the surprising fact that the index of a subfactor can take on any value greater than 4, but only a discrete spectrum of values below 4. Thus the index of a subfactor is "quantised".

In proving the index theorem, a key ingredient is the presence of Temperley-Lieb algebras, which had first appeared in work on statistical mechanics in the early 1970s. The Temperley-Lieb algebras are generated by elements which obey relations formally similar to relations satisfied by strings "braided" past each other in three-dimensional space.

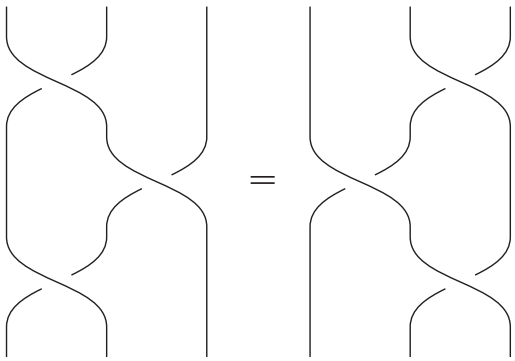

Figure 1: The braid group relation: $\sigma_i\sigma_{i+1}\sigma_i = \sigma_{i+1}\sigma_i\sigma_{i+1}$
Similarly the Temperley-Lieb relation is: $e_i e_{i\pm1} e_i = \tau e_i$
(for Temperley-Lieb algebras coming from a finite-index subfactor, the parameter is $\tau = [M : N]^{-1}$, the reciprocal of the Jones index).

Jones realised that there are natural representations of the braid group in the Temperley-Lieb algebras, which led to the surprising discovery of the Jones polynomial of a knot.

Two knots in three-dimensional space are considered to be equivalent if one can be deformed to the other without "cutting the string". A basic question in geometric topology is how to tell whether two knots are equivalent. The Jones polynomial is a powerful invariant which can distinguish certain knots that are not distinguished by earlier invariants such as the Alexander polynomial. Jones' discovery launched the new field of quantum topology, and Jones was awarded a Fields Medal in 1990.

Since the pioneering work of Jones in the 1980s, subfactor theory has developed into a mature branch of mathematics, sitting at the intersection of operator algebras, representation theory, and quantum topology. Of particular note is the discovery, through the classification of small-index subfactors by Haagerup and others, of "exotic" quantum symmetries.

In the opening talk of the workshop, Vaughan Jones presented a new perspective on the long-standing mystery of the relation between the Hecke groups and the index of subfactors. The key challenge is to find a direct connection which links the discreteness of these groups to the admissibility of the index value. While this problem has been open for 30 years, Jones indicated a new approach to the problem using recent developments in the theory of planar algebras.

In recent years, there has been increasing interaction between research in subfactors and mathematical physics. We will highlight two such connections, which were among the main themes of the workshop.

SUBFACTORS AND CONFORMAL FIELD THEORY

Algebraic quantum field theory, introduced by Haag and Kastler in the 1960s, is an approach to quantum field theory where the data of a theory is encoded by families of operator algebras associated to regions of spacetime. In chiral conformal field theory (CFT), the spacetime is a circle, and the assignment of von Neumann factors to intervals is called a conformal net. In this picture, local extensions of a given theory are related to finite-index subfactors of the algebras of observables.

Two of the main architects of the conformal net approach to CFT, Yasuyuki Kawahigashi, of the University of Tokyo, and Roberto Longo, of the University of Rome, Tor Vergata, spoke at the workshop on recent developments in the field.

One of the most intriguing questions in the field is whether every subfactor is "realised" by a CFT, in a suitable sense. Terry Gannon, of the University of Alberta, gave a talk at the workshop which detailed recent breakthroughs in his pioneering approach to realising exotic symmetries, such as the Haagerup subfactor, via CFT.

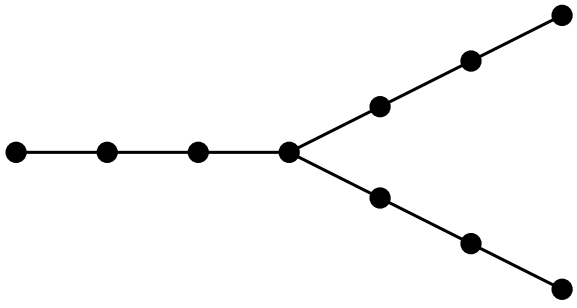

Figure 2: The principal graph of the Haagerup subfactor. Is this exotic quantum symmetry realised by conformal field theory?

SUBFACTORS AND QUANTUM COMPUTING

A computer stores information in "bits". A bit is a switch that can be in two positions, which can be called 0 and 1. When performing a calculation, the computer starts with a set of bits in some initial state, and then performs a sequence of operations on the bits according to an algorithm. The final state of the bits gives the result of the calculation.

Quantum computing seeks to use quantum mechanical systems to perform calculations. The initial state of a quantum computer is a set of "qubits", which correspond to vectors in a two-dimensional Hilbert space. To perform a calculation, the qubits are manipulated by acting on them with "quantum gates", which correspond to unitary matrices. Subtle properties of quantum mechanics, involving "cancelling probabilities", promise the possibility that certain computations can be performed much faster on a quantum computer.

Physically realising qubits and quantum gates is the subject of much current research, with scientists exploring a variety of approaches. One idea, proposed by Kitaev in the 1990s, is the topological quantum computer, in which particles called anyons in a two-dimensional space are braided over time.

Mathematically, a topological quantum computer can be modelled by a structure called a modular tensor category. Modular tensor categories first arose in conformal field theory, and are closely related to quantum topology. Modular tensor categories also appear as invariants of a certain type of subfactor. The representation theory of the subfactor is closely related to the structure of the corresponding modular tensor category.

Microsoft has a research lab in Santa Barbara, California, where a group of mathematicians and physicists works on building a topological quantum computer. The founder of this group is Michael Freedman, a topologist who was awarded the Fields Medal in 1986 for his work on the topology of four-dimensional spaces.

Freedman gave a talk at the workshop about the GNVW index, which measures transport of quantum information in 1-dimensional quantum mechanical systems, addressing possible generalisations to higher dimensions and applications to new invariants in low-dimensional topology.

$$I(P+Q) = I(P) + I(Q)$$

Figure 3: Freedman used topological tricks to show that for codimension 1 cycles, the GNVW index is additive.

Dr Arnaud Brothier *is a lecturer in the School of Mathematics at the University of New South Wales.*

Dr Pinhas Grossman *is a lecturer in the School of Mathematics at the University of New South Wales*

Associate Professor Scott Morrison *is a Future Fellow in the Mathematical Sciences Institute at The Australian National University*

Assistant Professor Julia Plavnik *is the Charlotte Ann Griffin Assistant Professor in the Department of Mathematics at Indiana University Bloomington (USA)*

Dr Andrew Schopieray *is a post-doc at The University of New South Wales*

Dr James Tener *is a lecturer in the Mathematical Sciences Institute at The Australian National University*

1.11 10TH INTERNATIONAL CONFERENCE ON MATRIX-ANALYTIC METHODS IN STOCHASTIC MODELS

Hobart, 13–15 February 2019

With a focus on theoretical developments and real-world applications of matrix-analytic methods (MAM), field leaders converged on Tasmania to explore recent research advances and new directions for investigation.

A branch of mathematics founded in the work by Marcel Neuts, MAM theory focuses on development of results well-suited for computer implementation. Stochastic models are analysed by purely probabilistic methods leading to efficient algorithms, rather than through the use of complex analysis techniques. This approach has resulted in many novel methodologies that have enriched the literature of queueing theory and applied probability in general.

MAM are used to discover probabilistic structures intrinsic to stochastic models and to develop numerical algorithms for computing performance metrics of the underlying stochastic processes. These probabilistic structures and computational algorithms can be applied to a wide variety of fields, including computer science and engineering, communication networks, electrical and industrial engineering, operations research, management science, bio-statistics and financial and risk analysis, providing deep insights and understanding from a mathematical and applications perspective.

This year's program focused on the strong interplay between theoretical advances and applications in real world systems. Theoretical results lead to algorithms that can be implemented in applications, while real-life problems inspire the development of the theory. Research themes included branching processes, random walks, phase-type distributions, matrix-exponential distributions, stochastic fluid models, quasi-birth-and-death processes and Brownian motion, as well as applications to real-world problems in epidemics, health care modelling and evolution.

There were several very interesting talks on theoretical and numerical topics in the area. For example, novel algorithms were presented that will improve the efficiency of practical applications of the matrix-analytic methods, which rely on such algorithms. Novel theoretical results were reported, which will drive future research on new models and methodologies.

WORKSHOP PARTICIPATION

45 attendees
13 postgraduate students
9 ECRs
12 women
19 international participants

Among the highlights were:

- Tutorial-style invited talks on Lévy processes and Markovian additive processes delivered by keynote speakers Jevgenijs Ivanovs and Zbigniew Palmowski, highlighting the potential for further advances in the theory of MAMs
- Keynote speaker Giang Nguyen presented novel results on convergence of stochastic fluid processes to Markovian-modulate Brownian motion
- Keynote speaker Phil Pollett gave an invited talk on quasi stationarity, a topic of interest to probabilists developing theoretical results as well as researchers working in the area of modelling evolution

The range of topics covered was an indication that the theory of matrix-analytic methods is an area with many exciting ongoing projects as well as opportunities for future research, for collaborative teams involving universities in Australia and abroad. Workshop participants indicated interest in continuing the series of MAM workshops into the future.

University of Tasmania PhD student Aviva Samuelson took out the Student Prize for Best Talk for her presentation on the *Construction of algorithms for discrete-time quasi-birth-and-death processes through physical interpretation*.

The proceedings of the conference were published online (maths.utas.edu.au/People/oreilly/mam/proceedings_final.pdf) and a series of papers will be published in a special issue of *Stochastic Models* (tandfonline.com/toc/lstm20/current) devoted to this conference.

"MAM10 was an outstanding workshop, most likely the best of the series."

Anonymous

Organisers

Assoc. Prof. Małgorzata O'Reilly, University of Tasmania
Dr Sophie Hautphenne, The University of Melbourne
Dr Federico Poloni, University of Pisa
Dr Mark Fackrell, The University of Melbourne
Prof. Barbara Holland, University of Tasmania
Dr Michael Brideson, University of Tasmania

Special Presenters

Dr Azam Asanjarani, University of Auckland
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Research Interests: applied probability, queueing theory, insurance risk, and simulation methodology
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Dr Giang Nguyen, The University of Adelaide
Research Interests: stochastic differential equations, Markov-modulated Brownian motion, stochastic fluid flows, matrix-analytic methods, branching processes, the Hamiltonian cycle problem
Prof. Zbigniew Palmowski, Wrocław University of Science and Technology, Poland
Research Interests: applied probability, stochastic modelling, stochastic processes, risk analysis, quantitative finance
E/Prof. Phil Pollett, The University of Queensland
Research Interests: Markov process theory, mathematical modelling

MathSciNet Classification

60 Probability theory and stochastic processes K 20
60 Probability theory and stochastic processes J 20
60 Probability theory and stochastic processes J 28

Web Links

www.maths.utas.edu.au/People/oreilly/mam/mam10.html

Other Sponsors

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Key Contact

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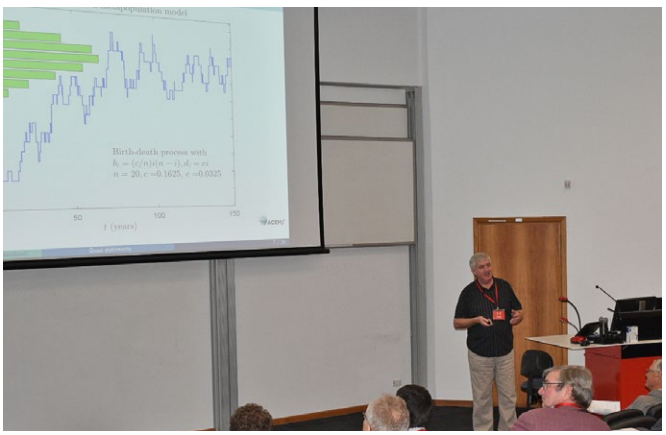
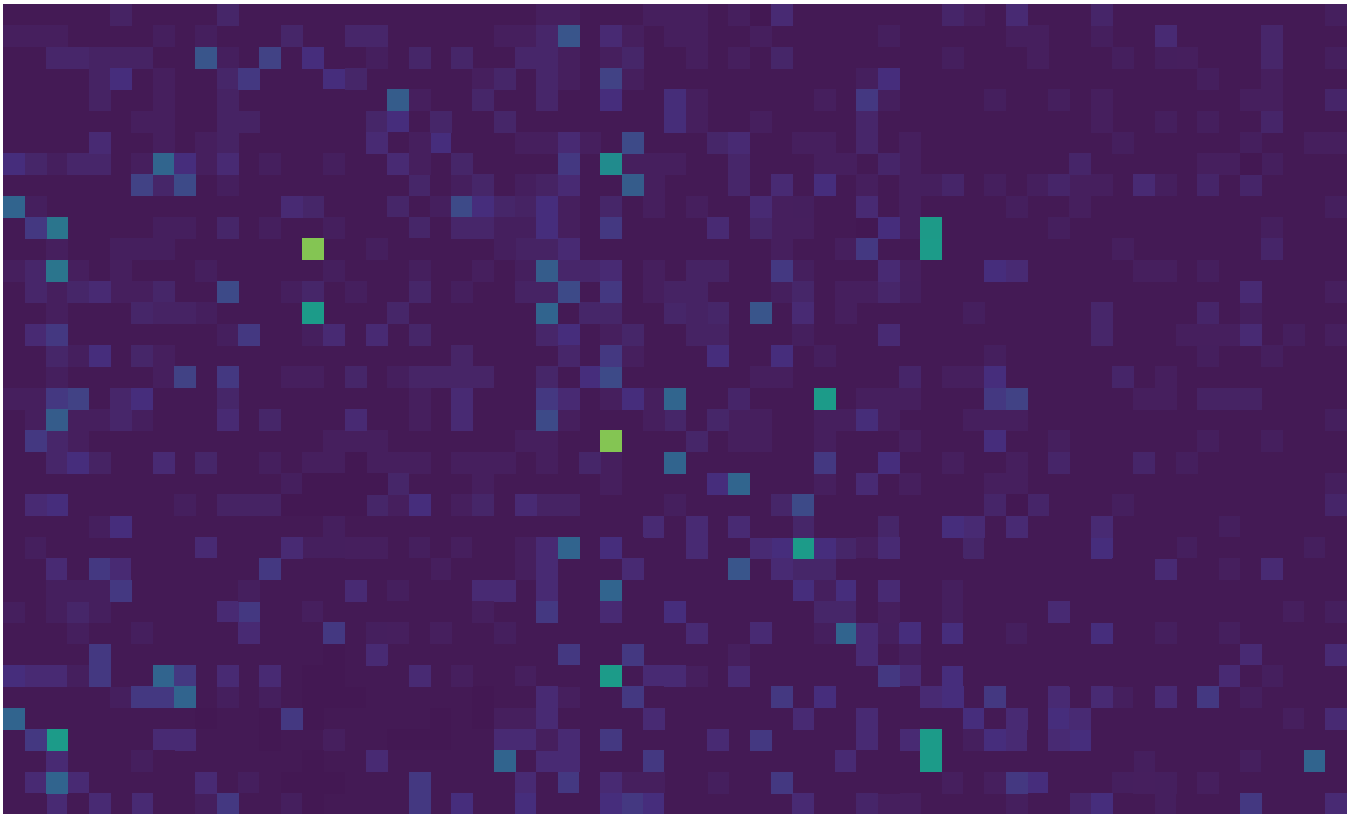


Participants at the 10th International Conference on Matrix-Analytic Methods in Stochastic Models PHOTO: SUPPLIED



MATRIX-ANALYTIC METHODS

STOCHASTIC MODELS FOR THE REAL WORLD

By Associate Professor Małgorzata O'Reilly and Professor Barbara Holland

The algorithmic approach to the craft of probabilistic modelling was pioneered by Professor Marcel Neuts, the founding editor of *Stochastic Models*, who brought a breath of fresh air into the theory of applied probability. His transformative idea was that, rather than developing mathematical structures that have little use for practical applications, the focus should be on constructing models and methods of analysis that can be applied efficiently, using fast algorithms and computers.

Since then, this area of research, known as matrix-analytic methods (MAMs), has expanded in many exciting directions, involving theoretical analysis of a multitude of stochastic models, algorithms for fast computation of performance measures of interest, and applications to a diverse range of real-world problems.

The *10th International Conference on Matrix-Analytic Methods in Stochastic Models* (MAM10), held at the University of Tasmania in Hobart in 2019, attracted collaborative teams of mathematicians, from all over the world, to discuss the recent advances in the area. The talks highlighted novel theoretical and numerical results for MAMs, and the expanding breadth of applications. Several talks were presented on topics in healthcare modelling, and in phylogenetics, showing a growing interest in the potential of MAMs in new application areas.

CASE STUDY: THE PROBABILITIES OF EXTINCTION IN A BRANCHING RANDOM WALK

Dr Sophie Hautphenne *is a Senior Lecturer within the School of Mathematics and Statistics at the University of Melbourne, and an Associate Investigator at the ARC Centre of Excellence of the Mathematical and Statistical Frontiers (ACEMS).*

Branching processes (BPs), one of Sophie's key research interests and contributions to MAMs, are a class of stochastic models for the evolution of a population of individuals. BPs have numerous applications in populations biology and phylogenetics. The models describe the dynamics of a population of individuals, in which each individual gives birth to a number of individuals of various types, at the end of their life. A question of interest is the probability of extinction of the population, in whole or part, as a function of the parameters of the model.

Lower Hessenberg Branching Processes (LHBPs) are a class of BPs with countably many types, in which the mean progeny matrix M has a lower Hessenberg form. Here, the (i,j)th entry of M is interpreted as the expected number of type-j children born to a parent of type i. Sophie, in her recent collaborative work on the LHBPs with Dr Peter Braunsteins, has established criteria for extinction, and an algorithm for computing the probabilities of

extinction in any subset of types.

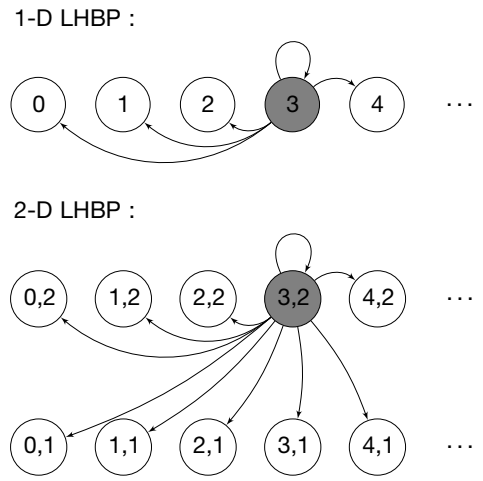
By adding further dimensions to the LHBPs, multi-dimensional LHBPs — a novel class of models — can be obtained, which further extends the application potential of the BPs to real-world problems.

- We assume M is lower Hessenberg

$$M = \begin{bmatrix} m_{00} & m_{01} & 0 & 0 & 0 & \dots \\ m_{10} & m_{11} & m_{12} & 0 & 0 & \\ m_{20} & m_{21} & m_{22} & m_{23} & 0 & \\ \vdots & & & & & \ddots \end{bmatrix}$$

- Type $i \geq 0$ individuals cannot have offspring of type $j > i+1$.
- We assume $m_{i,i+1} > 0$ for all $i \geq 0$.

The structure of a one-dimensional LHBP (1-D LHBP).



Generalising 1-D LHBP to multi-dimensional LHBPs by adding layers. *(source: Dr Sophie Hautphenne.)*

CASE STUDY: APPLICATION OF STOCHASTIC MODELLING TO HEALTHCARE SYSTEMS

Aregawi Abera *is a PhD student at the University of Tasmania, working on stochastic modelling of healthcare systems.*

The patient admission scheduling problem (PAS) arises when patients arriving to the hospital system need to be assigned to beds in an optimal manner. The mathematical models in the literature so far apply a *deterministic* objective function $f(\sigma)$ which is the total of all costs, for a given assignment σ.

However, the optimal solutions obtained from deterministic models are inadequate for systems that evolve in a stochastic environment. Aregawi's contribution is a *stochastic* model with random arrivals and departures, and a stochastic objective function, which calculates the total expected cost. In order to evaluate the objective function, Aregawi assumed that a random variable L_p which records the length of stay of a patient of type p, follows a discrete phase-type distribution.

Aregawi's initial analysis indicates that the stochastic model outperforms the deterministic model to a considerable extent, as anticipated. Specifically, the expected cost of the optimal solution of the stochastic model, $f(\sigma^*)$, is considerably lower than the expected cost of the optimal solution of an existing deterministic model, $f(\sigma^L)$. Therefore, a stochastic model should be used in presence of random arrivals and departures, and the effect of randomness on the system may not be ignored.

Aregawi is currently working on the application of his model to real data, in collaboration with the bed management team at the Monash Medical Center in Melbourne.

$$\min_{\sigma} \Bigg\{ \sum_{p\in\mathcal{P}} \sum_{d\in\mathcal{D}} \sum_{r\in\mathcal{R}} c_{p,r,d} \times x_{p,r,d}(\sigma) \times Pr(L_p \geq d - d_p(\sigma)) + \sum_{p\in\mathcal{P}} \sum_{d\in\mathcal{D}} \sum_{r\in\mathcal{R}} c^{(T)}_{p,r,r^*,d} \times t_{p,r,r^*,d}(\sigma) \times Pr(L_p \geq d - d_p(\sigma)) + \sum_{d\in\mathcal{D}} \sum_{r\in\mathcal{R}} c^{(G)}_{r,d} \times P_r(Q_{r,d}(\sigma)) + \sum_{d\in\mathcal{D}} \sum_{r\in\mathcal{R}} c^{(O)}_{r,d} \times \left(\frac{\max\{0,\ E(Y_{r,d}(\sigma)) - \kappa_r\}}{\widehat{\kappa}_r - \kappa_r} \right) + \sum_{p\in\mathcal{P}} c^{(De)}_{p,d} \times \sum_{d\in\mathcal{D}} \left(\frac{d - d_p^{plan}}{d_p^{max} - d_p^{plan}} \right) \times y_{p,d}(\sigma) \Bigg\},$$

Stochastic objective function for the PAS problem, the five components involve allocation, transfer, violation of gender policy, overcrowding, and overstaying.

Families	Instances	$f(\sigma^L)$		$f(\sigma^*)$		$\Delta\,\%$
		Avg	Best	Avg	Best	
Small-Short	20 (20)	2,755	2,262	953	809	−65.4
Small-Medium	20 (20)	6,283	4,638	3,161	2,665	−49.7
Small-Long	20 (20)	14,994	12,484	10,922	9,864	−27.2

Example: The stochastic model outperforms the deterministic model by at least 27.2%. *(source: Aregawi Abera.)*

FUTURE DIRECTIONS

A research group from the Budapest University of Technology and Economics has developed a novel algorithm for inverting Laplace transforms, which has opened the door to efficient computations of many performance measures of significance in a wide range of applications. Currently, the applications of the MAMs are being pursued by a collaborative group in phylogenetics at the University of Tasmania. The applications of MAMs are also the key focus of members of the Cumberland Initiative Australia, a network of academics and healthcare professionals, whose aim is to transform the quality and the cost of healthcare delivery in hospital systems through systems thinking.

Conference proceedings of the MAM10 conference were published in 2019. A Special Issue of Stochastic Models devoted to full papers associated with this conference is currently in preparation. It is expected to appear in 2020.

The next MAM conference will be held in Seoul in 2021. We look forward to the new developments in the theory and applications of MAMs.

Małgorzata O'Reilly *is an Associate Professor within the School of Natural Sciences at the University of Tasmania, and an Associate Investigator at ACEMS.*

Barbara Holland *is a Professor within the School of Natural Sciences at the University of Tasmania.*

1.12 DYNAMICS AND NUMBER THEORY

Sydney, 12–14 June 2019

Resulting in the formation of several new collaborations, this workshop provided a rare opportunity for Australian number theory specialists to hear from international experts.

Number theory and ergodic theory are not as well represented in Australia as other fields of pure mathematics. This conference provided an opportunity for domestic mathematicians with an interest in this field to hear from several international experts in the fields of ergodic theory, homogeneous dynamics and analytic number theory. In particular the focus of the conference was on connections between ergodic theory and Diophantine approximation.

With a generous allocation of time for both talks and discussion, attendees including students and ECRs were encouraged to share ideas and form collaborative links.

Among the highlights were:

- Recent results presented by the renowned expert in ergodic theorems Alex Gorodnik. The results improve by the logarithmic factor the famous Littlewood conjecture in Diophantine approximation for a co-null set of pairs (alpha, beta) in the real plane.
- A talk by Dmitry Kleinbock on the topic of shrinking targets and the new challenges for this subject if instead of the event of being inside infinitely many of the targets, it is inside a co-finite set of the targets. The presented results have applications in Diophantine approximation.
- Sanju Velani's talk on mass transfer principle and its applications to Diophantine approximation, in particular his progress in some of Schmidt's problems.

Several new collaborations were formed during the conference, giving a significant boost to the subjects of dynamics and number theory in Australia. These include a joint project between John Griesmer and Alexander Fish in additive combinatorics, which is still in the early stages of the development but has the potential to resolve a central problem open for more than 40 years.

Another collaboration initiated at the workshop between Johannes Schelishitz and Dzmitry Badziahin at the University of Sydney in the area of Diophantine approximation, is focusing on new estimates on Hausdorff dimension for certain well-behaved points on manifolds.

Additionally, a collaboration of Mumtaz Hussain and his PhD student Ayreena Bakhtawar (La Trobe University) with Dmitry Kleinbock might result in some joint projects which would be an excellent achievement.

WORKSHOP PARTICIPATION

30 attendees
3 postgraduate students
5 ECRs
7 women
9 international participants

Organisers

Assoc. Prof. Dzmitry Badziahin, The University of Sydney
Dr Alexander Fish, The University of Sydney
Dr Mumtaz Hussain, La Trobe University

Special Presenters

Assoc. Prof. Michael Bjorklund, Chalmers University, Sweden
Research Interests: ergodic theory, arithmetic combinatorics (mostly approximate groups), geometry and dynamics on homogeneous spaces
Dr Sam Chow, University of Oxford, UK
Research Interests: Diophantine approximation and Diophantine equations, with most of the techniques coming from additive combinatorics or harmonic analysis
Assoc. Prof. Michael Coons, The University of Newcastle
Research Interests: number theory, combinatorics, theoretical computer science, analysis, algebra, dynamical systems
Prof. Alexander Gorodnik, University of Zurich, Switzerland
Research Interests: theory of dynamical systems, number theory, geometry and representation theory
Dr John Griesmer, Colorado School of Mines, USA
Research Interests: ergodic theory, additive combinatorics, harmonic analysis
Dr Mumtaz Hussain, La Trobe University
Research Interests: analytical number theory, ergodic theory and dynamical systems, number theoretic applications
Prof. Dmitry Kleinbock, Brandeis University, USA
Research Interests: Lie groups, discrete subgroups and homogeneous spaces, ergodic theory and dynamical systems, metric Diophantine approximation
Prof. Bing Li, South China University of Technology, China
Research Interests: fractal geometry, geometric measure theory, dynamic system and ergodic theory, metric number theory, Diophantine approximation, random covering
Prof. Seonhee Lim, Seoul National University, South Korea
Research Interests: homogeneous dynamics and geometric group theory
Dr Alina Ostafe, The University of New South Wales
Research Interests: arithmetic dynamical systems, polynomials and rational functions over local and global fields, finite fields and their applications
Assoc. Prof. Johannes Schleischitz, Middle East Technical University, Turkey
Research Interests: number theory, geometry of numbers
Prof. Sanju Velani, University of York, UK
Research Interests: number theory, dynamical systems, and discrete groups

MathSciNet Classification

11 Number Theory
37 Dynamical Systems and Ergodic Theory

Web Links

maths.usyd.edu.au/DNT2019/

Other Sponsors

AustMS, The University of Sydney

Key Contact

Dr Alexander Fish, The University of Sydney, alexander.fish@sydney.edu.au

1.13 APPLICATIONS OF NONLINEAR DIFFUSION EQUATIONS 2019

Melbourne, 19–21 June 2019

Attended by a significant gathering of leading international experts in symmetry analysis of nonlinear PDEs, this three-day meeting looked at applications of nonlinear diffusion equations on a variety of physical problems and processes, facilitating ample discussions and new collaborations between participants.

Nonlinear diffusion equations can be used to describe processes and behaviours in fields as diverse as biology, heat transfer, ground water modelling, industrial processes, chemical reactions, and mathematical physics. Bringing together experts in the application and solution of nonlinear diffusion models, this workshop focused on two broad aspects: first, the use of nonlinear PDEs in modelling various physical problems, in particular in the areas of ground water flow, mathematical biology, and mathematical physics; and second, the use of symmetry techniques to find useful analytic solutions to these types of models.

The workshop was very friendly and collaborative, with a stimulating combination of theory and application. The three-day meeting facilitated a significant gathering of leading international experts in the field of symmetry analysis of nonlinear PDEs. There was ample time for questions both during and after the talks. The scheduled collaborative times each day were popular, with many vigorous discussions held in various parts of the workshop venue. At least four new collaborations were initiated during the workshop, and many existing collaborative works were progressed.

The program included 7 invited talks and 26 contributed talks on a wide range of topics relevant to nonlinear PDE models and applications to nonlinear diffusion models. Demonstrating Australia's world-class contributions to the field, 22 of the talks were given by Australian researchers.

Highlights among the invited speakers included:

- Phil Broadbridge's discussion of conditionally integrable nonlinear diffusion models, with applications to three different problems
- Roman Cherniha's presentation on some new Lie and conditional symmetries for a system of equations describing the spread of farmers into a region occupied by hunter-gatherers
- A talk on the Lie symmetry properties of two biologically-motivated problems by Maureen Edwards
- Institute of Mathematics for Industry (Kyushu University) Deputy Director Kenji Kajiwara's talk about Burgers-type equations in the deformation of curves
- Maria Nucci's discussion of the heir equation method, a technique she developed to systematically solve determining equations in systems of nonlinear PDEs
- A talk in two parts by Mary Pugh, focusing on electro-convection in liquid crystal film and ion transport with Faradaic reactions
- A discussion by Kyushu University's Vice President Masato Wakayama on the heat kernel of the quantum Rabi model describing a strongly coupled quantum system

A special issue of *Entropy* focusing on nonlinear diffusion equations as the result of irreversible processes is planned.

Organisers

Dr Rebecca Chisholm, The University of Melbourne
Dr Bronwyn Hajek, University of South Australia
Dr Dimetre Triadis, La Trobe University/Kyushu University Australia

Special Presenters

E/Prof. Philip Broadbridge, La Trobe University
Research Interests: mathematical physics, fundamental physics, applied nonlinear PDEs, hydrology, heat and mass transport and population genetics
Prof. Roman Cherniha, National Academy of Sciences of Ukraine, Ukraine
Research Interests: nonlinear PDEs, Lie and conditional symmetries, mathematical physics, mathematical biology
Dr Maureen Edwards, University of Wollongong
Research Interests: applied mathematics, mathematical models, nonlinear PDEs motivated by biological invasion and population dynamics, Lie symmetry techniques, nonlinear reaction-diffusion equations
Prof. Kenji Kajiwara, Kyushu University, Japan
Research Interests: discrete differential geometry, integrable systems, Painlevé systems, discrete and ultradiscrete systems
Assoc. Prof. Maria Clara Nucci, University of Perugia, Italy
Research Interests: Lie symmetries in classical and quantum mechanics, Lie symmetries in biomathematics, magnetohydrodynamics, history of mathematics
Prof. Mary Pugh, University of Toronto, Canada
Research Interests: scientific computing, nonlinear PDEs, fluid dynamics, computational neuroscience
Prof. Masato Wakayama, Kyushu University, Japan
Research Interests: representation theory, automorphic forms and zeta functions, harmonic analysis

MathSciNet Classification

01 Mathematical Sciences 02 07
01 Mathematical Sciences 02 99
01 Mathematical Sciences 05 99

Web Links

www2.math.kyushu-u.ac.jp/~ande2019/

Other Sponsors

La Trobe University, Institute of Mathematics for Industry (Kyushu University), AustMS

Key Contact

Dr Bronwyn Hajek, University of South Australia,
bronwyn.hajek@unisa.edu.au

WORKSHOP PARTICIPATION

48 attendees
8 postgraduate students
1 ECR
16 women
12 international participants

1.14 GEOMETRIC ANALYSIS AND HOMOGENEOUS GEOMETRY

The University of Queensland, 24–28 June 2019

Capitalising on recent momentum establishing Australia as a hub for geometry research, this workshop featured several prominent local and international experts, reinforcing and enhancing Australia's reputation in this field

In the recent past geometric analysis achieved many remarkable results and established a number of deep connections with other fields, reaching far beyond pure mathematics into areas such as relativity, quantum field theory, biology and ecological modelling.

Focusing on two related aspects, curvature flows and geometric differential equations on homogeneous spaces, this workshop aimed to bridge the gaps between the two areas, which are currently enjoying rapid development with numerous applications and have tremendous potential to advance each other. On the one hand, analysis of geometric flows on homogeneous spaces gives deep insights into the behaviour of these flows in general. On the other hand, flow techniques yield deep structure results for homogeneous spaces and help us understand Einstein metrics. The workshop facilitated interaction between researchers in the two fields, resulting in new effective collaborations and impact across a range of fields, from pure mathematics to physics and other sciences.

Highlights of the conference included talks by:

- Gérard Besson, who discussed whether there is any relation between the entropy of a closed manifold and the algebraic entropy of its fundamental group, describing some instances in the case of Gromov-hyperbolic spaces in which the relationship exists
- UCLA geometer Peter Petersen, who gave an overview of known analytical techniques for bounding Betti numbers and simplifying tolls for controlling the curvature terms appearing in Lichnerowicz Laplacians
- Meera Mainkar, who proved that a homogeneous 3-sphere is naturally reductive if and only if all of its metric foliations are homogeneous
- Wolfgang Ziller, who discussed the initial-value problem for the Einstein equation, Ricci soliton equation and the prescribed Ricci curvature problem on a cohomogeneity one manifold with singular orbits

WORKSHOP PARTICIPATION

34 attendees
3 postgraduate students
8 ECRs
4 women
17 international participants

Ample discussion time was built into the program, including a free session on Wednesday afternoon, during which Christoph Bohm led an extended learning session aiming to understand significant but convoluted works by Graev.

In addition, several collaborations were established and intensified during the conference. One example is an ongoing collaboration between Timothy Buttsworth, Artem Pulemotov and Wolfgang Ziller, which resulted in several new projects conceived at the conference, focusing on the study of prescribed curvature problems on homogeneous and cohomogeneity-one manifolds. A paper on this subject by Pulemotov and Ziller is in the final stages of preparation. A number of future research visits by the participants to each other's home institutions were planned.

While the expected numbers of postgraduate students was low, the number of undergraduate students attending the conference exceeded expectations, providing them with the opportunity to network with leading experts in the field.

The organisers have discussed the possibility of a new conference on similar topics at The University of Queensland to be held in three to five years.

"Apart from excellent talks by a well-balanced spectrum of promising early career researchers through to field-leading experts, the conference also gave me the opportunity to discuss current research with participants, leading to some promising new directions."

Dr Paul Bryan, Macquarie University

Participants at the Geometric Analysis and Homogeneous Geometry workshop held at The University of Queensland PHOTO: SUPPLIED

Organisers

Dr Romina Arroyo, The University of Queensland
Dr Wolfgang Globke, The University of Vienna, Austria
Dr Ramiro Lafuente, The University of Queensland
Dr Yuri Nikolayevsky, La Trobe University
Dr Artem Pulemotov, The University of Queensland

Special Presenters

Dr Romina Arroyo, The University of Queensland
Research Interests: geometric flows in homogeneous spaces
Assoc. Prof. Andreas Arvanitoyeorgos, University of Patras, Greece
Research Interests: Lie groups and homogeneous spaces, homogeneous Einstein metrics, geometry of submanifolds, didactics of mathematics
Prof. Gérard Besson, University of Grenoble, France
Research Interests: geometry, geometric analysis, topology
Prof. Christoph Böhm, University of Münster, Germany
Research Interests: differential geometry, Ricci flow, Einstein geometry of homogeneous and cohomogeneity one spaces, positive Ricci curvature
Dr Paul Bryan, Macquarie University
Research Interests: geometric analysis, particularly hypersurface flows
Timothy Buttsworth, The University of Queensland
Research Interests: geometry of Lie groups and homogeneous spaces, geometric PDEs, theory of ordinary differential equations
Prof. Vicente Cortés, The University of Hamburg, Germany
Research Interests: differential geometry
Dr Jonas Deré, KU Leuven, Belgium
Research Interests: hyperbolic dynamical systems, expanding maps, Anosov diffeomorphisms, separability problems of finitely generated groups, geometry of homogeneous manifolds, geometric group theory
Prof. Anthony Dooley, University of Technology Sydney
Research Interests: harmonic analysis, dynamical systems
Assoc. Prof. Meera Mainkar, Central Michigan University, USA
Research Interests: Lie theory
Prof. Yurii Nikonorov, Vladikavkaz Scientific Center, Russian Academy of Sciences
Research Interests: integral mean value theorems, integral inequalities with deviating argument, convex geometry, differential geometry, global Riemannian geometry, homogeneous spaces, Einstein homogeneous manifolds, geodesic orbit spaces, killing vector fields of constant length
Prof. Jeonghyeong Park, Sungkyunkwan University, Korea
Research Interests: geometric structures on manifolds, spectral geometry, differential geometry, foliation theory
Prof. Peter Petersen, University of California Los Angeles, USA
Research Interests: Riemannian geometry
Prof. Gerd Schmalz, University of New England
Research Interests: complex analysis and geometry
Prof. Hiroshi Tamaru, Osaka City University
Research Interests: differential geometry, Lie groups, homogeneous spaces
Assoc. Prof. Luigi Vezzoni, University of Torino
Research Interests: Special structures with torsion on real and complex manifolds
Prof. Joseph Wolf, University of California Berkeley, USA
Research Interests: Lie groups and homogeneous spaces, harmonic analysis, complex manifolds, Riemannian geometry
Dr Haotian Wu, The University of Sydney
Research Interests: geometric analysis, differential geometry, PDEs
Assoc. Prof. William Wylie, Syracuse University
Research Interests: differential geometry, Riemannian geometry, geometric analysis
Assoc. Prof. Zhou Zhang, The University of Sydney
Research Interests: complex differential geometry, several complex variables, algebraic geometry
Prof. Wolfgang Ziller, University of Pennsylvania
Research Interests: Einstein metrics, geometry of homogeneous metrics, symmetric spaces, biquotients, equivariant geometry, and existence of closed geodesics, geometry and topology of cohomogeneity one manifolds, manifolds with non-negative or positive sectional curvature

MathSciNet Classification

53 Differential Geometry C 44
53 Differential Geometry C 30

Web Links

people.smp.uq.edu.au/ArtemPulemotov/gahs19

Other Sponsors

AustMS, The University of Queensland, La Trobe University

Key Contact

Dr Artem Pulemotov, The University of Queensland, a.pulemotov@uq.edu.au

1.15 WORKSHOP ON MATHEMATICAL BILLIARDS

Sydney, 24–27 June 2019

Underrepresented in Australian research, mathematical billiards is a key aspect of dynamical systems used to model a number of complex phenomena. This workshop brought together several international experts to share their knowledge with local mathematicians.

Mathematical billiards—a key area in dynamical systems—have been an established topic for research since the early 20th century. Many complex phenomena can be modelled using a simple mathematical billiards setting involving collisions and reflections. Such phenomena occur naturally in various parts of mathematics and mathematical physics dealing with physical models, e.g. in geometry, scattering theory and spectral theory of partial differential equations. Various applications of billiard models are used in laser techniques, the statistical interpretation of the second law of thermodynamics, the dynamics of ideal gas and the modelling of aerodynamic resistance of various bodies.

The field of mathematical billiards is at the cutting edge of mathematics research, and work in the field is highly valued: two recipients of the Fields Medals in 2014, Artur Avila and Maryam Mirzakhani, were recognised for their contributions in the area.

In spite of the importance and popularity of mathematical billiards, research in this area is underrepresented in the Australian mathematical community. This workshop brought some of the most prominent international experts in the field to Australia to provide updates on current research.

In total 17 lectures were presented at the workshop, including 3 by students. A generous amount of discussion time was provided each day and an afternoon was devoted to an open-problem session which identified many questions of interest to participants.

Attracting a wider audience from the University of Sydney's School of Mathematics and Statistics, several high-profile international participants gave outstanding talks that were particular highlights, including:

- Leonid Bunimovich, who spoke about the relationship between mathematical and physical billiards
- Vered Rom-Kedar, whose presentation was about near separable systems with impacts
- Alexey Glutsyuk, who spoke about curves with Poritsky properties and Liouville nets

The workshop participants hope to organise a similar workshop in Australia in a couple of years.

WORKSHOP PARTICIPATION

19	attendees
5	postgraduate students
2	ECRs
7	women
13	international participants

Organisers

Dr Milena Radnovic, The University of Sydney
Dr Vera Roshchina, The University of New South Wales
Prof. Luchezar Stoyanov, The University of Western Australia
Dr Viktoria Vedyushkina, Moscow State University, Russia

Special Presenters

Prof. Leonid Bunimovich, Georgia Institute of Technology, USA
Research Interests: dynamical systems, ergodic theory, statistical mechanics, mathematical physics, mathematical biology
Prof. Vladimir Dragovic, University of Texas, Dallas, USA
Research Interests: integrable dynamical systems, algebraic and differential geometry, applications to classical and statistical mechanics
Assoc. Prof. Krzysztof Fraczek, Nicolaus Copernicus University, Poland
Research Interests: ergodic theory and dynamical systems, spectral theory of dynamical systems, cohomology of cocycles, smooth ergodic theory
Dr Alexey Glutsyuk, CNRS, Ecole Normale Supérieure, Lyon, France
Research Interests: real and complex dynamic systems: billiards, the analytical theory of ordinary differential equations, holomorphic foliations, transformation groups, Josephson effect model in superconductivity
Assoc. Prof. Kei Irie, The University of Tokyo, Japan
Research Interests: symplectic Floer theory and related topics
Prof. Nalini Joshi, The University of Sydney
Research Interests: integrable systems, the Painlevé equations, discrete Painlevé equations, lattice equations, geometric asymptotics, nonlinear dynamics, nonlinear waves, perturbation theory
Dr Andrey Mironov, Sobolev Institute of Mathematics, Russia
Research Interests: integrable systems, geometry, mathematical physics, dynamical systems
Prof. Sonia Pinto de Carvalho, Universidade Federal de Minas Gerais, Brazil
Research Interests: dynamical systems, chaos theory, differential equations, nonlinear dynamics, nonlinear systems, nonlinear physics, mathematical biology, chaotic dynamics and applications
Prof. Vered Rom-Kedar, Weizmann Institute of Science, Israel
Research Interests: steep billiard-like potentials, transport theory, chaotic fluid mixing, exponentially small splitting, forced NLS and parabolic resonances, modelling and medicine
Prof. Imre Peter Toth, Budapest University of Technology and Economics, Hungary
Research Interests: hyperbolic dynamical systems, chaotic billiards, mathematical statistical physics

MathSciNet Classification

37 Dynamical Systems and Ergodic Theory Close

Web Links

mathbilliards.org/

Other Sponsors

AustMS, UNSW, The University of Sydney, UWA

Key Contact

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Participants at the Workshop on Mathematical Billiards

PHOTO: SUPPLIED

Lecture Series 2

2018 AMSI-SSA Lecturer Professor Susan Murphy, Harvard University, USA

PHOTO: MICHAEL SHAW

2 LECTURE SERIES

Through world-class national tours, specialist lectures and outreach events, AMSI stimulates discussion and collaboration at the cutting edge of the mathematical sciences. Both challenging and inspiring, close engagement with international field experts enhances the research experience for students, early career researchers and established mathematical scientists.

In 2018 and 2019 AMSI sponsored
13 specialist talks and
7 public lectures through the
AMSI–SSA and Mahler Lecture series

The proposed 2019 AMSI-ANZIAM Lecture Tour did not go ahead for reasons beyond the control of AMSI and ANZIAM

2.1 2018 AMSI-SSA LECTURER

Professor Susan Murphy, Harvard University, USA

14–24 August 2018

Co-sponsored by AMSI and the Statistical Society of Australia (SSA), this biennual lecture tour provides both the mathematical sciences research community and the general public with the opportunity to engage with top international statisticians.

Featuring Susan Murphy, Professor of Statistics at Harvard University, the 2018 AMSI-SSA Lecture Tour delivered a series of five public lectures and four specialist talks on two topics, in Adelaide, Perth, Melbourne, Brisbane and Sydney, to more than 500 attendees in total.

With a background in clinical trial design and data analysis, Professor Murphy explored the possibilities of mobile devices and wearable sensors as health-intervention aids that can indicate optimal times and places for treatment. AMSI outreach was supported by media engagement, including coverage in *The Australian*. With three different perspectives on the topic of mobile health, the 2018 AMSI-SSA Lecture Tour encouraged the research and general communities to engage with new ideas at the cutting edge of statistics.

Biography

Susan A. Murphy is Professor of Statistics, Professor of Computer Science at the Harvard John A. Paulson School of Engineering and Applied Sciences and Radcliffe Alumnae Professor at the Radcliffe Institute at Harvard University. Her lab focuses on improving sequential, individualised decision-making in health, in particular on clinical trial design and data analysis to inform the development of personalised just-in-time adaptive interventions in mobile health. Her work is funded by the National Institutes of Health, USA.

Susan is a Fellow of the Institute of Mathematical Statistics, a Fellow of the College on Problems in Drug Dependence, a former editor of the *Annals of Statistics*, a member of the US National Academy of Sciences, a member of the US National Academy of Medicine and a 2013 MacArthur Fellow.

ATTENDANCE

525 people attended the lecture series including:
351 at the public lectures and
174 at the specialist lectures

Tour Schedule

Date	Host	Type
14 Aug	La Trobe University	Public Lecture
15 Aug	The University of Melbourne	Specialist Lecture – Topic 2
16 Aug	Flinders University	Public Lecture
16 Aug	Flinders University	Specialist Lecture – Topic 2
20 Aug	Murdoch University	Public Lecture
22 Aug	The University of Queensland	Public Lecture
22 Aug	Queensland University of Technology and The University of Queensland	Specialist Lecture – Topic 1
23 Aug	University of Technology Sydney	Public Lecture
24 Aug	Macquarie University	Specialist – Topic 2

2018 AMSI-SSA Lecturer Professor Susan Murphy, Harvard University, USA PHOTO: MICHAEL SHAW

Lecture Topics

PUBLIC LECTURE: OPTIMISING MOBILE HEALTH INTERVENTIONS

Mobile devices along with wearable sensors allow us to deliver supportive treatments, anytime and anywhere. Mobile interventions are transforming treatments and preventative health management, including support for HIV medication adherence, assisting recovery in addictions and encouraging physical activity and healthy eating. The question remains: 'when and in which contexts is it most useful to deliver treatments to the user?' Using data, we can determine if key factors such as location, stress, time of day, mood, ambient noise and so on, impact when and where these treatments are most useful. This talk concerned a new clinical trial design: the micro-randomised trial and associated data analytics for use in addressing this question. The talk used multiple mobile health studies including the study 'HeartSteps: A Physical Activity Mobile Intervention' to illustrate the ideas.

SPECIALIST LECTURE – TOPIC 1: STRATIFIED MICRO-RANDOMISED TRIALS WITH APPLICATIONS IN MOBILE HEALTH

Technological advancements in the field of mobile devices and wearable sensors make it possible to deliver treatments anytime and anywhere to users like you and me. Increasingly the delivery of these treatments is triggered by detections/predictions of vulnerability and receptivity. These observations are likely to have been impacted by prior treatments. Furthermore the treatments are often designed to have an impact on users over a span of time during which subsequent treatments may be provided. Here we discussed our work on the design of a mobile health smoking cessation study in which the above two challenges arose.

This work involved the use of multiple online data analysis algorithms. Online algorithms are used in the detection, for example, of physiological stress. Other algorithms are used to forecast at each vulnerable time, the remaining number of vulnerable times in the day. These algorithms are then input into a randomisation algorithm that ensures that each user is randomised to each treatment an appropriate number of times per day. We developed the stratified micro-randomised trial which involved not only the randomisation algorithm but a precise statement of the meaning of the treatment effects and the primary scientific hypotheses along with primary analyses and sample size calculations. Considerations of causal inference and potential causal bias incurred by inappropriate data analyses played a large role throughout.

SPECIALIST LECTURE – TOPIC 2: ASSESSING TIME-VARYING CAUSAL INTERACTIONS AND TREATMENT EFFECTS WITH APPLICATIONS TO MOBILE HEALTH

Mobile devices along with wearable sensors facilitate our ability to deliver supportive treatments anytime and anywhere. Indeed mobile interventions are being developed and employed across a variety of health fields, including to support HIV medication adherence, encourage physical activity and healthier eating as well as to support recovery in addictions. A critical question in the optimisation of mobile health interventions is: 'when and in which contexts is it most useful to deliver treatments to the user?' This question concerns time-varying dynamic moderation by the context (location, stress, time of day, mood, ambient noise, etc.) of the effectiveness of the treatments on user behaviour. In this talk we discussed the micro-randomised trial design and associated data analyses for use in assessing moderation. We illustrated this approach with the micro-randomised trial of HeartSteps, a physical activity mobile intervention.

WHAT MAKES AUSTRALIA'S MINDTICK? MOBILE HEALTH OPTIMISING CARE

Optimising mobile health interventions such as MindTick, now trialling in Adelaide, may transform mental health management, particularly for Australians living in remote and regional areas, says Harvard Professor Susan Murphy.

A global leader in statistics and computer science, she is using mathematics and statistics to explore how Australia can optimise mobile health technology including phone apps to support management of chronic illness and mental health.

"Using data, we can determine the impact of key factors such as location, stress, time of day and mood on when and where treatments are most useful," she explains.

As Aussie farmers struggle with mental health in drought conditions, Murphy believes technology, including her Australian collaboration, MindTick, could deliver enormous benefits for Australians unable to frequently access health services.

"Mobile health interventions are readily accessible to people who live in rural or isolated areas expanding service delivery and access to critical supports"

Long-time collaborator Associate Professor Niranjan Bidargaddi is based at Flinders University in Adelaide, and works closely with Murphy on mobile interventions, including the development of MindTick.

Now in trial, the Flinders University-developed phone app aims to assist early diagnosis and management of mental illness using mobile phone data to monitor known risks and trigger intervention.

"By detecting subtle changes in user feelings and behaviour, we can act on early warning signs before a crisis," explains Bidargaddi.

As well as enabling naturalistic intervention to support self-management and awareness of support needs in the participant's own environment, it is hoped the tool will allow personalised care and prioritisation of crisis patients.

Flinders University Professor of Psychiatry and member of the Beyond Blue Board of Directors Michael Baigent says Australians have benefited from similar apps such as the Beyond Now app. He believes MindTick will change mental healthcare.

"The MindTick app offers many patient and therapeutic benefits with the potential to bring about game-changing results in research and treatment," he says.

2.2 2018 MAHLER LECTURER

Professor Ivan Corwin, Columbia University, USA

29 October – 9 November 2018

The Mahler lectures are a biennial activity organised by the Australian Mathematical Society (AustMS), and supported by AMSI, in which a prominent mathematician tours Australian universities giving lectures at a variety of levels, including several public lectures.

Co-sponsored by AMSI and AustMS, the 2018 Mahler Lecture Tour featured Ivan Corwin, Professor of Mathematics at Columbia University. During the tour, Professor Corwin visited universities in Canberra, Adelaide, Melbourne, Brisbane and Sydney to deliver a series of lectures (*Beyond the Gaussian Universality Class*) and specialist talks on three topics (*Random Permutations, Partitions and PDEs*, *Diffusion in Random Media* and *The Stochastic Six-Vertex Model*).

Biography

Ivan Corwin is currently a Professor of Mathematics at Columbia University. His thesis included (in joint work with Amir and Quastel) the exact solution to the Kardar–Parisi–Zhang stochastic PDE. Subsequently, with Borodin, he introduced and developed the theory of Macdonald processes. Along with other collaborators, he has developed the area of Integrable Probability, including the study of stochastic vertex models and the Markov duality approach. He has also worked on discrete approximation theory to stochastic PDEs.

Corwin received his PhD from the Courant Institute in 2011 and has since held positions at Microsoft Research, MIT, Institute Henri Poincaré and now Columbia. He was a Clay Research Fellow and is presently a Packard Fellow, and a Fellow of the Institute of Mathematical Statistics. He was the recipient of the Alexanderson Award, Rollo Davidson Prize and Young Scientist Prize of the IUPAP, and gave an invited lecture at the 2014 International Congress of Mathematics.

Lecture Topics

BEYOND THE GAUSSIAN UNIVERSALITY CLASS

The Gaussian distribution describes fluctuations arising in many systems across mathematics, science and society. However, complex random systems such as those related to interface growth, big data, stochastic optimisation, traffic/queuing flow and stochastic PDEs often do not fall into this universality class. This talk will explain how these and other important types of real-world systems fall into a different universality class—the so-called Kardar-Parisi-Zhang class.

RANDOM PERMUTATIONS, PARTITIONS AND PDEs

We start with a seemingly innocuous question — what do large random permutations look like? Focusing on the structure of their increasing subsequences we encounter some remarkable mathematics related to symmetric functions (e.g. Schur and Macdonald), random matrices and stochastic PDEs.

DIFFUSION IN RANDOM MEDIA

In 1827 the botanist Robert Brown observed the seemingly irregular motion of pollen immersed in water. A mathematical model for this Brownian motion was proposed later by Einstein in 1905. Since then, it is well validated that motion in quickly mixing random media is well modelled by Brownian motion. In this talk we consider what happens when many particles are released in the same media. Do they behave like independent Brownian motions or does their common environment affect their collective behaviour? We will see that the extreme-value statistics (i.e. largest displacement) are heavily influenced by the random media and in a one-dimensional model, relying upon some surprising exact solvability techniques from quantum integrable systems, we will relate these statistics to random matrix theory and the Kardar–Parisi–Zhang universality class for random growth models.

THE STOCHASTIC SIX-VERTEX MODEL

From statistical physics to quantum algebra, the six-vertex model has enthralled generations of physicists and mathematicians. In this talk we will discuss a less-studied stochastic twist of the model and highlight a few remarkable recent results. The talk will touch on topics including the Bethe Ansatz, symmetric function theory and stochastic PDEs.

Tour Schedule

Date	Host	Lecture Title
29 Oct	University of Sydney	Random Permutations Partitions and PDEs
30 Oct	University of Technology Sydney	Beyond the Gaussian Universality Class
31 Oct	Macquarie University	Public Lecture: Beyond the Gaussian Universality Class
1 Nov	Australian National University	Beyond the Gaussian Universality Class
2 Nov	La Trobe University	Diffusion in Random Media
5 Nov	Monash University	Random Permutations Partitions and PDEs
6 Nov	University of Melbourne	Diffusion in Random Media
7 Nov	University of Melbourne	Public Lecture: Beyond the Gaussian Universality Class
8 Nov	University of Adelaide	Diffusion in Random Media
9 Nov	University of Queensland	Beyond the Gaussian Universality Class
9 Nov	University of Queensland	Random Permutations Partitions and PDEs

2018 Mahler Lecturer Professor Ivan Corwin, Columbia University, USA

PHOTO: MICHAEL SHAW

2.3 ACE SHORT COURSES AND SEMINARS

Through the Advanced Collaborative Environment (ACE) Network, AMSI offers a variety of seminars and short courses of interest to members.

Fourteen Australian universities—about half of AMSI's 29 member and non-member universities—belong to the ACE Network. In addition to offering honours courses (see page 74), the facilities are used to bring interest groups from the mathematical sciences community together for workshops and seminars.

During the period 1 July 2018 – 30 June 2019, around 13 research seminars were broadcast by universities around Australia using the ACE Network.

ACE Network

The ACE Network at AMSI member universities enables maths departments to collaborate through advanced video conferencing and desktop-sharing facilities. It has been established to facilitate greater collaboration in the mathematical sciences community both within Australia and internationally.

AustMS/AMSI Teaching Seminar Series

An initiative of the AustMS Standing Committee on Mathematics Education in response to an identified need for an online seminar series for university mathematics teaching, this nation-wide seminar series includes talks and discussion forums with a focus on academic teaching of mathematics and statistics at universities. The events aim to strengthen engagement between university teaching staff within Australia's mathematical sciences departments (and related areas) and broader networks with vested interest in university mathematics and statistics education best practice.

SEMINAR: A METHOD OF CREATING AUTOMATED FORMATIVE ASSESSMENT BY MEANS OF COMPUTER ALGEBRA, LATEX AND PDF FORMS

Dmitry Demskoy, Charles Sturt University
8 August 2018

This seminar explained a method of creating maths/stats assessments using a computer algebra system (e.g. Maple) and showed some examples of such assessments from the subjects taught by the presenter. The method requires some programming experience from the teaching staff, but allows the creation of individualised assessments that can also be automatically marked. The presenter explored the potential benefits of this method to both students and staff.

SEMINAR: INTEGRATING INTEGRITY

Katherine Seaton, La Trobe University
27 November 2018

Mathematics tasks of the type assigned to undergraduates are overlooked in the academic integrity literature, and in much of the instructional material for students about misconduct. An overview of a forthcoming e-book which begins to address this lack of specific and targeted information was presented. In particular, the presenter discussed what mathematics can apply from the general scholarship, and from areas like computer science which have, by way of contrast, developed a large body of discipline-specific literature. She then presented some of the 26 scenarios provided as online or in-class discussion starters in the book, which will be published as an open educational resource by La Trobe University's e-Bureau early next year.

Research Training 3

Dr Erika Duan from La Trobe University, one of three awardees of best poster at AMSI BioInfoSummer 2018.

PHOTO: MARISA DUONG

3 RESEARCH TRAINING

Funded by the Department of Education and Training's Securing Australia's Mathematical Workforce: 2016–2020 agreement, AMSI's Higher Education program enhances the undergraduate and postgraduate experience for students studying the mathematical sciences and related disciplines. Featuring training schools, graduate courses and scholarship programs, it sets the gold standard for research training infrastructure.

Through exposure to cutting-edge methodologies and topics not routinely covered by academic courses, AMSI's Higher Education programs prepare STEM graduates to engage in cross-disciplinary research and drive industry innovation.

This year's flagship training programs attracted over 500 students and researchers, more than 35 per cent of them female.

503 attendees at AMSI flagship programs
- **37% female participants**
- **31% undergraduate students** (includes honours)*
- **44% postgraduate students** (includes masters and PhD)**
- **26% early career researchers**
- **31% international students*****

91 lecturers and speakers at flagship events
- **47% female**
- **12% international**

92 students received **AMSI Travel Grants**

57 female students received **Choose Maths Grants**

* Undergraduate students include honours students
** Postgraduate students include both masters and PhD students
*** International participants include those on student visas, temporary visas and any other international participants

3.1 AMSI WINTER SCHOOL 2018 ON CURVATURE

The University of Queensland, 2–13 July 2018

Now in its 14th year, the AMSI Winter School is an integral part of the events calendar for PhD and postgraduate students and early career researchers in the mathematical sciences and cognate disciplines. Its two-week residential program offers a range of specialist topics with an overarching theme, drawing on the knowledge of national and international lecturers at the forefront of their fields. Attracting students from all around Australia, the program is rounded out with guest public lectures, participant talks and networking events.

With the specialised theme of Curvature, AMSI Winter School 2018 attracted a small group of participants with a variety of mathematical backgrounds, and in most cases, a working interest in at least one of the four topics on offer. Two courses were offered each week, and the program included informal tutorial and problem-solving sessions. The 27 participants, mostly postgraduate students, represented 12 different universities across Australia, with one participant from industry.

Alongside the formal learning sessions was a lively program of extracurricular activities, including a public lecture by Winter School lecturer Associate Professor Julie Rowlett, from Chalmers University of Technology in Sweden. Her talk, entitled *The spectrum: Incomputable yet physically tangible numbers*, examined the role of eigenvalues in creating sound, heat flow and energy in quantum particles, and attracted an audience of about 100 guests including Winter School participants, local academics and members of the general public. The associated media campaign received strong coverage with a total reach of over 13 million.

The annual Women in Maths event, held in collaboration with WIMSIG, was another highlight of the Winter School, celebrating women's achievements in the mathematical sciences. With more than 50 guests in attendance, the event featured a panel discussion on the diverse career experiences of the panellists and a Q&A discussion sharing experiences and tips on encouraging diversity within the mathematical sciences. Panel members included Ellie Hubbard (senior electrical engineer, Aurecon Australasia), Associate Professor Mariel Sáez (Pontificia Universidad Católica de Chile and 2018 Winter School lecturer), Natalie Lawler (mathematics and science teacher, Kenmore State High School) and Professor Kim Anh Do (University of Texas MD Anderson Cancer Center). Julia Collins from AMSI also spoke to guests about the AMSI Choose Maths project and the positive long-term impacts on encouraging more diversity in the mathematical sciences.

Other events included a tour of Boeing's labs, situated on the University of Queensland's St Lucia campus, organised by one of the Winter School participants, as well as a tour of the Queensland Brain Institute's computational neuroscience facilities. Networking events including formal and informal dinners rounded out the program.

PHOTO: JENNY CUEREL PHOTOGRAPHY

"The Winter School as a whole was very well organised… The lecturers were not only extremely knowledgeable, but also easily approachable. Personally, I found the time set aside for tutorials/discussions after the lectures to be particularly helpful."

Sebastian Murk, Macquarie University

WS.AMSI.ORG.AU

Director: **Professor Phillip Isaac**, The University of Queensland

EVENT PARTICIPATION

27 Attendees
11% Female participants
19% Undergraduate students (includes honours)
78% Postgraduate students (includes masters and PhD)
4% Early career researchers
4% industry participants
33% international students

PROGRAMS

4 Lecturers
2 Female speakers
3 International speakers

PARTICIPATION SUPPORT

19 Students from **10** member universities received AMSI Travel Grants
2 female attendees received Choose Maths Grants to support their participation

Organising Committee

Prof. Phillip Isaac, The University of Queensland (Event Director)
Prof. Joseph Grotowski, The University of Queensland
Andree McFarlane, The University of Queensland
Chloe Pearse, AMSI
Anna Muscara, AMSI

Other Sponsors

Department of Education and Training; The University of Queensland; Queensland Cyber Infrastructure Foundation (QCIF); the Australian Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS); The Simulation Group; Silicon Graphics International Corp (SGI); BHP Foundation (part of the Choose Maths project)

Winter School organising committee members, Andree McFarlane (The University of Queensland) and Anna Muscara (AMSI)
PHOTO: JENNY CUEREL PHOTOGRAPHY

THE COSMOS OF MATHS

Mark Bugden, The Australian National University

As a theoretical physicist with a passion for string theory, Mark Bugden knows the importance of understanding space and how things fit together.

"String theory helps us to increase our understanding of the fundamental laws of the universe, and in doing so helps us understand our place in the cosmos," he explains.

While not quite the cosmos, AMSI Winter School 2018 gave the Australian National University PhD student the opportunity to "understand a larger part of the tapestry of mathematics, which is especially important in an interdisciplinary field."

The chance to explore new ideas beyond his PhD also provided insight into their impact and significance in relation to his field.

"This year's theme of curvature helped clarify a lot of hazy ideas and solidify my knowledge."

The two-week residential school also provided a compelling platform to network and exchange ideas, something often missing from the PhD experience in a country plagued by the tyranny of geographical isolation.

"The event provides opportunity to meet students from other universities, as well as academics outside your area. This is essential to maintain competitiveness in an ever-demanding academic environment"

Instrumental to his capacity to attend, Bugden knows he wouldn't have made it to Winter School without support from AMSI—something he is very grateful to have received. "Without travel and accommodation costs covered, I wouldn't have been able to attend. In that sense, the travel grant was vital," he says.

Bugden, who won the AMSI Winter School 2018 participant talks, says the event was a perfect mix of opportunities to build knowledge and communication skills. Just don't ask him what he liked best.

"It is an even split between the mathematical content and networking. The student talks, in particular, were a chance to present research and compete in a relatively stress-free environment."

As for what comes next, Bugden hopes to take up a permanent university position and a place in the rich tapestry of the mathematical sciences. Where that leads is anyone's guess.

"Who knows, perhaps in 50 or 100 years there will be some practical application nobody could have foreseen. As we've seen, Einstein's general theory of relativity led to the development of GPS satellites, and quantum theory to the development of computers," he says.

Mark Bugden received an AMSI Travel Grant to attend the 2018 Winter School

Speakers at the AMSI Winter School's Women in the Mathematical Sciences Networking event PHOTO: JENNY CUEREL PHOTOGRAPHY

COURSE DETAILS

Theme 1: Curvature in Conformal Geometry

Prof. Rod Gover, University of Auckland, New Zealand

Lecture 1: *Conformal problems in Riemannian geometry, pseudo-Riemannian geometry and mathematical physics*
Beginning with the notation etc. in (pseudo-)Riemannian geometry, this lecture then covered some motivating problems including constructing invariants, invariant differential operators, curvature prescription and conformal compactification.

Lecture 2: *Conformal geometry, tractor calculus and the geometry of scale*
We defined conformal manifolds and constructed on these the basic conformally invariant calculus. We then explained how (pseudo-)Riemannian objects should be treated in this picture.

Lecture 3: *Hypersurfaces and their geometry*
We developed the basic calculus for hypersurfaces in (pseudo-) Riemannian and conformal manifolds, arriving at the usual curvature quantities such as the second fundamental form, the mean curvature etc. We explained the place of these in conformal geometry. We saw how to use conformal geometry to describe e.g. minimal, CMC and totally umbilic hypersurfaces.

Lecture 4: *The geometry of conformal infinity and boundary calculus*
The use of conformally compact manifolds (following the initial ideas of Fefferman-Graham) as a tool in conformal geometry was explained and demonstrated. Motivated by this, the tools developed in the earlier lectures were applied to study the boundary at infinity of conformally compact manifolds.

Lecture 5: *Higher Willmore invariants and energies*
The final application was to understand how the Willmore energy and its functional gradient (with respect to variation of embedding) fit into the picture and then the generalisation of this to higher dimensions was explained, as well the link between these objects and Q-curvatures.

Theme 2: Curvature Flow of Networks

Assoc. Prof. Mariel Sáez, Pontificia Universidad Católica de Chile, Chile

The study of geometric flows has gained a lot of attention in mathematics over the last few decades, both as a powerful tool in addressing problems in several branches of the discipline, as well as for its own interest. These flows can often be understood as non-linear quasi-parabolic equations with a geometrical meaning.

An important example is the extrinsic flow, known as the "mean curvature flow", which has been extensively studied in the smooth setting. Particularly when the evolution of curves is considered, the flow is known as "curve-shortening flow" and it is fully understood for closed embedded curves. Nonetheless, an early motivation for curve-shortening flow comes from the work of Mullins in the 1950s, where the evolving curves are interpreted as evolving interfaces that appear naturally in material sciences. However, in that context it is expected that certain natural "built-in" singularities (which are not present in the smooth case) appear through the evolution. Such behaviour is mathematically modelled by the evolution of networks under curve-shortening flow, which has proven to be more challenging to study than its smooth counterpart.

In these lectures I gave an overview of the classical theory for smooth curves and compared it to its counterpart in the network case. More precisely, I discussed the results of Gage-Hamilton and Grayson and more recent proofs of these theorems and then defined the flow of networks and possible different approaches to study this flow. I described existence results and long-time behaviour for networks with no loops and some results in the case with loops.

Theme 3: Comparison Geometry

Dr Paul Bryan, Macquarie University

The role of curvature in geometry and topology is quite subtle but comparison geometry allows us to glimpse some of the hidden interactions between geometry and topology. The material is both classical and contemporary with classical fundamental results like the Bishop-Gromov volume comparison


Public lecture by Associate Professor Julie Rowlett

PHOTO: JENNY CUEREL PHOTOGRAPHY

playing a very important role in contemporary research such as in the study of the Ricci flow. The theory is quite beautiful, exhibiting how powerful modern techniques in analysis may be used to expose geometric and topological phenomena and illuminate aspects of Gromov's little monster, namely the curvature tensor.

We developed comparison geometry as expressed by the Rauch comparison theorems through the Riccati equation, which is the linearisation of the geodesic equation, an innocuous-looking equation belying much complexity. In particular we saw how curvature affects distance, triangles volume and surface area, and discovered some topological implications. We also sketched the proof of the famous, classical topological sphere theorem of Berger-Klinenberg and discussed the contemporary differentiable sphere theorem of Brendle-Schoen as well as some open problems.

Theme 4: Heat Flow and Geometry

Assoc. Prof. Julie Rowlett, Chalmers University of Technology, Sweden

Lecture 1: We began with the very basics.

- Suggested reading for this lecture was *The Atiyah-Patodi-Singer index theorem* by Richard Melrose, Chapter 7
- The heat kernel: what is it?
- Explicit computation of the heat kernel in Rn
- Heat spaces: what are they?
- The heat space for Rn
- Properties of the heat kernel on Rn

Lecture 2: Moving right along, we next considered compact smooth manifolds

- Suggested reading was *The Laplacian on a Riemannian manifold*, by Steve Rosenburg, Chapter 3
- Duhamel construction of the heat kernel
- The short time asymptotic expansion of the heat trace
- Geometry captured by the heat trace
- Spectral invariants and "hearing things"

Lecture 3: We continued with the notion of "hearing things" as well as increasing the geometric complexity. We considered smoothly-bounded domains in Rn as well as heat kernels associated with Schrödinger operators on Rn with compactly supported L∞ potentials.

- Suggested reading was *Can one hear the shape of a drum*, by Mark Kac
- Locality principles (generalisations of Kac's principle of "not feeling the boundary")
- Kac's "hole"

Lecture 4: We finally arrived at non-smooth geometric settings: domains in Rn, which have non-smooth boundaries. We also looked at manifolds with singularities. In this context we investigated:

- Locality principles
- Hearing singularities

Lecture 5: In conclusion we learned about the dangers of heat, specifically:

- Infinite speed of propagation
- Randomness

Student Presentations

A highlight of the program was the Participant Talks, with all 70 students presenting their research in 15-minute presentations with an added five minutes for questions. Participants were separated into five groups and asked to vote for the best presentation in their group. Speakers from this shortlist went on to present to the whole cohort.

Mark Bugden (Australian National University) was voted Best Speaker, for his presentation entitled *Light orbiting a five-dimensional black hole*.

Grace Garden (Boeing Research and Technology, Australia) received an honourable mention for her talk *The mathematics of collision avoidance*.

3.2 AMSI BIOINFOSUMMER 2018

The University of Western Australia, 3–7 December 2018

Focused on building Australia's bioinformatics and computational biology research capability, AMSI BioInfoSummer is Australia's leading training event in the rapidly-growing interdisciplinary field of bioinformatics and mathematical/computational biology.

Bioinformatics is an exciting discipline analysing and simulating both the structures and processes of biological systems. It is a constantly evolving field that offers researchers and students a wide range of opportunities.

Western Australia hosted BioInfoSummer for the first time in 2018, attracting almost 140 researchers and students with diverse scientific backgrounds from across Australia for the five-day program. Commencing with an opening address by Professor Susan Wilson (UNSW), the conference's major themes were single cell 'omics, plants and animals, epigenetics, and metabolomics and proteomics. With both scientific seminars and practical workshops, the program featured 25 national and international speakers. Networking events were scheduled throughout the conference, including catered lunches and evening receptions, to facilitate networking between delegates.

More than 70 attendees gathered to hear Professor Rebecca Johnson, Director of the Australian Museum Research Institute, give a public lecture entitled *Wildlife detectives: The story of genome research, discovery and exploration at Australia's first museum*. Rebecca presented case studies from her work to demonstrate how important museum research is in engaging, educating and inspiring custodianship in the next generation of researchers.

On the final evening, the COMBINE Careers Session showcased bioinformatics career opportunities and pathways, with presentations and a panel discussion from Rachel Geddes (APR.Intern), Professor Matthew Hahn (Indiana University), Dr Monica Kehoe (WA Department of Primary Industries and Regional Development), Dr Ashley Waardenberg (James Cook University) and Professor Susan Wilson (UNSW).

"Five days of action-packed lectures and hands-on workshops from the best in the bioinformatics field, from Australia and abroad."

Liam Crowhurst, Queensland University of Technology

BIS.AMSI.ORG.AU

Director: **Assoc. Prof. Nicola Armstrong**, Murdoch University

EVENT PARTICIPATION

138 Attendees
54% Female participants
17% Undergraduate students (includes honours)
48% Postgraduate students (includes masters and PhD)
13% Early career researchers
47% International students

PROGRAMS

25 Lecturers and workshop presenters
12 Female speakers
5 International speakers

PARTICIPATION SUPPORT

14 Students and ECRs from **10** member universities received AMSI Travel Grants
17 Female attendees from **8** member universities received Choose Maths Grants to support their participation

Organising Committee

Assoc. Prof. Nicola Armstrong, Murdoch University (Event Director)
Angela Coughlin, AMSI
Jeya Jeybalan, The University of Western Australia
Chloe Pearse, AMSI
Prof. Luchezar Stoyanov, The University of Western Australia
Claire Walker, The University of Western Australia

Other Sponsors

Department of Education and Training, The University of Western Australia, Murdoch University, Edith Cowan University, Pawsey Supercomputing Centre, EMBL Australia Bioinformatics Resource, BHP Foundation (part of the Choose Maths project), Decode Science, Harry Butler Institute

Opening address was delivered by Professor Susan Wilson PHOTO: MARISA DUONG

Conference Speakers

Speaker	Organisation	Talk Title
Prof. Matthew Hahn	Indiana University	Errors and error-correction in plant and animal genomes
A/Prof. Stephanie Hicks	Johns Hopkins Bloomberg School of Public Health, USA	Missing data and technical variability in single-cell RNA-sequencing experiments
A/Prof. Simon van Herringen	Radboud University, Netherlands	Deciphering the sequence determinants of regulatory dynamics
Prof. Zhiping Weng	University of Massachusetts Medical School, USA	The genome of the Hi5 germ cell line from Trichoplusia ni, an agricultural pest and novel model for small RNA biology
Jason Williams	Cold Spring Harbor Laboratory, DNA Learning Center	Improving the bioinformatics curriculum
Dr Laura M. Boykin	The Cassava Virus Action Project, The University of Western Australia	Real-time portable genome sequencing for global food security
Prof. Dave Edwards	The University of Western Australia	Improving crops with genomics and bioinformatics
Prof. Alistair Forrest	Harry Perkins Institute of Medical Research	Western Australian cancer single-cell initiative
Dr Saskia Freytag	Walter & Eliza Hall Institute of Medical Research	Fast-forward poster session facilitator
Dr Shila Ghazanfar	The University of Sydney	scMerge: integration of multiple single-cell transcriptomics datasets leveraging stable expression and pseudo-replication
Dr James Hane	Centre for Crop & Disease Management, Curtin University	Bioinformatics and genomics application in plant pathology
Dr Camilla Hill	Murdoch University	Genome sequencing and association mapping to dissect the genetic basis of yield and adaption in barley
Dr Rebecca Johnson	Australian Museum Research Institute	Wildlife detectives: the story of genome research discovery and exploration at Australia's first museum
Dr Timo Lassmann	Telethon Kids Institute	Modelling biological sequences using infinite hidden Markov models
Dr Ryan Lister	The Harry Perkins Institute of Medical Research, The University of Western Australia	Emerging technologies in reading and writing the epigenome
Marina Naval Sanchez	CSIRO	Sheep functional annotation reveals proximal regulatory elements contributed to the evolution of modern breeds
Dr Stacey Reinke	Centre for Integrative Metabolomics & Computational Biology, Edith Cowan University	Multi-block multivariate data integration: insights into asthma
A/Prof. Torsten Seemann	The University of Melbourne	How bioinformatics, genomics and open data are transforming public health and clinical microbiology
Prof. Gordon Smyth	Walter & Eliza Hall Institute of Medical Research	Hi-C explores genome-wide chromatic architecture and identifies long-range enhancers
Dr Ashley Waardenberg	Australian Tropical Health and Medicine (AITHM), James Cook University	Kinase activity prediction from phosphoproteomics data
Prof. Susan Wilson	The University of New South Wales	Opening plenary lecture

Participants at AMSI BioInfo Summer 2018 PHOTO: MARISA DUONG

Workshops

Workshop leader	Organisation	Workshop Title
Dr Shila Ghazanfar	The University of Sydney	scMerge
Mark Gray	Pawsey Supercomputing Centre	Introduction to Pawsey Cloud
Dr Joel Gummer	Murdoch University	The integration of analytical workflows and data analytics for metabolomics
A/Prof. Stephanie Hicks	Johns Hopkins Bloomberg School of Public Health, USA	Statistical analysis and comprehension of single-cell RNA-sequencing data in R/ Bioconductor
Dr Rebecca Lange	Curtin University	Building Shiny apps
Dr Alethea Rea	The University of Western Australia	Introduction to R
A/Prof. Torsten Seemann	The University of Melbourne	Introduction to genome assembly and annotation
A/Prof. Simon van Herringen	Radboud University, Netherlands	Integrative analysis of epigenomic dynamics at regulatory elements
Dr Ashley Waardenberg	Australian Tropical Health and Medicine (AITHM), James Cook University	Predicting kinase activity from phosphor-proteomics data with KinSwingR
Prof. Zhiping Weng	University of Massachusetts Medical School, USA	Building a registry of candidate cis-regulatory elements for human and mouse

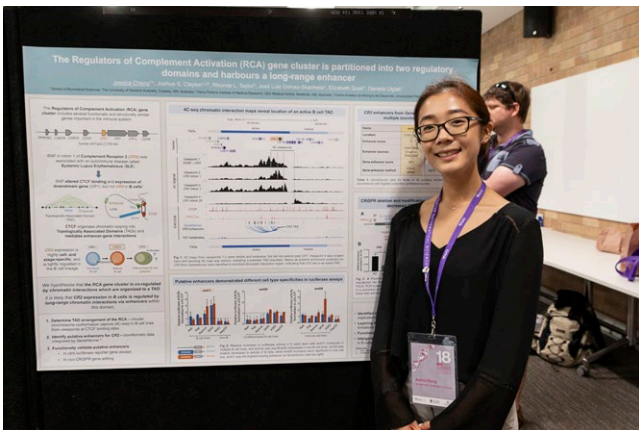
Best Poster

This year's poster competition attracted 12 entries from event participants. A fast-forward poster session, where each presenter had two minutes to talk about their research, was followed by the traditional poster-viewing over a catered lunch focusing on diversity in STEM. Both the posters and presentations were of high scientific quality, making the judges' decisions very difficult, and in the end three prizes were awarded to students. The winners were:

Dr Erika Duan, La Trobe University, *Transcriptomics versus proteomics: A side-by-side study of immune cell behaviour*

Jessica Cheng, The University of Western Australia, *Chromatin interactions across the regulators of complement activation (RCA) gene cluster are partitioned into regulatory domains which harbour functional long-range enhancer elements*

Gabriel Hauswirth, Australian Regenerative Medicine Institute & EMBL Australia, Monash University, *Identifying regulators of posterior Hox gene activation and axis elongation*



Jessica Cheng, The University of Western Australia PHOTO: MARISA DUONG

AMSI BioInfoSummer 2018 public lecturer Professor Rebecca Johnson with Associate Professor Torsten Seemann PHOTO: MARISA DUONG

MAKING AN IMPACT: CHOOSE MATHS OPENS DOOR TO BIOINFOSUMMER

Lucinda Ham, The University of Melbourne

Having completed her PhD in pure mathematics, Dr Lucinda Ham found herself at the intersection of logic, universal algebra and theoretical computer science and intrigued by the possibilities of an applied pathway. After a brief left turn into architecture, she settled on theoretical systems biology.

Theoretical systems biology uses mathematics to help understand underlying biological systems with focus on modelling stochastic processes. This research has the potential to enhance medical and biological research and assist in tackling disease.

"The development of mathematical, statistical and computational tools in cell biology helps us better understand and explain complex biological processes and their evolution," she explains.

Grappling with this career change and a limited background in biology and programming, the University of Melbourne postdoctoral student was drawn to the cutting-edge program on offer at Australian Mathematical Sciences Institute (AMSI) BioInfoSummer 2018.

"AMSI BioInfoSummer assisted enormously with my transition from pure mathematical research to systems biology and statistical bioinformatics. I gained a much deeper understanding of the biological mechanisms and processes underlying my research," she says.

With only casual work as a demonstrator at La Trobe University, attending AMSI BioInfoSummer would have been out of reach for Dr Ham without the support of a Choose Maths grant. Such support, she believes, is critical to fostering the participation of women in mathematics and righting their underrepresentation in STEM fields.

"I see these initiatives as extremely important to encourage female scientists to explore opportunities and continue their career development. The opportunity to network with other women in the area creates a sense of unity and this is empowering," she says.

For Dr Ham, AMSI BioInfoSummer was a chance to deepen her understanding of the various challenges and complexities in cell biology and genetics, insights already helping her refocus her efforts in theoretical systems biology.

"My understanding of the fundamental workings of gene transcription opened my mind to expanding models I was considering, which quickly led to improvements to work I was involved in. I've also learnt many statistical ideas to use when explaining basic mathematics and statistics to students"

Now a long way from 2017, Dr Ham knows she has made the right choice and looks forward to using her skills to make an impact where it is needed most.

"I am passionate about mathematics and contributing to the scientific knowledge base. In five, ten years' time I hope to be making advances on my field that impact positively on biological research."

Lucinda Ham received a Choose Maths Grant to attend AMSI BioInfoSummer in 2018

3.3 AMSI SUMMER SCHOOL 2019

7 January – 1 February 2019, The University of New South Wales

A four-week residential program, AMSI Summer School is one of the most important calendar events for honours and postgraduate students in the mathematical sciences and cognate disciplines. With a commitment to outstanding education and training, sessions count as course credits and provide students with the opportunity to learn from highly experienced lecturers from around Australia. Career development and networking opportunities give students a competitive edge as they move forward to pursue their research careers.

Now in its 17th year, this year's intensive four-week program brought together 171 honours and postgraduate students from around the country. Students participated in eight intensive courses covering all aspects of mathematical research, from pure and applied mathematics to statistics and cognate quantitative disciplines such as mathematical biology and earth science, incorporating lectures, tutorials and computer labs.

Complementing the academic program were social events ranging from the welcome reception and closing dinner to BBQ lunches, movie nights and virtual reality experiences.

Public lecturer Dr Stephen Griffies (Princeton University) drew a crowd of about 120 attendees for his talk *A maths/physics view of ocean circulation*, focused on some of the mechanisms of ocean circulation and questions confronting ocean scientists today.

Hosted by AMSI Director Professor Tim Brown, the Summer School Careers Day Fair was also extremely popular. Three panel sessions, on AMSI's APR.Intern program, Diversity in STEM, and Academic and Industry Career Pathways, provided students with the opportunity to find out more about different career paths and experiences. The Fair included an expo where students could network directly with presenters and stallholders, asking them about career paths and graduate employment opportunities.

In addition to the Diversity in STEM panel at the Career Day Fair, AMSI's Choose Maths project hosted a networking dinner for female participants and academics.

"I enjoyed the opportunity to learn maths at a higher level and really push myself. It just ignited my curiosity and passion for maths. I loved the opportunity to live in the residential college and form meaningful connections with people from so many different places and different areas of study. It really was just a brilliant experience."

Storm Logan, RMIT University

SS.AMSI.ORG.AU

Directors: **Assoc. Prof. Guoyin Li** and **Dr Shane Keating**, The University of New South Wales

EVENT PARTICIPATION

171 Attendees
85 Attendees took courses for credit
28% Female participants
35% Undergraduate students (includes honours)
65% Postgraduate students (includes masters and PhD)
47% Early career researchers

PROGRAM

8 Honours level courses
11 Lecturers
4 Female lecturers

PARTICIPATION SUPPORT

55 Students from **11** member universities received AMSI Travel Grants
33 Female attendees from **9** member universities received Choose Maths grants to support their participation

Organising Committee

Assoc. Prof. Guoyin Li, The University of New South Wales (AMSI Summer School 2019 Co-Director)
Dr Shane Keating, The University of New South Wales (AMSI Summer School 2019 Co-Director)
Prof. Bruce Henry, The University of New South Wales
Suzie Scandurra, The University of New South Wales
Susannah Waters, The University of New South Wales
Beatta Zarrabi, The University of New South Wales
Dr Diana Combe, The University of New South Wales
Altaf Syed, The University of New South Wales
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Chloe Pearse, AMSI
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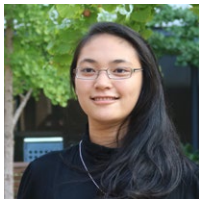
Other Sponsors

Department of Education and Training, The University of New South Wales, BHP Foundation (part of the Choose Maths project), AustMS, ANZIAM, SSA, Department of Defence, Optiver, Commonwealth Bank


PHOTO: SCANDURRA PHOTOGRAPY

GRANT ADDS UP TO SUMMER OF MATHS



Storm Logan, The University of Adelaide

For as long as she can remember, Storm Logan has been captivated by the beauty of maths. In Year Four, she even begged her mother to let her attend Saturday Maths School.

"I love seeing maths used, watching the way it applies in the real world. As far as I'm concerned, the more maths experience you get, the better," she says.

Now an RMIT Masters of Statistics and Operations Research student, the same passion spills over as she talks about attending the 2019 AMSI Summer School.

"Many universities can offer subjects, but AMSI Summer School gave me access to people I may have never met. It fuelled my interest in operations research and has prepared me for the maths I'm likely to encounter in coming years," enthuses Storm.

Without the support of a Choose Maths grant, she may never have had her summer of mathematics. Storm believes she would have been one step further from her dream of being the operations researcher who uses analytical methods and mathematical algorithms to optimise management, logistics and scheduling.

"Receiving my grant was essential to my attending, without this support I highly doubt I would have been able to afford accommodation for the month."

Storm believes grants and networking opportunities for women open a world of opportunities. They benefit not only the women themselves, but the wider community as they are able to hone and apply their skills.

"These grants and the networking opportunities they provide are extremely important. They give women the chance to participate in programs and training that they may have otherwise missed out on."

With her eye on an industry career, it was the chance to network that Storm believes was the most valuable part of the AMSI Summer School 2019 for her.

"[Networking] is just as important as the actual courses you study," says Storm. "It is important to reach out to the other students—they're the ones you can turn to during assignment times."

Her advice to anyone thinking of going to Summer School is simple—apply!

"You could spend your whole life thinking that someone else will get it. But that 'someone else' could very well be you. There's no harm in trying and everything to gain if you succeed."

The little girl excited to do more mathematics on a Saturday would no doubt agree. Not that Storm was always so certain about her path.

"I came from a very maths- and science-oriented family. I don't think I knew I would pursue maths as a career but when I look back, it should have been obvious."

Storm Logan received a Choose Maths Grant to attend AMSI's 2019 Summer School


PHOTO: SCANDURRA PHOTOGRAPY

Course Details

An Introduction to Non-Commutative Functional Analysis: Quantised Calculus

Prof. Fedor Sukochev and Dr Galina Levitina, UNSW

Synopsis: Functional analysis, a central pillar of modern analysis and its foundations, was covered in this course with an emphasis on the study of compact linear maps on Hilbert spaces. This course provided the basic tools for the development of such areas as quantum mechanics, harmonic analysis and stochastic calculus. Special attention was given to applications in noncommutative geometry, specifically quantised calculus. The quantised calculus was introduced by Alain Connes in his 1994 book *Noncommutative Geometry*. This is a means of doing calculus which makes sense in a high degree of generality and has many properties analogous to the classical notion of "infinitesimal calculus". We gave a brief overview of applications to Julia sets.

Course Overview:

- Review of general functional analysis (measure and integration, Banach spaces and their duals, Hilbert spaces, bounded linear operators on Hilbert spaces)
- Compact operators (spectral theory of compact operators and singular value decomposition)
- Ideals of compact operators: Calkin theorem for two-sided ideals, Schatten and weak Schatten ideals
- Traces on ideals of compact operators: the classical trace and singular traces
- Applications: quantised calculus on the circle and an overview of quantised calculus for fractals, Connes trace theorem

Analytic Number Theory

Dr Michael Coons, The University of Newcastle

Synopsis: Questions in number theory have driven the main stream of mathematical research for millennia, producing avenues leading to significant advancement in several other areas of mathematics. Stemming from the interest in the arithmetic of the integers one encounters the basic operations of "plus" and "times". While "plus" is easy enough, the intricacies of "times" continue to be an object of rigorous mathematical study. The first important result in this vein is the proof of the infinitude of the primes—the multiplicative building blocks of the integers—recorded by Euclid in his *Elements*.

In this course, we studied the distribution of primes in its classical development before moving onto other important functions in the context of the multiplicative properties of integers.

Course Overview:

- Infinitude of primes
- Chebyshev's functions
- Bertrand's theorem
- Partial summation
- Riemann's zeta function
- Prime number theorem
- Newman's theorem
- Dirichlet L-functions
- Primes in arithmetic progressions

We also covered:

- Primitive roots and quadratic reciprocity
- Sums of multiplicative functions and density
- Roth's theorem and the circle method
- Vinogradov's three-prime theorem

Dynamical Systems: Models of Chaotic Dynamics

Dr Andy Hammerlindl, Monash University

Course Overview: Dynamics is the study of systems that change in time. In some cases, the long-term behaviour is simple, such as a system settling down to an equilibrium or a regular periodic motion. In other cases, the system is chaotic. This does not


PHOTO: SCANDURRA PHOTOGRAPY

mean, however, that we cannot analyse the system or determine its properties. In fact, many highly chaotic dynamical systems are very well understood.

In this course, we covered dynamical systems theory, starting with Poincaré's foundational work showing that no chaos is possible for flows on the plane, and going up to recent advances and discoveries. A large focus of the course was on known models of chaotic dynamics and the geometric and topological objects associated with their behaviour. These included horseshoes, geometric Lorenz attractors, Anosov systems, homoclinic tangencies, heterodimensional cycles and blenders. We also covered classification results that showed how well these models relate to dynamical systems that arise in the physical world.

Mathematical Methods for Machine Learning

Dr Zdravko Botev, UNSW

Synopsis: to someone starting to learn data science, the multitude of computational techniques and mathematical ideas may seem overwhelming. Some may be satisfied with only learning how to use off-the-shelf recipes to apply to practical situations. But what if the assumptions of the black-box recipe are violated? Can we still trust the results? How should the algorithms be adapted?

The purpose of this short course was to provide an accessible introduction to the basic ideas in data science and machine learning. It was intended for anyone interested in gaining a better understanding of the mathematics and statistics that underpin the rich variety of ideas and machine-learning algorithms in data science. This understanding is needed because computer implementations come and go, but the underlying key ideas and algorithms will remain, and will form the basis for ongoing research and future practice.

Course Overview:

- Handling data
- Fundamentals of supervised learning and regression
- Monte Carlo methods for Bayesian learning
- Unsupervised learning (clustering and mixture modelling)
- Kernel methods and support vector machines for classification
- Deep learning and neural networks

Optimisation

Assoc. Prof. Regina Burachik, The University of South Australia

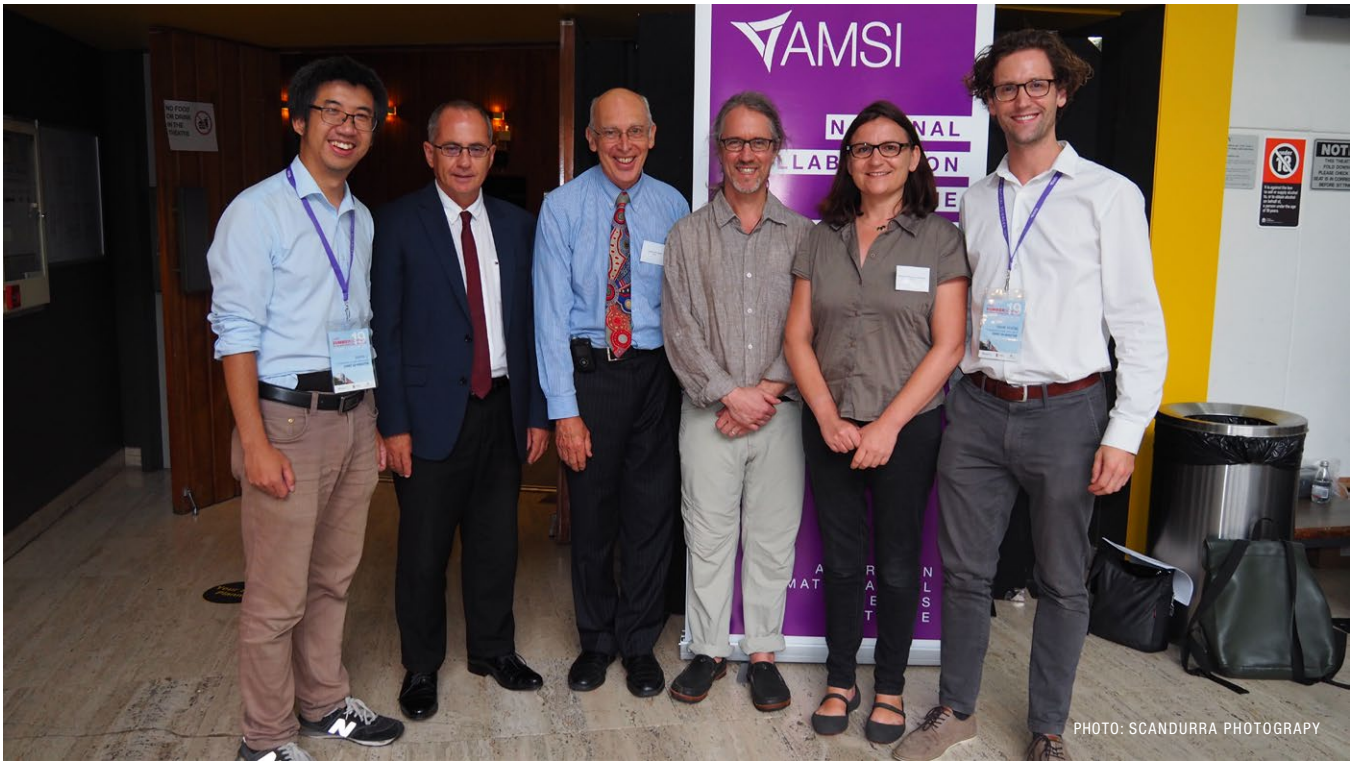
Synopsis: Optimisation training including (i) theoretical analysis and algorithms, (ii) their relation to practical problems, and (iii) the ability to apply the theory and algorithms to these "real-life" problems.

Hence, we covered the following general areas:

- Modelling: formulation of a given problem as an optimisation problem
- Theory: study of the existence and uniqueness of solutions, and characterisation of the solutions of optimisation problems
- Methods: development and convergence analysis of algorithms for solving optimisation problems
- Implementation: transcription of the algorithm to the medium of a suitable technical device (e.g. a digital computer). For instance, on a digital computer, the implementation of a method consists of writing a code corresponding to the method and running it on the computer

All these four stages were part of this optimisation course. To implement the methods, we used MATLAB (or a similar language, such as octave).

Many topics were demonstrated by MATLAB programs, and students found satisfaction in the ability of solving problems on their own!



Course Details - *continued*

At the end of this course, students were able to:

- Identify the main features of a given optimisation problem (i.e. whether the problem was constrained or not, differentiable or not, convex or not, etc.)
- Decide whether the problem had solutions, and whether these solutions could be found analytically
- Become acquainted with numerical algorithms and able to compute/approximate the solutions
- Analyse the convergence of optimisation techniques
- Model and solve optimisation problems using MATLAB

Course Overview:

- Week 1: Review of mathematical tools: inner product and norms. Matrices, eigenvectors and eigenvalues. Topology concepts, open/closed balls, open/closed sets. Optimality conditions for unconstrained optimisation: global and local optima, first-order optimality conditions, second-order optimality conditions. Conditions for existence of solutions. Global optimality conditions. The quadratic case. (Chapters 1 and 2 of textbook.)
- Week 2: Least squares problem (Chapter 3). The gradient method, scaled gradient method, Gauss-Newton Method. Newton's method, damped Newton method, Cholesky factorisation (Chapters 4 and 5)
- Week 3: Hybrid Gradient-Newton (Chapter 5). Convex sets and their topological properties (Chapter 6). Convex functions. Connection with global optimality conditions. Continuity and differentiability of convex functions, and other related properties (Chapter 7, up to 7.9)
- Week 4: Convex optimisation: important examples: linear programming, convex quadratic problems. Examples of use of CVX software for solving convex optimisation problems (Chapter 8). Optimality for problems with continuously differentiable objective over a convex constraint set
- Optimality conditions for some special cases (Chapter 9). KKT conditions for inequality constrained problems (Chapter 11, up to 11.7)

Mathematics of Planet Earth

Dr Shane Keating and Assoc. Prof. Lisa Alexander, UNSW

Synopsis: This course aimed to introduce key concepts and mathematical methods for understanding our planet and the dynamical processes that shape it. We introduced the fundamental equations of motion and conservation laws that govern the fluid dynamics of the atmosphere and ocean. These equations are systematically simplified to develop the elegant and powerful theory of geophysical fluid dynamics, which is then used to quantitatively model a rich variety of atmospheric and oceanic phenomena and their interaction with Earth's climate.

Students also developed an understanding of how climate models are built, executed and evaluated. We examined statistical methods for interrogating large climate datasets, including model evaluation metrics, uncertainty quantification and extreme value theory. Theoretical understanding gained in lectures was explored in practical sessions and hands-on activities using a coupled climate model (CSIRO Mk3L) to simulate a range of climate scenarios such as double-CO2, Snowball Earth and the Last Glacial Maximum.

Course Overview:

1. Fundamental concepts—Eulerian and Lagrangian frames, continuity, Navier-Stokes equation, vorticity, frozen-in law, Kelvin's theorem, equation of state, energy conservation
2. Geophysical fluid dynamics—stratification, Boussinesq approximation, internal gravity waves, rotating coordinate systems, Coriolis force, geostrophic balance, f-plane and beta-plane approximations, Rossby waves

PHOTO: SCANDURRA PHOTOGRAPHY

3. Atmospheric circulation—overview of atmospheric circulation, thermal wind balance, baroclinic instability, wave-mean interaction, zonal jets
4. Ocean circulation—Overview of ocean circulation, planetary geostrophic equations, wind-driven circulation, Ekman layer, Sverdrup balance, abyssal flow, Stommel-Arons model, buoyancy-driven circulation
5. Climate models—model hierarchies from conceptual to comprehensive, chaos and initial conditions, climate models, energy budgets, fluxes
6. Climate data science and statistics—evaluation metrics, uncertainty estimation, interpreting ensembles, bias correction, weighting, statistical methods for climate date, extreme value theory

PDE Methods and Models in Mathematical Biology

Assoc. Prof. Peter Kim, The University of Sydney
Dr Justin Tzou, Macquarie University

Synopsis: Mathematics can be useful for studying biological systems. In this course, we showed how to utilise partial differential equations (PDEs) to model and analyse a range of biological systems. PDE models capture a wide range of biological phenomena, including spatial and age-structured interactions. Particular topics included age-/maturity-structured models, diffusion and reaction-diffusion models for predator-prey dynamics, chemotaxis, pattern formation and mean first-passage time models for applications such as intracellular transport. We also discussed a recently developing area of mathematical modelling, that of bridging agent-based (or individual) models and differential equations.

Course Overview:

- Age-structured models
- Diffusion
- PDE approach for mean first-passage time problems in 1-D and 2-D
- Chemotaxis
- Fisher's equation
- Travelling waves/fronts
- Reaction-diffusion systems
- Turing stability analysis
- Weakly nonlinear analysis for small amplitude patterns
- Asymptotic methods for large amplitude patterns in 1-D and 2-D
- Connecting PDEs to agent-based models

Stochastic Modelling

Dr Giang Nguyen, The University of Adelaide

Synopsis: randomness is an important factor in modelling and analysing various real-life situations. This course covered some key aspects in stochastic modelling, including the theory underlying Brownian motions and diffusion processes, as well as techniques for numerical simulations.

Course Overview:

- Preliminaries from measure-theoretic probability
- Modes of convergence
- Brownian motion
- Simulation algorithms
- Filtration, martingales and stopping times
- Basics of Ito calculus

3.4 AMSI OPTIMISE 2019: MINING, OIL, GAS, AGRICULTURE, WATER

17–21 June 2019, Curtin University

Optimisation is an increasingly crucial field for industry to drive growth and profitability. AMSI Optimise, the Institute's newest flagship networking and research training event, was launched in 2017 to strengthen mathematical optimisation research collaboration and its applications across industry.

In its third year AMSI Optimise moved to Perth, bringing together academic experts, industry leaders from the natural resources sector and the nation's current postgraduate talent. The event provided a platform to understand industry drivers and foster research collaborations, connecting business with Australia's future workforce.

As in previous years, the first three days of the program had a conference format, while the final two days were workshop-based. A hands-on session with an agricultural focus held on the third day proved popular. Several well-attended networking sessions, including a conference dinner and a welcome reception with an accompanying poster session, were held during the workshop. Participants came from 18 academic organisations, including 4 international universities, and 16 industry leaders. The four Western Australian member universities were particularly well-represented.

Hosted jointly by AMSI and BHP, and well-attended by delegates and guests, the Business Breakfast was a highlight of the conference. Opened by Dr Gaurav Singh (Research and Innovation Manager, BHP) the program included a discussion on the challenges of attracting maths and related-discipline graduates and professionals into the mining, oil and gas, agriculture and water sectors in a competitive labour market. Panellists included:

- Dr Liz Dallimore (Director, WA Data Science Innovation Hub)—facilitator
- Dr Kylie Hollins (Alcoa)
- Jane Mitchell (Water Corporation)
- Dr Julie Howell (Curtin University)

"It was a great opportunity to understand what industry people are working on in different areas. Then, finding how mathematics can play a role to improve their operations."

Deleram Pahlevani, RMIT University

OPTIMISE.AMSI.ORG.AU

Director: **Professor Louis Caceta**, Curtin University

EVENT PARTICIPATION

99 Registered attendees
42% Female participants
54% Undergraduate and postgraduate students
7% Early career researchers
27% Industry/agency participants
23% International participants

PROGRAM

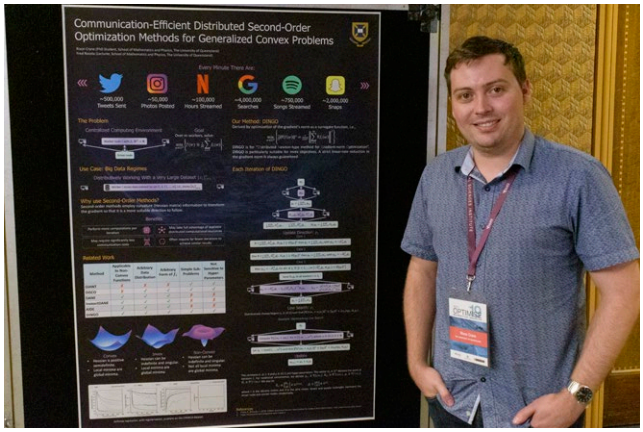
48 Speakers/workshop presenters
24 Female speakers/workshop presenters
3 International speakers/workshop presenters

PARTICIPATION SUPPORT

4 Students and ECRs from **3** member universities received AMSI Travel Grants
5 Female attendees from **4** member universities received Choose Maths grants

"There is a strong need for collaboration between industry and research to ensure that relevant problems are being solved. The AMSI Optimise conference provided the ideal forum for this."

Tarrant Elkington, Snowden Group



PHOTOS: KCURTIN UNIVERSITY PHOTOGRAPHY CLUB

Best Poster

The Optimise poster session gave participating researchers the opportunity to present their optimisation work in under two minutes to the conference delegates. Following the rapid presentations, the authors discussed their work in more depth during a Q&A session held in conjunction with the welcome reception. Of the nine posters, two were awarded Best Poster:

Rixon Crane, University of Queensland, with co-author Dr Fred Roosta: *Communication-efficient distributed second-order optimisation methods for generalised convex problems*

Dr Philipp Braun, University of Newcastle, *Model predictive control and distributed optimisation in the context of smart grids*

Organising Committee

Prof. Louis Caccetta, Curtin University (Event Director)
Angela Coughlin, AMSI
Tasneem Dawood, Curtin University
Chloe Pearse, AMSI

Other Sponsors

Department of Education and Training, Curtin University, Biarri, BHP, The Curtin Institute for Computation

OPTIMISING COLLABORATION

Ekta Sharma, University of Southern Queensland

As a mathematician who has worked on both industry and academic projects, University of Southern Queensland PhD student Ekta Sharma understands the importance of applying new ideas and techniques to existing problems.

Currently working on optimising models for air quality predictions through artificial intelligence algorithms, Ekta attended AMSI's Optimise 2019 conference in Perth in June.

"I was drawn to the event because of the focus on applying optimisation techniques to different scenarios, the collaboration between academia and industry, and the discussion of women in optimisation which was particularly inspirational. The event was a great way to share my research and to hear about similar research and solution approaches."

The wide variety of talks spanned theoretical through practical aspects of optimisation, providing insight into the diverse industries making use of optimisation techniques to improve processes, Ekta says, with scenarios and problems she had never encountered before. A common theme was collaboration between academic researchers and industry to solve problems.

"Discussions were helpful and insightful as to which type of projects industry are looking to collaborate [sic], and their expectations as to the project outcomes and timelines, as well as communicating effectively with them."

But just as importantly, the opportunity to discuss algorithmic and optimisation techniques with other researchers and students was invaluable, according to Ekta, giving her more confidence about her own research and new connections with others. She notes that the speakers at the conference were generous with sharing knowledge and experience.

"Attending this event provided me a good experience and I am sure will be very useful to my research career," she says.

Ekta was the recipient of a Choose Maths Grant, supporting her attendance at the conference and assisting her by covering childcare costs while she was away. She says these grants are great because they allow women with young families to increase their networking opportunities by enabling access to childcare support whilst attending the conference.

"Receiving the Choose Maths Grant was the key in providing me the opportunity to attend and actively participate for the duration of the conference and workshop with a worry-free mindset. It meant I could concentrate on learning the content," she says.

Ekta Sharma received a Choose Maths Grant to attend AMSI Optimise 2019

Keynote talks

Speaker	Organisation	Talk Title
Prof. Rafael Epstein	Universidad de Chile, Chile	Optimising mine planning and operations
		Optimisation of forest industry operations
Prof. Martine Labbé	Université Libre de Bruxelles	Keynote: A bilevel programming model for a problem of market regulation: application to the Mexican petrochemical industry
		Keynote: Bilevel programming, Stackelberg games and pricing problems
A/Prof. Amina Lamghari	University of Quebec, Canada	Keynote: Simultaneous stochastic optimisation of mining complexes / mineral value chains
		Keynote: Solution methods for stochastic mine planning

Conference Talks

Speaker	Organisation	Talk Title
Dr Stephen Beckwith	Optika Solutions	Port product delivery optimisation
Dr Christina Burt	Water Corporation	Optimising the use of pumping stations in a wastewater network
Adjunct Prof. Jose Charango Munizaga-Rosas	Universidad de Chile, Chile	Divide and conquer: taming blending constraints in mine-planning models with stockpiles
Dr Alysson M. Costa & Simon Bowly	The University of Melbourne	Hands-on session: Optimising crop rotation schedules
Prof. Peter Dowd	University of Adelaide	Optimisation challenges in mineral and energy resource applications
Dr Tarrant Elkington	Snowden	Optimisation opportunities to unlock further value from mine automation
Prof. Jerzy A. Filar	Centre for Applications in Natural Resource Mathematics	Threshold risk and uncertainty quantification in environmental modelling
Chet Fong	RPM Global	Solving real-world problems through maths—improving mining productivity with operational simulation
Prof. Maria Garcia De La Banda	Monash University	Optimising the layout of a chemical process plant
Brad Holding	Innovation Central—Cisco Systems	The Wireless Industrial Sensor Environment (WISE) program
Pulkit Jain	Finity Consulting	Australian Actuaries Climate Index
Prof. Craig T. Simmons	National Centre for Groundwater Research & Training	The groundwater grand challenge
Dan Sutherland	Biarri EMI	Opportunities for optimisation in oil and gas & considerations for uptake
Herbert Taco Arana	Curtin University	Synthesis of supply chain transport data using generative neural networks
Prof. Emeritus Doreen Thomas	The University of Melbourne	Network optimisation in the access design for underground mines

Workshop Talks

Speaker	Organisation	Workshop Title
Simon Bowly	The University of Melbourne	Generating mixed integer programming test instances with challenging properties
Dr Philipp Braun	University of Newcastle	Model predictive control and distributed optimisation in the context of smart grids
A/Prof. Rachel Cardell-Oliver	The University of Western Australia	Intelligent sensing for urban water systems
Laura Cartwright	University of Wollongong	Bayesian atmospheric tomography for detection and estimation of methane emissions
Dr Minh N. Dao	The University of Newcastle	A flexible approach for finding the best approximation to the intersection of convex sets
Dr Giovanni Firmani	Roy Hill Iron Ore	Integrated water balance optimisation at Roy Hill
Dr Elham Mardaneh	Curtin University	Integrated vessel and helicopter routing for offshore oil and gas facilities
Dr Fred Roosta	University of Queensland	Newton-MR: Newton's method without smoothness or convexity
Dr Bjorn Ruffer	The University of Newcastle	Lyapunov functions and convergence of Douglas-Rachford method for non-convex problems
Ekta Sharma	University of Southern Queensland	Real time optimisation of air quality predictions for Australia through artificial intelligence
Shaymaa Shraida	Murdoch University	Potential flow of fluid from an elevated, two-dimensional source
Mark Turner	Zuse Institute Berlin	Control of complex intersection areas in transient gas networks

Speakers and delegates at the 2019 AMSI Optimise conference

PHOTOS: KCURTIN UNIVERSITY PHOTOGRAPHY CLUB

3.5 AMSI VACATION RESEARCH SCHOLARSHIPS

December 2018 – January 2019

With its biggest intake to date, the 2018–19 AMSI Vacation Research Scholarships gave almost 70 undergraduate students the opportunity to spend six weeks getting a taste of mathematical sciences research over the summer break. At the end of the summer, participants came together for the two-day AMSIConnect conference, which challenged each student to present their research to their peers, fostering networking and providing information on mathematical career pathways. An inspiring and empowering experience, the AMSI Vacation Research Scholarships give students valuable insight into a research future.

From 91 applications for this year's AMSI Vacation Research Scholarship (VRS) program, 71 students were awarded scholarships and 68 completed their research projects (3 students withdrew due to external circumstances). Mentored by established researchers at their home universities, the students took on six-week research projects and submitted research reports at the end of the project.

At the end of the summer, students presented their findings at the AMSIConnect student conference at the University of Melbourne. In addition to presenting their work to their peers, students wrote blog posts outlining their research and results, giving them experience in scientific writing for broader audiences.

VRS.AMSI.ORG.AU

PROGRAM PARTICIPATION

68* Participants completed research projects
*(*3 withdrawals due to external circumstances)*
28% Female students
9% International students
20 Member universities participating
3 guest speakers at AMSIConnect

"My favourite part was experiencing what research is like. I enjoyed studying a specific concept in detail and making new discoveries was extremely rewarding. This project and AMSIConnect, in particular, showed me the path I want to take with my career and education clearly; it had always been unclear to me."

Daniel Molent, RMIT University

AMSIConnect

6–8 February 2019, The University of Melbourne

Rounding out the summer of research, all of the Vacation Research Scholars gathered at the University of Melbourne for the annual AMSIConnect residential student conference. The conference provided the students with the opportunity to present their research projects to their peers and supervisors, while also boosting their communication and networking skills.

The program began with the annual VRS dodgeball tournament to break the ice. Over the next two days, all Scholars delivered 20-minute talks, providing an overview of their projects and findings.

AMSI Director Professor Tim Brown welcomed all of the students and their supervisors to the conference. Guest speaker and PhD candidate Laura Karantgis talked about her career progression and passed on some good tips from her own student days at La Trobe University. She was followed by Monash University's Professor Steven Siems who provided some advice on the importance of being flexible and taking on new challenges to create a successful and fulfilling career in the mathematical sciences. Closing out the conference, Professor Tim Brown returned to discuss future study and career opportunities and present the awards for the best presentations.


PHOTO: AMSI

Best Presentation Awards

Students voted for the three best presentations of the conference:

Alexander Lai De Oliveira, The University of Adelaide: *Schemes and their functors of points*

Kyria Wawryk, Monash University: *Precession of the perihelia in a Schwarzschild spacetime*

Theresa O'Brien, University of Wollongong: *A giggle a minute: Agent-based modelling of laughter propagation in an audience*

Web Links

vrs.amsi.org.au/past-projects/

Other sponsor

Department of Education and Training

VRS STORIES

A MARKOV CHAIN-BASED INVESTIGATION INTO RENEWABLE ENERGY STORAGE IN SA

Scholar: **Scott Carnie-Bronca**—Bachelor of Mathematical Sciences (Advanced) majoring in applied mathematics and statistics, The University of Adelaide
Supervisor: **Dr Giang Nguyen**

Ice-cream and long days at the beach would top most people's list for a summer cool-down. Teen scientist Scott Carnie-Bronca, however, swapped sand and sun for the chance to use statistical modelling to simulate the effects of energy transfer in and out of a battery.

"Scott's work used mathematics and real-life data to estimate the required amount of battery storage—much, much more than what we have right now—to achieve the ultimate goal of an all-renewable energy grid," says Scott's supervisor Dr Giang Nguyen.

During initial project stages, Scott compiled datasets for both renewable energy generation and usage for 2018. This data was then used to create a model for energy transfer into and out of a battery using various real-world effects such as battery capacity and degradations of charge to provide accurate simulations of a battery's charge throughout the year.

"From the simulations, I determined that the optimal combination is approximately 4.2GW of solar generation, or about 80 medium-sized solar farms, connected to 5,200,000MWh of energy storage—a battery 40,000 times larger in capacity than the current largest battery in Australia. These amounts could be reduced by including alternative generation methods to the model, such as wind or geothermal which are steadier over time," explains Scott.

For Scott, the project provided practical experience and valuable insight into applying research to real-world problems.

"Working on a project through VRS allowed me to experience mathematical research with other students interested in mathematics. The project also helped me decide to continue in research after university. I plan on continuing to work in the field of stochastic modelling, however probably not in the field of energy," said Scott.

Scott's project report and blog post can be found at vrs.amsi.org.au/student-profile-scott-carnie-bronca/

SPREADING THE GIGGLES: THE MATHS OF LAUGHTER

Scholar: **Theresa O'Brien**—Bachelor of Mathematics, The University of Wollongong
Supervisors: **Mark Nelson**, **Tristam Alexander**

Who doesn't enjoy a night out at a comedy show? The build-up of tension and the shock of the punchline are designed to get a giggle. What can maths tell us about the spread of laughter?

For the University of Wollongong's Theresa O'Brien, the VRS experience provided a fantastic space to combine her broad interdisciplinary background in social sciences with maths and stats.

Using a mixture of mathematical equations and stochastic processes to create a computer simulation reflecting the somewhat random and intensely social experience of stand-up comedy, Theresa's project investigated how laughter spreads through a comedy audience. The simulation was then compared to real-world data collected from recordings of comedy performances.

"This research helps us to understand contagious social behaviour. Laughter is one type, but there are others like information and opinion spread in social networks and this research may have extensions to those"

A core part of this project was checking whether the simulation behaved like people in the real world. To do this Theresa collected recordings of stand-up comedy and used the volume of laughter as a way of estimating how much of the audience was laughing. She


PHOTO: AMSI

compared the proportion of the simulated audience against the real-world data to see if the model was realistic.

"I have gained a lot of insight into how hard it is to model social behaviour with maths, because humans don't lend themselves to this kind of research very well. We have to be really careful to not overstate our results and to verify our models because it's much easier to program something completely unrealistic and disconnected from reality than something that reflects what people actually do."

Theresa also found that the project offered clarity and direction to her future studies.

"There is a lot of future research potential in this project. My hope is to publish a paper out of what we have so far. I plan to do more work in this field, namely mathematical modelling in social science, even if it isn't related to this specific project," she said.

Theresa's research report and blog post can be found at vrs.amsi.org.au/student-profile-theresa-obrien/

2018/19 Students and projects

Student	Supervisor/s	Project Title
THE AUSTRALIAN NATIONAL UNIVERSITY		
Alexander Cox	Michael Norrish	Equivalence of natural deduction, sequent calculus in HOL4
Douglas Coulter	Laurence Field	Brownian motion, harmonic functions
James Martini	Stephen Roberts	Utilising sparse grids for airfoil simulations & uncertainty quantification
DEAKIN UNIVERSITY		
Rudra Kumar	Sophie McKenzie, Shaun Bangay	Evaluating an AR experience to determine play strategies
LA TROBE UNIVERSITY		
Emily Groves	Yuri Nikolayevsky, Grant Cairns	Drawings of the complete graphs K5, K6, the complete bipartite graph K3,3
Jade Bujeya	Toen Castle, Christopher Lenard	Chemically feasible configurations of topologically tangled cubes
Kevin Newman	Natalie Karavarsamis, Hien Nguyen	Is anybody home? Modelling frog occupancy at the La Trobe Wildlife Sanctuary
Phillip Newbold	Natalie Karavarsamis	An R package for occupancy model-parameter estimation using the two-stage approach
MACQUARIE UNIVERSITY		
Andy Tang	Georgy Sofronov	Analysis of chances of winning in a poker game: Combinatorial probability, the law of large numbers
Hugh Entwistle	Georgy Sofronov	Convergence in the central limit theorem
Shay Tobin	Frank Valckenborgh	The geometric, probabilistic structure of classical physical theories
MONASH UNIVERSITY		
Chang Yu Wang	Todd Oliynyk	Gravitational waves: A mathematical analysis
Eliza Jones	Anja Slim	Dynamics of compound droplets
Kshitija Vaidya	Santiago Barrera Acevedo	Cocyclic Hadamard matrices
Kyria Wawryk	Leo Brewin	Precession of the perihelia in a Schwarzschild spacetime
Siksha Sivaramakrishnan	Julie Clutterbuck	Symmetrisations, other rearrangement inequalities
MURDOCH UNIVERSITY		
Michelle Gardiner	Gerd Schroeder-Turk, Bruce Gardiner	Disordered analogues of triply-periodic minimal surfaces
QUEENSLAND UNIVERSITY OF TECHNOLOGY		
Christyn Wood	Elliot Carr	Calculating thermal diffusivity from laser-flash experiments
Kanupriya Agarwal	Michael Bode	How to measure a halo
Ryan Watson	Elliot Carr	Extracting insight into advection-dispersion processes through moment analysis
Solene Hegarty-Cremer	Pascal Buenzli	A grid-based particle method for solving hyperbolic curvature flows
Jamie Owen	Belinda Spratt	Including patient preference in outpatient appointment scheduling
RMIT UNIVERSITY		
Genevieve Batten	Stephen Davis	Mathematical modelling of the long-term dynamics of Cyprinid Herpes Virus 3
Guo Feng Anders Yeo	Vural Aksakalli	Single document key phrase extraction, clustering
Daniel Glasson	Graham Clarke	Cayley graphs of finite semigroups
Daniel Molent	Andrew Eberhard	Experiments with trust regions, the BFGS method in non-smooth optimisation
Shidan Liu	Laleh Tafakori	Predicting behaviour of financial systems based on a multivariate GARCH perspective, dynamical network
THE UNIVERSITY OF ADELAIDE		
Alexander Lai De Oliveira	Finnur Lárusson	Schemes, their functors of points
John Davey	Lewis Mitchell	Do the rich get richer on Reddit?
Scott Carnie-Bronca	Giang Nguyen	A Markov-chain-based investigation into renewable energy storage in South Australia
William Abbott	Giang Nguyen	Modelling wind farm power output using hidden Markov models, its implications for South Australian wind farms
James McCusker	Thomas Leistner	Quaternions, octonions
THE UNIVERSITY OF MELBOURNE		
Adrian Hendrawan Putra	Marcy Robertson	A topological study of the Grothendieck-Teichmüller group
Amir Farid Kaveh	James McCaw, Pengxing Cao	The TIV model: Robustness with respect to parameter variation
Jonathon Liu	Nick Beaton, Thomas Wong	Generating function approach to a directed-walk model for polymer propagation
Leo Li	Nick Beaton, Thomas Wong	The transfer matrix approach to polymer-modelling Dyck paths
Somya Mehra	Jennifer Flegg, James McCaw	Developing a within-host model for *Plasmodium Vivax* in an endemic setting
Stephen Zhang	Barry Hughes	A continuum-limit approach to a persistent exclusion process
Alex Savvinos	John Sader	Dynamics of small-scale devices in gas
Tim Kay	John Sader, Jesse Collis	Hydrodynamic particle trapping in microvortices
THE UNIVERSITY OF NEW ENGLAND		
Daniel Sykes	Gerd Schmalz	Rigid spheres, CR structures in general relativity
Mitchell Harris	Thomas Kalinowski	Convex hulls of graphs of bilinear functions
THE UNIVERSITY OF NEW SOUTH WALES		
Ian Powell	Maarit Laaksonen, Jake Olivier	Estimating population-attributable fractions in the presence of competing risks
Rumi Salazar	Michael Cowling	The shape of a drum

Student	Supervisor/s	Project Title
THE UNIVERSITY OF NEWCASTLE		
Alastair Anderberg	Dave Robertson	Random walks on derived graphs
Chloe Wilkins	Bishnu Lamichhane	Earthquake modelling with differential equations
Peter Groenhout	George Willis, Colin Reed	Simple groups of infinite matrices
Max Carter	George Willis, Stephan Tornier	Free products of graphs
William Roland-Batty	Jeffrey Hogan	Fourier optics, hermite functions, prolates
THE UNIVERSITY OF QUEENSLAND		
Gavrilo Šipka	Valentin Buciumas	Fusion categories from representations of quantum sl2 at roots of unity
Jackson Ryder	Diane Donovan	Adoption of agricultural technologies in African countries
Jacquie Omnet	Chris van der Heide	Non-uniqueness in geometric partial differential equations
Rohin Berichon	Ramiro Lafuente	Closed geodesics on Euclidean homogeneous spaces
THE UNIVERSITY OF SYDNEY		
John Su	Emi Tanaka	Visual inference for linear mixed models
Michael Zhao	Stephan Tillmann	Trisecting hyperbolic 4-manifolds
Nicholas Fazio	Peter Kim	Modelling of sexual conflict within primates
William Trad	Daniel Hauer	Powers of maximal monotone operators on Hilbert spaces
Timothy Lapuz	Milena Radnovic	Modelling of infectious diseases
THE UNIVERSITY OF WESTERN AUSTRALIA		
James Evans	John Bamberg	Generalised polygons, their symmetries
THE UNIVERSITY OF SOUTH AUSTRALIA		
Maria Kapsis	Amie Albrecht, Peter Pudney	Optimal partitioning of photovoltaic modules on a curved solar collector
Thomas Miller	Peter Pudney, Pung Zhou	Optimal cruise control with dual electric motors
UNIVERSITY OF TECHNOLOGY SYDNEY		
Daniel Condon	Adel Rahmani	Performance of artificial neural networks on small structured datasets
Thomas Goodwin	Anthony Dooley	Mathematical model of neuron flows and structures in the brain
UNIVERSITY OF WOLLONGONG		
Ngoc Lan Chi (Emma) Nguyen	Xiaoping Lu	A Laplace transform approach to pricing convertible bonds
Theresa O'Brien	Mark Nelson, Tristram Alexander	A giggle a minute: Agent-based simulation of laughter propagation in an audience
Vivien Yeung	Mark Nelson, Xiaoping Lu	Baking cake: A mathematical model
James Lawless	Ben Whale, Adam Rennie	Why the increasing surface-area law for black holes is an open problem
WESTERN SYDNEY UNIVERSITY		
Sajit Gurubacharya	Laurence Park	Detection of Australian racism in social networks

Gavrilo Sipka presenting at AMSI Connect PHOTO: ANJANETTE WEBB

3.6 CHOOSE MATHS GRANTS

Providing full or partial support for Australian female students and early career researchers to attend AMSI training events, Choose Maths Grants help women in the mathematical sciences to build and extend their skills and professional networks.

Awarded on a competitive basis by the Choose Maths Grant Committee, the grants support:

- Attendance at AMSI Flagship events (including support for second-time attendees)
- Partner & child travel and/or accommodation support

Caring responsibility support (for example, childcare or temporary respite)

The grants are a key component of AMSI's Choose Maths project, a partnership with the BHP Foundation to strengthen mathematics teaching and foster the participation and career awareness of girls and women in mathematics.

Working across four key components including a national career awareness campaign and network for women in maths, the Choose Maths project aims to improve the health of the mathematical pipeline from the classroom through the university and the workplace.

WINTER SCHOOL: AN INSPIRATION FOR EMERGING MATHS TALENT

Dr Claudia Bucur, The University of Melbourne

University of Melbourne Research Fellow and AMSI Winter School 2018 attendee Dr Claudia Bucur came to maths later in life. Her love for the subject, however, began much earlier thanks to an inspiring teacher.

"I had the fortune of having a very good maths teacher through high school. Having her for an example, it never occurred to me that men could be more inclined [toward] or better at maths than women," says Bucur.

Given her introduction to maths, it seems fitting that her Winter School 2018 experience was made possible thanks to a Choose Maths Grant. It was crucial to meeting the cost of attending.

> *"[Without the grant] it would have been quite challenging for me to attend Winter School. It allowed me to fully focus on the mathematics,"*

Focused on mathematics related to the theme of curvature, Winter School 2018 proved very relevant to Bucur's work in the field of integro-differential equations.

"Some of the courses were quite close to my area of research, some a little bit further away. It was thus challenging and very useful at the same time. I would definitely like to pursue studying and working on some of the subjects I got to know during Winter School," she says.

Previously based at Italy's University of Milan, Bucur returned to mathematics studies in 2012 after working in the industry as a statistical analysis system developer for six years. Now at the University of Melbourne, she is interested in issues related to the existence, regularity, quantitative and geometric properties of solutions in problems involving fractional nonlocal operators of integral type.

"This type of operators and problems give rise [sic] to a beautiful theory and to a lot of work. The applications are numerous, for instance in models describing anomalous diffusion, geomorphology, viscoelasticity, signal processing and materials sciences or fractals," she explains.

As she continues her new journey in mathematical science, AMSI Winter School offered not only exposure to new subjects and field areas but powerful networking opportunities to build ties in her field.

"[It was valuable] to meet and exchange opinions with some great mathematicians, setting the basis for future collaborations."

This rare access to add her voice to discussion in her field and foundational ties for future collaboration is why Bucur sees Choose Maths as such an enormous opportunity for women in mathematics.

"The Choose Maths grant provides a valid support for women mathematicians in their early career to access amazing courses. For me, meeting the women lecturers and the Women in Maths ambassadors was really inspiring," she enthuses.

Claudia Bucur received a Choose Maths Grant to attend AMSI's 2018 Winter School

2018–2019 recipients:

AMSI Winter School

Hadil Alhazmi, The Australian National University
Claudia Bucur, The University of Melbourne

AMSI BioInfoSummer

Shanika Amarasinghe, The University of Melbourne
Jennifer Boer, RMIT University
Bobbie Cansdale, The University of Sydney
Yue Cao, The University of Sydney
Erika Duan, La Trobe University
Lucinda Ham, The University of Melbourne
Jiru Han, The University of Melbourne
Tooba Jalalidil, Monash University
Alice Johnstone, RMIT University
Hue Mai La, Monash University
Dilys Lam, The University of New South Wales
Yingxin Lin, The University of Sydney
Marina Masioti, La Trobe University
Jannina Ong, Monash University
Veronika Petrova, The University of Sydney
Evelyn Phlox, The University of Adelaide
Huiwen (Vivian) Zheng, The University of Queensland

AMSI Summer School

Dongpei Bian, The University of Melbourne
Madhurima Biswas, The University of Melbourne
Rose Crocker, The University of Adelaide
Ashley Dennis-Henderson, The University of Adelaide
Chelsea Just, The University of Queensland
Yazheng Kang, Australian National University
Saritha Kodikara, RMIT University
Shenzhengyi Kuang, The University of Queensland
Jiayi Li, The University of Queensland
Peijing Li, The University of Melbourne
Bing Liu, The University of Melbourne
Xuemei Liu, The University of South Australia
Ziwei Liu, The University of Melbourne
Cherish Chen Huay Lo, The University of Queensland
Storm Logan, RMIT University
Rachael McCullough, The University of Melbourne
Wenfei Shi, The University of Melbourne
Siksha Sivaramakrishnan, Monash University
Miriam Slattery, The University of Adelaide
Haripriya Sridharan, The University of Adelaide
Anita Sugo, The University of Newcastle
Youxin Tan, The University of Melbourne
Yao Tang, La Trobe University
Shiyu Tian, The University of Melbourne
Chengcheng Wang, The University of Queensland
Zhiwang Wen, The University of Queensland
Yahang Wang, The University of Melbourne
Jiayi Wu, The University of Melbourne
Yi Xing, The University of Melbourne
Qin Xu, The University of Melbourne
Zhu Yao, The University of Melbourne
Hangfei Zheng, The University of Melbourne
Qi Zhuang, The University of Melbourne

AMSI Optimise

Olanike Adeoye, Victoria University
Laura Cartwright, University of Wollongong
Delaram Pahlevani, RMIT University
Zoe Renwick, RMIT University
Ekta Sharma, University of Southern Queensland

3.7 ACE NETWORK

Through the Advanced Collaborative Environment (ACE) platform, member institutions remotely deliver mathematical honours and masters subjects to students from universities around Australia. Short courses in specialised mathematical topics are also offered to both students and academics on an occasional basis.

Fourteen Australian universities—about half of AMSI's 29 member and non-member universities—belong to the ACE Network. In addition to offering honours and masters courses, the facilities are used to bring interest groups from the mathematical sciences community together for workshops and seminars.

RHED.AMSI.ORG.AU/ACE/

7 subjects offered by **5** universities in semester 2 2018

9 subjects offered by **6** universities in semester 1 2019

Overall **32** students from **9** universities accessed honours courses remotely

ACE Network

The ACE Network enables mathematical sciences departments to collaborate through advanced videoconferencing and desktop-sharing facilities. It was established to facilitate greater collaboration between the mathematical sciences community within Australia and internationally.

ACE facilities are used by AMSI members in a variety of ways:

- Events and seminars—broadcasting seminars, lectures and workshops
- Subjects and courses—providing additional honours and masters subjects, as well as short courses
- Collaborative research with peers within Australia and internationally
- Undergraduate mathematics teaching
- Professional development for mathematics teachers
- Meetings

Dr Judy-anne Osborn joined AMSI as the program director of the ACE Network in late 2018.

ACE Honours/Masters Courses

AMSI member institutions run mathematical honours- and masters-level subjects in the ACE Network enabling students from several universities at once to participate in subjects remotely.

2018 Semester 2

Host University	Name of Course	Lecturer	Number of Students Enrolled
Macquarie University	Differential geometry	Paul Bryan	4
Macquarie University	Topology	Adam Sikora	3
Macquarie University	Introduction to vortex dynamics	Christopher Green	3
RMIT University	Mathematical epidemiology: Modelling wildlife disease	Stephen Davis	4
RMIT University	Complexity theory and polynomial approximation of NP-hard problems	Marc Demange	1
University of Newcastle	Introduction to nonlinear PDEs	Michael Meylan	Subject cancelled
University of Sydney/Flinders University	Integrable systems	Nalini Joshi, Milena Radnovic, Yang Shi	No remote students

2019 Semester 1

Host University	Name of Course	Lecturer	Number of Students Enrolled
The University of Sydney	Asymptotic methods and perturbation theory	Sharon Stephen	3
The University of Sydney	Random graphs vs. complex networks	Eduardo Altmann	2
La Trobe University	Theory of statistics	Paul Kabaila	1
RMIT University	Advanced topics in cryptography	Serdar Boztas	Subject cancelled
The University of Western Australia	Algebra: Advanced group theory	Michael Giudici	4
University of Wollongong	Statistical consulting	David Steel	4
University of Wollongong	C*-Algebras	Aidan Sims	No remote students
University of Wollongong	Advanced data analysis	Pavel Krivitsky	1
The University of Newcastle	Introduction to valued fields	Florian Breuer, George Willis	2

3.8 AUSTRALIAN MATHEMATICAL SCIENCES STUDENT CONFERENCE

University of South Australia, 28–30 November 2018

The Australian Mathematical Sciences Student Conference (AMSSC) is an opportunity for postgraduate students from across the country to communicate their work and collaborate. Students attending gain conference experience in a friendly, informal environment and develop networks with their peers.

Complementing the AMSI Summer and Winter Schools, AMSSC is primarily directed towards Australian postgraduate and honours students from all areas of the mathematical sciences, inclusive of but not limited to applied/pure mathematics, statistics, mathematical physics, oceanography and mathematical biology. For many of the honours and postgraduate students in attendance, the conference is the first opportunity to present their own research to an audience outside their own institution.

In 2018, 31 students attended the AMSSC conference. The program included 27 research presentations by attendees on a broad range of applied and pure mathematics topics, while three plenary speakers talked about their own research and provided career advice.

As a student-run conference, AMSSC also provides the organising committee with experience in successfully organising and running a conference.

Organisers

Elizabeth Bradford, University of South Australia
Trang Nguyen, University of South Australia
Stephanie Mills, University of South Australia
Jody McKerral, Flinders University
Maria Kleshnina, The University of Queensland
Phillip Brown, The University of Adelaide

Invited Speakers

Prof. Benjamin Burton, The University of Queensland
Dr Douglas Brumley, The University of Melbourne
Dr Juliette Woods, South Australian Department for Environment and Water

Weblinks

amssc.org/2018/

Other Sponsors

AustMS, University of South Australia, Flinders University, The University of Adelaide

Contact

amssc2018@gmail.com

3.9 AMSI–AUSTMS EARLY CAREER WORKSHOP

Adelaide, 2–3 December 2018

Scheduled every second year as a satellite workshop to the annual AustMS meeting, the Early Career Workshop provides an opportunity for postgraduate students and early career researchers to learn from the experience of a panel of mathematical science leaders.

Held immediately preceding the AustMS conference in December, the 2018 workshop attracted 58 participants, comprised of PhD students, postdoctoral researchers and other early career mathematicians, as well as the speakers. The conference provided attendees with a mixture of career advice topics and discussion of research pathways, with three talks focused on career advice, three from early career researchers, and a talk from a mathematician working in the financial industry.

Among the highlights of the conference were several lively Q&A sessions involving the full panel of speakers.

Organisers

Dr Luke Bennetts, The University of Adelaide
Assoc. Prof. Michael Coons, University of Newcastle

Invited Speakers

A/Prof. Renato Bettiol, City University of New York, USA
Dr Corey Bradshaw, Flinders University
Dr Adrian Dudek, Optiver
Prof. Jan de Gier, The University of Melbourne
Dr Cecilia González Tokman, The University of Queensland
Dr Lewis Mitchell, The University of Adelaide
Prof. Hinke Osinga, University of Auckland

Weblinks

maths.adelaide.edu.au/luke.bennetts/AustMSECW2018.html

Other Sponsors

AustMS

Contact

Dr Luke Bennetts, The University of Adelaide, luke.bennetts@adelaide.edu.au

3.10 HEIDELBERG LAUREATE FORUM

Heidelberg, Germany, 18–23 September 2018

A highlight of the international mathematics and computer science calendars, the Heidelberg Laureate Forum (HLF) is a platform for scientific dialogue across generations. Each year, AMSI and AustMS provide funding for talented young Australian researchers to attend the event.

The annual HLF brings together winners of the most prestigious scientific awards in mathematics (Abel Prize, Fields Medal and Nevanlinna Prize) and computer science (ACM Turing Award) with a select group of highly talented young researchers.

Roughly 200 young scientists from all over the world get the unique opportunity to interact with their scholarly role models during lectures, panels and discussions. At the same time, the up-and-coming scientists can engage in inspiring and motivating conversations with the laureates during various social events as well as meet and network with other young mathematical scientists from around the world.

2018 recipients

Becky Armstrong, The University of Sydney
Pooladvand, The University of Sydney

WOMEN IN MATHEMATICS

AMSI's approaches to improving gender ratios in the mathematical sciences

Women and girls continue to be underrepresented across Australia's mathematical sciences. Through programs and initiatives such as APR.Intern and Choose Maths, AMSI is challenging traditional mathematical career narratives and championing gender equity at all stages of the discipline pipeline.

62 per cent of undergraduate and 66 per cent of postgraduate students in the Australian mathematical sciences are male, and women make up only 25 per cent of departmental staff. At senior levels, gender inequity is even more stark, with women accounting for only 10 per cent of professors in the mathematical sciences.

As a core focus of its mission and programs, AMSI is working with the mathematical and general communities to address this systemic threat to future capability and capacity. As a supporter of the Australian Mathematical Society's Women in Mathematics Special Interest Group (WIMSIG), AMSI embeds public *Women in Mathematics* and *Diversity in STEM* events within its flagship programs. Exploring key challenges faced by women in the mathematical sciences, these sessions generate critical discussion and help foster a national support network of women in mathematics.

The Institute is also actively working with workshop partners to increase female participation across AMSI-sponsored events to at least 30 per cent. AMSI's Scientific Advisory Committee recommends that conference/workshop organisers use a number of strategies to increase numbers of women attending AMSI-sponsored workshops. These include:

- Mandatory presence of women on event committees
- Proactive engagement of prominent female mathematicians to speak at the workshops
- Promotion of events through targeted channels such as women in mathematics networks and organisations such as WIMSIG
- Strengthened focus on encouraging women attending workshops to apply for funding through AMSI's travel grants, or through other travel awards such as the AustMS WIMSIG Cheryl E. Praeger Travel Award
- Inclusion of formal or informal opportunities in workshop programs to highlight issues facing women in maths and foster networking
- Provision of targeted support information such as assistance with childcare arrangements

We have seen some growth in 2018–2019, with participation figures showing 27 per cent female attendance across 15 workshops. This is up from 21 per cent during the previous year. However, a number of barriers continue to impact gender equity at mathematical sciences events, with key factors driving lower than expected attendance including:

- A low level of female participation in specific fields of maths
- Difficulty in travelling/being away due to family commitments
- Over-commitment, i.e. being invited to or expected to attend too many events

WORKSHOPS STATS

Invited speakers receiving funding: **31%** female (**25%** in 2017–2018)
Workshop participants: **27%** female (**22%** in 2017–2018)
Female students/ECRs receiving travel funding from AMSI: **36%** (**47%** in 2017–2018)

FLAGSHIP PROGRAM STATS

Overall, women accounted for **37%** of attendees across the five flagship training programs in 2018–2019, down from **41%** in 2017–2018.
(The decrease can be attributed to the low number of women attending the 2018 Winter School)

Winter School
11% female students, **50%** female lecturers
BioInfoSummer
54% female participants, **48%** female speakers
Summer School
28% female students, **36%** female lecturers
Optimise
42% female participants, **50%** female speakers
Vacation Research Scholarships
28% female students

OTHER PROGRAMS

APR.Intern
In 2018–2019, **50%** of the participants in the APR.Intern program were female, up from **29%** in 2017–2018

"Initiatives such as the Choose Maths Grants are a great way to encourage and ensure the participation of women in events such as these and to foster networking between women. It [sic] opens up more training opportunities, and highlights the achievement of women in mathematics, in an otherwise predominantly male-dominated field."

Dilys Lam, Garvan Institute

Assoc. Prof Mariel Sáez with Ellie Hubbard at the AMSI Winter School's Women in Maths Panel Event PHOTO: ANJANETTE WEBB

Choose Maths

AMSI Schools' partnership with the BHP Foundation continued to deliver the national Choose Maths project in 2018 and 2019. The Choose Maths initiative aims to turn around the public perception of mathematics, and contribute to the health of Australian mathematics pipeline from school through university and out to industry and the workplace by challenging community attitudes to participation in mathematics through a variety of programs and initiatives including:

- The Choose Maths Outreach program, providing teacher professional development and support at 120 schools across Australia. Data collected about student preferences and teacher self-efficacy is analysed and reported to the wider mathematics education community by AMSI's dedicated Choose Maths research staff.
- The national Choose Maths Awards for both teachers and students celebrating mathematics achievements, creativity and excellence.
- A national Careers Awareness campaign aimed at inspiring young women and men to continue with maths through high school and into university and the workplace.
- The Women in Mathematics Network, which includes both the Choose Maths Mentoring program for girls in Years 11 and 12, and the Choose Maths Days, which aim to engage high school students, particularly girls, with mathematics.
- Choose Maths Travel Grants for early career female researchers and students.

Choose Maths Grants

AMSI Choose Maths Grants empower Australian female mathematical sciences students and early career researchers by removing key economic and social barriers to participation in AMSI's flagship training events (Winter and Summer Schools, BioInfoSummer and Optimise). Competitively awarded, these grants cover event travel, accommodation and/or costs such as childcare, and support for partner and child travel.

Networking events are held for recipients at several of AMSI's major flagship events including the Winter and Summer Schools and BioInfoSummer.

APR.Intern

Under the *National Research Internships Program: supporting more women into STEM careers*, APR.Intern has increased the proportion of internships awarded to female students to 50 per cent during the 2018–2019 reporting period. Overall, since 2017 the female interns taking part in the program comprise 41 per cent, with a goal of 50 per cent across the program by the end of the funding period in 2020.

AMSI BioInfoSummer Women in Maths networking event PHOTO: ANJANETTE WEBB

Events in 2018–19:

- July 2018—Held over supper, AMSI Winter School's Women in Maths networking event was attended by more than 50 people. This was a lively discussion on the career experiences of women in mathematics, and how to encourage more diversity within the mathematical sciences. Panel members included Ellie Hubbard (senior electrical engineer, Aurecon Australasia), Associate Professor Mariel Sáez (Pontificia Universidad Católica de Chile and 2018 Winter School lecturer), Natalie Lawler (mathematics and science teacher, Kenmore State High School) and Professor Kim Anh Do (University of Texas MD Anderson Cancer Center). Dr Julia Collins from AMSI also spoke to guests about the AMSI Choose Maths project.
- September 2018—APR.Intern hosted the nationally livestreamed Women in the STEM Workforce event. The one-day forum focused on identifying existing initiatives and new opportunities to address barriers for women in STEM as well as solutions to accelerate and support their careers. Keynote speakers Dr Milica Ng (Head of Data Science, CSL) and Kathryn Fagg (President of Chief Executive Women) were joined by panels featuring representatives from Westpac, Telstra, Alcoa, STA Superstar of STEM, IMNIS, Australian Academy of Science, Australian Research Council, Engineers Australia and SAGE Athena Swan. Online access significantly boosted engagement with key audiences within industry, government and universities (academics and PhDs). The event attracted 413 total attendees, including 366 viewers of the webinar.
- November 2018—a WIMSIG lunch was held at the AMSI-CARMA Workshop on Mathematical Thinking.
- December 2018—This year's Diversity in STEM Lunch at BioInfoSummer was held in conjunction with the poster session to raise awareness about diversity issues including gender in STEM
- December 2018—A Choose Maths lunch, hosted by Associate Professor Inge Koch (Choose Maths Executive Director) was also held at BioInfoSummer.
- January 2019—The Summer School Diversity in STEM lunch featuring a panel of Summer School lecturers and other academic guests and a lively discussion on barriers hindering diversity in academia.
- January 2019—Hosted by AMSI's Dr Julia Collins, a Choose Maths networking dinner was also on the program at Summer School.

MAKING THE **INVISIBLE VISIBLE**

Interview with Professor Jacqui Ramagge

Head of the School of Mathematics at The University of Sydney, President of AustMS, and soon to be Executive Dean of Science at Durham University

Can you tell me a little about your background and mathematical influences?

I was born in London to Spanish immigrants. Culturally, I consider myself a combination of Spanish and English; Spanglish perhaps! Neither of my parents had undertaken any higher education. My mother left school at 14 and my father had been skipping school to work in the fields from the age of eight. We spoke Spanish at home. When I started school at the age of five my English was quite hesitant, but I always remember being able to do the maths exercises. From a cultural perspective I was lucky because people are expected to do maths in Spain; it is not seen as something that only the talented do. In fact, maths is so much in the mainstream of the culture that there is a mathematical insult: "you are more useless than a zero on the left." My family valued education highly and encouraged me at every step of the way.

Who were your role models and mentors as a woman entering the mathematical sciences? How important was this support?

With exception of Cheryl Praeger, most of my mentors were men, and they were all very supportive. Both of my physics teachers in senior high school were women and they were very unsupportive. I don't think someone is a good mentor just because they are a woman. There is of course the question of visibility. At high school, there were only three of us studying Further Maths (the highest level of maths available) and two of us were girls. So at that time I was in the majority! It was only much later that I realised this was unusual. Frankly, I had never really thought about it. However, I am painfully aware that I am a survivor of the system, and that those for whom a role model is important have likely not survived. I try to be visible and make the invisible visible. For example, when I give talks in schools, I start by saying "Hi! My name is Jacqui and I am a Professor of Mathematics at the University of Sydney. There are two things about me that are not obvious. It is not obvious that English is my second language, and it is not obvious that I was the first person in my family to go to university." I usually close by saying something along the lines of "If I can do it, so can you."

"I think the most insidious bias is that of low expectations. People talk about women being less ambitious than men. I know some women who are ambitious and many who are not."

In what ways have you encountered gender bias within the mathematical sciences and how has it shaped your career experience?

It's hard to say because I think my awareness of gender bias and sexism has grown significantly over time. For a long time I was simply oblivious to it. I think the most insidious bias is that of low expectations. People talk about women being less ambitious than men. I know some women who are ambitious and many who are not. Many may not be ambitious because they have internalised the low expectations they have been exposed to in society from a very young age. Much worse than their own ambition is the low expectation of others on their behalf, because it means they are less likely to be sponsored or proposed for roles. For example, I was lucky enough to be asked by the Australian Research Council to chair the Laureate Selection Advisory Committee. For various reasons, I needed to talk to my Dean about it. When I told him of the request, he looked very confused and said, "That is very prestigious." He had trouble coming to terms with the fact that they had asked me and would clearly never have suggested me himself.

Similarly, a few weeks ago I was presiding over graduation and was asked to go to the robing room early for instructions. I arrived and went to the man I knew was in charge of the event, who happened to be sitting and talking to someone else at the time. I told him that I was "reporting for duty" and he suggested I speak to the staff. I did, and when I asked them questions, they kept telling me that John would brief me. I continued chatting to those who were in the procession and the guest speaker. Eventually John must have realised he was missing a presiding Dean and been informed by the staff that I had been waiting all along. He apologised profusely for not realising that I had been "reporting for very important duties" and that I was, apparently, a "very important person." And so it goes.

The low expectations and constant small drawbacks are emotionally draining. It takes a great deal of perseverance and resilience to counteract them.

Why do you think mathematics continues to have such a strong gender inequity issue? What are the barriers for women in the discipline?

We need culture change. The issue is complex or we would have solved it by now, but there are some things that certainly don't help. It doesn't help that women are often asked to do the labour-intensive jobs that do not translate into promotion or success, and it doesn't help that women are more likely to do the jobs they are asked to do and do them conscientiously. Managers have to be more careful about who they ask to do things. Keeping track of all the duties done by staff and allocating new duties accordingly would be a first step. Learning not to overload staff even when they are willing to be overloaded is another thing that would help.

Many women have internalised all the messages society has constantly given them and do not advocate strongly on their own behalf. For example, when the university called for promotions one year I notified staff in the School of the call for applications


PHOTO: SUPPLIED

and sent emails to all the academics who were at the top of their scale suggesting they make an appointment to see me if they wanted to apply. Four men I had not asked to see came to see me about promotion. Meanwhile, I had to chase up a woman who was at the top of her scale who had not thought the email was meant for her. In order to counteract all the effective messaging from society we have to be highly proactive about supporting women. This includes encouraging them to apply for particular positions, even if they already have a job.

When we advertise for positions in the school, I remind staff of the proportion of women in the mathematical sciences nationally (about 28 per cent) and point out that if we don't have a similar proportion of female applicants then we have not obtained a representative sample. I regularly monitor and report the proportion of female applicants, asking staff to encourage women to apply. Since we started this approach, 36 per cent of our appointments have been female. At a recent panel discussion of the Australian Council of Heads of Maths and Stats, those who had recently advertised women-only positions commented that the one thing that made the biggest difference was that their staff headhunted women. This is consistent with my experience that encouragement to apply makes the biggest difference to recruitment outcomes.

Once there are enough women in a School, particularly at the senior levels, the culture starts to change.

What can the mathematical sciences do to address this issue particularly at the higher levels of academia? What role can the Academy of Science's Women in STEM Decadal Plan play in this?

I think the key lies with men, for a number of reasons. First, there are roughly twice as many of them as there are women, so they can have a bigger impact given the same effort per person. Second, men are vastly over-represented in positions of power and influence. As a Head of School I have often been the only woman of the 36 Heads of School around Australia, and there have never been more than two of us. Finally, it is emotionally draining on the women to always be the ones who have to drive the cultural change. It is a great relief when a male colleague plays an active role.

"Once there are enough women in a School, particularly at the senior levels, the culture starts to change"

The Women in STEM Decadal Plan gives a great analysis of the situation and provides some specific actions. I think the SAGE program for Athena Swan accreditation will make a big difference. Mathematical scientists understand data, and the data is powerful.

From January 2020 Prof. Jacqui Ramagge will be Durham University's Executive Dean of Science. Currently the Head of the School of Mathematics and Statistics at the University of Sydney and President of AustMS 2019–2020, Jacqui has been a member of AMSI's Education Advisory Committee since 2009. Other roles include being on the advisory panel for the senior secondary mathematics curriculum for ACARA.

Industry Research and Training 4

Former APR PhD intern and CSL Research Scientist Meaghan FitzPatrick speaking at the first APR.Intern alumni event

PHOTO: MICHAEL SHAW

4 INDUSTRY RESEARCH AND TRAINING

Future mathematical capability requires decisive policy action and reform today. AMSI's industry research program is working to boost Australian business engagement with mathematical sciences research. With 75 per cent of Australia's fastest growing employment areas requiring STEM, it is essential to ensure that Australia has the mathematical and statistical skills to remain internationally competitive and protect national security, population health and climate stability.

From July 2018 through June 2019, AMSI's industry internship program placed **126 interns** from **19 disciplines** with **80 industry partners** across **12 industry sectors**
50% female interns
26% international student interns
AMSI's **400th intern student** was placed in June 2019

4.1 APR.INTERN

Working at the nexus between industry and academia, APR.Intern is a not-for-profit program open to all universities and industry sectors, including small-to-medium and large enterprise as well as government agencies. APR.Intern provides a platform for industry to further develop and innovate through short-term tightly focused research projects, giving postgraduate students the opportunity to apply highly analytical research expertise to the project while gaining invaluable experience in an industry setting.

Operating across all disciplines and sectors, AMSI's industry intern program provides PhD students with the opportunity to work with an industry partner on a research project of three to five months' duration. The program is open to women and men with an emphasis on gender equity and helping domestic, regional, Indigenous and disadvantaged PhD students into STEM internships.

Through the internships, PhD students have the opportunity to hone their research skills on commercial applications, in turn providing a platform for industry to engage with and attract talent into organisations through short-term tightly focused research projects.

Significant growth occurred in the APR.Intern program during the 2018–2019 reporting period, with the number of interns increasing by more than 50 per cent to 126 (from 82 in 2017–2018), and the number of industry partners almost doubling to 80 (from 45). Students came from 19 disciplines (up from 12) and 12 industry sectors were engaged (an increase of 3). Female interns taking part in the program almost doubled from 29 per cent in 2017–2018 to 50 per cent in 2018–2019. Overall, since 2017 the female interns taking part in the program comprise 41 per cent, with a goal of 50 per cent across the program by the end of the funding period in 2020.

With Business Development Officers now positioned in all states except Tasmania, much of the growth occurred in South Australia and Queensland. Tasmania was the only state with no interns participating during this reporting period, while students from both the Australian Capital Territory and the Northern Territory participated in the program.

APR.Intern has entered into a series of partnerships with both public sector and private organisations to place interns, including NSW's Defence Innovation Network and WA's Defence Science Centre, as well as the Innovative Manufacturing CRC, the ARC Centre for Personalised Therapeutics Technologies and the Victorian Comprehensive Cancer Institute. These agreements join other partnerships with Australian enterprises and organisations including the Australian Bureau of Statistics.

APR.Intern is Australia's leading PhD internship program having placed more than 400 postgraduate students from 33 universities into industry since the intern program began in 2009. More than 140 businesses and government agencies have hosted interns during this time, and significantly, more than 20 per cent are repeat customers.

APR.Intern hosted the nationally livestreamed Women in the STEM Workforce event in early September. Online access significantly boosted engagement with key audiences within industry, government and universities (academics and PhDs). The event attracted 413 total attendees, including 366 viewers of the webinar.

APR.Intern is supported by the Australian Government through the National Research Internships Program: Supporting more women into STEM careers (NRIP).

APRINTERN.ORG.AU

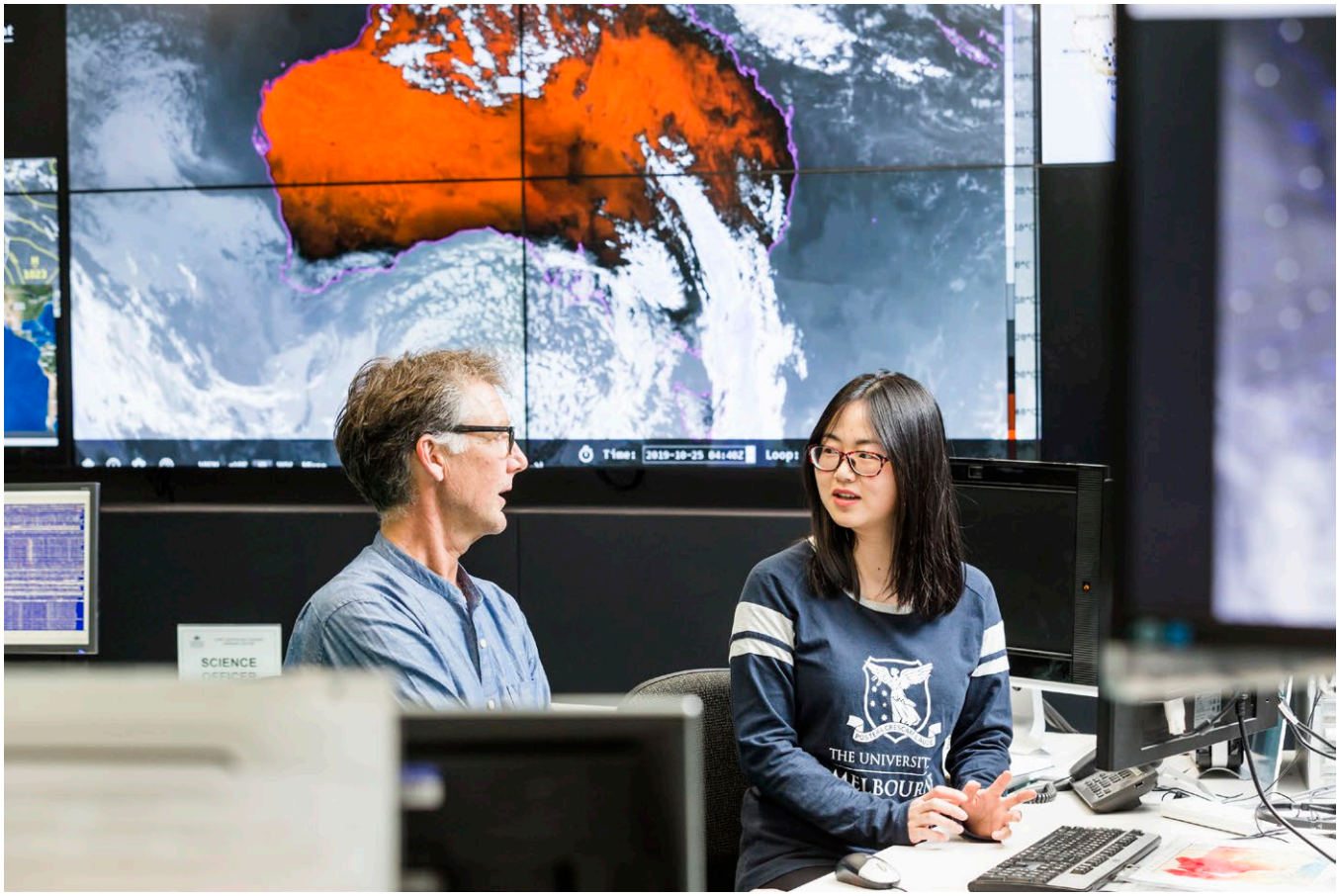
PROGRAM PARTICIPATION

From July 2018 through June 2019, **126** interns
from **19** disciplines with **80** industry partners
across **12** industry sectors
50% female interns **26%** international student interns

STATE BY STATE:

ACT – 5	NSW – 29
NT – 1	QLD – 9
SA – 21	VIC – 58
WA – 3	

Q&A panel of the challenges for women entering the STEM Workforce (top) and Milica Ng, Head of Data Science, CSL (bottom) speaking at the Women in the STEM Workforce 18 Event PHOTOS: DREW ECHBERG



Dr Peter Steinle, Bureau of Meteorology with Jie Jian, PhD student from the University of Melbourne PHOTO: DREW ECHBERG

CASE STUDY: CLIMATE CRISIS: PHD INTERN UNCOVERS RIVERFLOW TRENDS

When the Bureau of Meteorology set out to advance Australia's understanding of climate change, it brought on PhD expertise in a first-of-its-kind research project.

Utilising AMSI's national PhD internship program, APR. Intern, the Bureau was matched with the skillset of Jie Jian, a PhD student from the University of Melbourne.

Specialised in hydrological modelling, supercomputing and large data, Jie was able to provide the skills needed to study changes in river flows over the last decades for the *Bureau of Meteorology Atmospheric high-resolutions Regional Reanalysis for Australia* (BARRA) project. BARRA reproduces the Australian weather over the past 25 years and this enables studies of its impact in river catchments where it had not been monitored in the past.

Over the five-month internship, Jie's research accelerated the Bureau's investigation into river flows across the country. In turn, this provided valuable new climate data for Australia's research community and water managers to act on.

"BARRA's dataset provides a greater understanding of the Australian present climate, allowing for better planning and management to reduce future risk," said Dr Chun-Hsu Su, Bureau of Meteorology Research Scientist and Jie's Industry Supervisor.

"Jie's results are valuable for informing the next phase of re-analysis and highlight the potential for BARRA to improve Bureau's collection of key climate datasets," added Dr Peter Steinle, Bureau of Meteorology Team Leader in Data Assimilation.

The internship was also an opportunity for Jie to work with talented researchers and see the transferability of PhD skills.

> *"During my time at the Bureau, I was able to build long-term relationships and gain invaluable experience working in teams"*
>
> **Jie Jian, PhD student from the University of Melbourne**

"As well as working with cutting-edge climate data and tools, I gained a deeper understanding of the role government agencies play in Australia," Jie continued.

To date, the Bureau has engaged with nine PhD interns in its mission to remain at the forefront of Australian weather services.

This internship was supported by the Australian Government Department of Education, through the National Research Internships Program: Supporting more women into STEM careers.

CASE STUDY: DATA EXPERTS DELIVER LIFE-SAVING BUSHFIRE TOOL

As climate change continues to drive Australia's bushfire threat, new forecasting tools are needed more than ever.

To aid investment planning, the Queensland Fire and Emergency Services (QFES) partnered with PhD experts on a data-driven Future Decision Support Model that would assist in identifying the likelihood and severity of natural disasters, their impact on the community and assets of Queensland, and the services these disaster-driven impacts generate for QFES.

Developed by Queensland's whole-of-government analytics provider, Data Sharing & Analysis (DSA), the team engaged with APR.Intern to augment its skill in the area of data analytics. PhD student Puteri "Mita" Paramita from the Queensland University of Technology was a perfect match, able to work with the high-end data scientists on the strategic project.

"My five-month project helped me to gain confidence, identify transferable skills and understand commercial imperatives. The experience exceeded my expectations."

Puteri "Mita" Paramita, former PhD Intern at DSA

For DSA Program Director Jeffrey Popova-Clark, Mita's expertise and professionalism helped QFES adopt the use of modern data science to strategic investment decision-making.

"Mita was an excellent addition to this innovative project and I can't imagine its development without her. The internship increased the project's success by providing additional support and delivering rapid results through a tightly-focused research project."

Jeffrey Popova-Clark, DSA Program Director

QFES's new tool will assist Queensland communities in preparing for fires, floods, cyclones and earthquakes by informing the strategic investment of emergency response infrastructure, proactive skills building and predictive location of emergency response resources.

The data-driven capability was the first of its kind in Australia, catapulting QFES and the Queensland government in terms of its ability to use objective data during emergency services investment decision-making.

The DSA team acknowledges Mita's contribution to the project, which provided a lasting strategic legacy to support volatile emergency services.

This internship was supported by the Australian Government Department of Education, through the National Research Internships Program: Supporting more women into STEM careers.

North of Bamaga, Far North Queensland PHOTO: ISTOCKPHOTO

4.2 MATHEMATICS IN INDUSTRY STUDY GROUP (MISG)

University of South Australia, 21–25 January 2019

AMSI partners with ANZIAM to support the annual Mathematics in Industry Study Group (MISG). Applied mathematicians, statisticians, physical scientists and engineers apply cutting-edge mathematical science to provide practical working solutions to real-life industry challenges, creating business linkages, tools and technologies to improve capacity and capability in problem-solving and decision-making.

Using methods from the mathematical sciences, the annual MISG workshop provides practical, working solutions to real-life problems in business and industry, ranging from small-to-medium enterprises to multinational conglomerates, as well as government agencies and more. MISG has worked with a diverse range of more than 90 Australian and New Zealand business and industry partners on more than 160 different projects spanning a broad spectrum of industry sectors—including mining, car manufacturing, railways and freight, manufacturing, metal processing, food and beverages, oil and gas, utilities, biomedical science and technology.

Due to problems securing suitable industry problems this year, MISG ran a smaller event where participants worked on the Explorer Challenge—a global challenge with a $1 million prize pool run by Unearthed to find Australia's next big mineral deposit.

The objective of the Explorer Challenge was to predict economic mineralisation locations in the Mount Woods project area using publicly available data supplied by OZ Minerals from the Mount Woods project site in South Australia.

A geologist from the University of South Australia briefed participants at MISG on the problem and was on hand for technical advice during the week. Attendees split into smaller teams and worked on the problem throughout the week, with each team presenting their results to the full workshop group on the last day.

Despite the smaller event, 31 delegates attended MISG 2019. These included delegates from Oxford in the UK and from Japan. About half of the delegates were PhD students, with seven of these from the Industry Doctoral Training Centre (IDTC).

From 2020, MISG will move to the University of Newcastle.

MATHSININDUSTRY.COM
Director: **Assoc. Prof. Peter Pudney**
University of South Australia

EVENT PARTICIPATION

31	**Attendees**
15	**Students**
8	**Female participants**
7	**International participants**

Weblinks

mathsinindustry.com/about/misg-2019/

Other Sponsors

ANZIAM, University of South Australia

Contact

Assoc. Prof. Peter Pudney, University of South Australia,
peter.pudney@unisa.edu.au

4.3 PARKS VICTORIA PARTNERSHIP

Protecting Australia's iconic flora and fauna, sustained with statistics

Parks Victoria is responsible for managing a diverse estate that covers more than 4.1 million hectares (about 18 per cent of Victoria) and includes national parks, urban parks, wilderness areas and 70 per cent of Victoria's coastline. In 2010, AMSI entered into a three-year agreement with Parks Victoria to provide statistical support for their environmental monitoring, evaluation and reporting activities. Due to its continuing success, the agreement was extended until 2020.

Through this agreement, enabled through Parks Victoria's Research Partners Panel, AMSI statistician Kally Yuen has been embedded within Parks Victoria's Science and Management Effectiveness Branch, actively supporting research and monitoring activities to help improve park management. Projects include evaluation of data capture options for wildlife monitoring using remote cameras and assessing the effectiveness of invasive plant control programs. The AMSI partnership plays a key role in Parks Victoria's commitment to utilising evidence-based decision making in environmental management and in providing access to specialist skills.

AMSI acknowledges Parks Victoria for their continuing support of this important research collaboration.

Kally Yuen, AMSI Statistician

Kally is an experienced biostatistician, having worked at the Peter MacCallum Cancer Centre and the Centre for Youth Mental Health at the University of Melbourne.

Accredited by the Statistical Society of Australia in 2004, Kally has qualifications including a Master of Science degree in Statistics and a Bachelor of Science degree with First Class Honours in Statistics and Computer Science. She received the Maurice Belz First Prize for Statistics while she was an undergraduate at the University of Melbourne.

Kally specialises in survival analysis, generalised linear models and relational database management systems. She is experienced in statistical consulting, research study design, study protocol and research database development, statistical analyses of research data, protocol review for research and ethics committees and grant assessment. Highly published, she has been a co-author in more than 30 research publications, 14 as a senior author. She has nurtured new talent as an instructor in statistics training courses and supervisor for research students.

Projects

Sallow Wattle Control Monitoring Program in the Grampians National Park

Since 2015, AMSI and Parks Victoria have joined forces to fight the spread of Sallow wattle and protect biodiversity in the Grampians National Park. Home to more than one third of Victoria's flora species, the National Heritage-listed park's rich biodiversity is under threat from an invasive native plant species – Sallow wattle. This plant does not naturally occur in the area and is behaving like a weed, spreading and threatening the survival of important native species. AMSI and Parks Victoria have been examining the effectiveness and costs of five different treatments to control this native weed in the national park.

Results to date indicate that mulching is the most efficient treatment for controlling the weed, with no major impacts on native species. However, further monitoring is required to determine the most effective method in the long term. Recently-announced State Government funding of $647,000 to control Sallow wattle in the Grampians National Park has enabled the extension of the monitoring program (see opposite page). A joint regional media release, *Native species behaving badly*, focusing on impacts across the Grampians, resulted in significant ABC radio and print coverage of AMSI's partnership with Parks Victoria. Kally continues to work with Parks Victoria on this important program.

Mulcher in action at the Grampians National Park to control Sallow wattle

Evaluation of Software for Automated Analysis of Images from Remote Cameras

Remote cameras are frequently used by Parks Victoria for survey and monitoring of fauna. Cameras can capture thousands of images, and sorting these images is very tedious and time consuming. It involves manually viewing and removing unwanted images that result from false triggers (e.g. by vegetation moving with the wind) and identifying species present in the photos. An automated process that can reliably assist the above tasks will potentially save a lot of time and effort.

Parks Victoria and Arthur Rylah Research Institute for Environmental Research (ARIER) have recently collaborated in evaluating software developed for automated analysis of remote camera images. Kally worked with Dr Alan Robley from ARIER to develop a study protocol and conduct the analysis for the software evaluation. The results provided useful information for ongoing software development. Kally will continue to provide support for Parks Victoria in the evaluation of the product. This three-way collaboration is enabling Parks Victoria to refine and improve innovative wildlife survey techniques.

A black-tailed wallaby captured by one of the remote cameras in Wilsons Promontory National Park in September 2017

An Assessment of Feral Horse Impacts on Streams and Wetlands in the Australian Alps

Alpine streams at a horse-occupied site in the Alpine National Park. Signs of environmental damage including streambank disturbance are evident.

Feral horses are widespread across the Australian Alps and their numbers are increasing. Feral horses degrade alpine and sub-alpine ecosystems and damage the habitat of a range of threatened species and vegetation communities. Through the Australian Alps Cooperative management Program, Parks Victoria and the NSW Office of Environment and Heritage undertook a collaborative study to assess the impacts of feral horses on streams and wetlands across the Australian Alps. Kally conducted statistical analysis of the data. The study found significant differences between horse-occupied and horse-free sites for a number of soil and stream stability measures. Kally contributed to the writing of a manuscript which was published in the peer-reviewed journal *Ecological Management and Restoration* in January 2019 (Robertson, G., Wright, J., Brown D., Yuen, K. and Tongway, D. (2019). An assessment of feral horse impacts on treeless drainage lines in the Australian Alps. *Ecological Management & Restoration* 20(1): 21-30).

CASE STUDY: NATIVE SPECIES BEHAVING BADLY: HALTING THE SALLOW WATTLE THREAT TO GRAMPIANS NATIONAL PARK

A fast-growing native plant species taking over Grampians National Park is the target of a Parks Victoria study to determine the best and most effective controls.

Home to more than one third of Victoria's flora, the National Heritage-listed park's rich biodiversity is under threat from a rapidly spreading native plant species – the Sallow wattle (*Acacia longifolia*). This plant does not naturally occur in the area and is behaving like a weed, threatening the survival of other important native species in the park.

"This park has great cultural and environmental significance which is suffering from a massive weed problem. We are using science and data to find the most effective treatment for the problem."

"One of the reasons the Grampians National Park is on the National Heritage list is its amazing diversity of plants. People don't go to the Grampians to see a wall of wattle," said Grampians Environment and Heritage Team Leader Mike Stevens.

Parks Victoria and AMSI have been examining the effectiveness and costs of five different treatments to control the overabundant native weed in the national park, including brush-cut, manual removal, mulching and two types of herbicide. Results so far have indicated that mulching is the most efficient treatment in controlling the weed with no major side effects on native species surrounding the weed. However, further monitoring is required to determine the most effective method in the long term.

"Science, research and monitoring are important for measuring results of conservation actions and informing decision-making into the future," said Mr Stevens.

As part of the Victorian State Government's Biodiversity Response Planning, $1.8 million was allocated to conservation programs in the Grampians National Park in 2018, with $647,000 supporting Parks Victoria and AMSI's ongoing program to stop the invasive plant.

Despite being native to Australia, the Sallow wattle emerged as a significant problem in the Grampians following the 1999 Mt Difficult bushfire, which catalysed the plant's rapid spread through the park. The plant is thought to have been introduced to the Grampians as early as 1860 when it was used as fodder by troopers stationed at Troopers Creek.

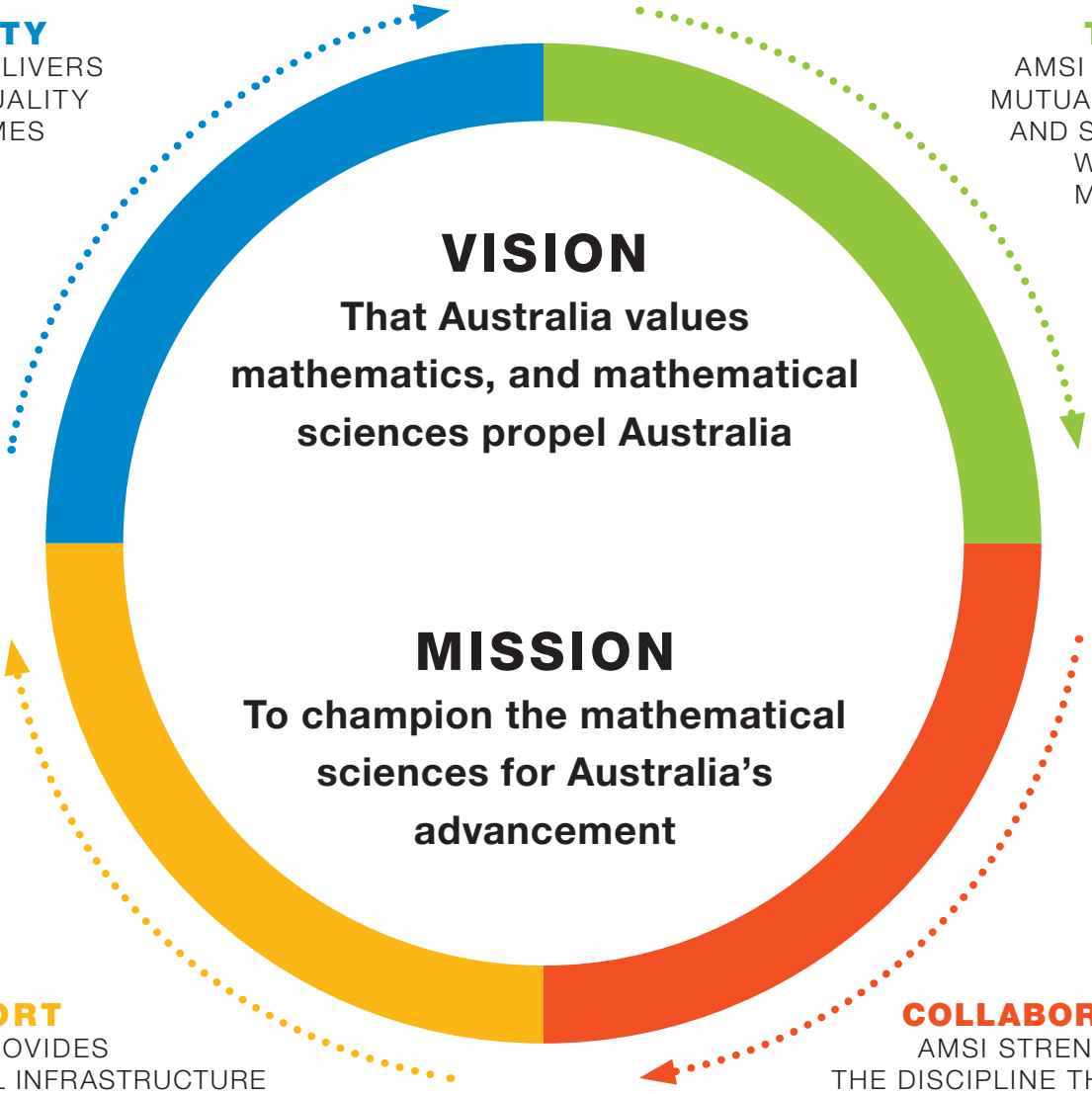
ABBREVIATIONS & ACRONYMS

ABACBS	Australian Bioinformatics and Computational Biology Society
ABS	Australian Bureau of Statistics
ACARA	Australian Curriculum, Assement and Reporting Authority
ACE	Advanced Collaborative Environment
ACEMS	ARC Centre of Excellence for Mathematical and Statistical Frontiers
AMSI	Australian Mathematical Sciences Institute
AMSSC	Australian Mathematical Sciences Student Conference
ANU	The Australian National University
ANZIAM	Australian and New Zealand Industrial and Applied Mathematics
APR.Intern	Australian Postgraduate Research Intern program
ARC	Australian Research Council
AustMS	Australian Mathematical Society
CARMA	The Priority Research Centre in Computer Assisted Mathematics and Applications, The University of Newcastle
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ECR	Early career researcher
EMBL Australia	European Molecular Biology Laboratory Australia
FIoT	Future Internet of Things
ICE-EM	International Centre of Excellence for Education in Mathematics
IMNIS	Industry Mentoring Network in STEM
IoT	Internet of Things
MASCOS	Centre of Excellence for Mathematics & Statistics of Complex Systems
MathSciNet	Mathematical Reviews Database (maintained by the American Mathematical Society)
MATRIX	Mathematical Research Institute (jointly administered by The University of Melbourne and Monash University with support from ACEMS)
MISG	Mathematics in Industry Study Group
MSI	Mathematical Sciences Institute (ANU)
NRIP	National Research Internships Program: Supporting more women into STEM careers
NSF	National Science Foundation (USA)
PDE	Partial Differential Equation
QCIF	The Queensland Cyber Infrastructure Foundation
QFES	Queensland Fire and Emergency Services
QUT	Queensland University of Technology
RHE	Research and Higher Education
RHEC	Research and Higher Education Committee
SAC	Scientific Advisory Committee
SSA	Statistical Society of Australia
STA	Science & Technology Australia
STEM	Science, Technology, Engineering and Mathematics
UNE	The University of New England
UniSA	University of South Australia
UNSW	The University of New South Wales
UoM	The University of Melbourne
UoN	The University of Newcastle
UOW	University of Wollongong
UQ	The University of Queensland
USQ	University of Southern Queensland
USyd	The University of Sydney
UTas	University of Tasmania
UTS	University of Technology Sydney
UWA	The University of Western Australia
UWS	Western Sydney University
VRS	Vacation Research Scholarships
WIMSIG	Women in Mathematics Special Interest Group

AMSI MISSION

QUALITY
AMSI DELIVERS HIGH QUALITY OUTCOMES

TRUST
AMSI SHARES MUTUAL TRUST AND SUPPORT WITH OUR MEMBERS



SUPPORT
AMSI PROVIDES CRITICAL INFRASTRUCTURE AND SUPPORT TO GROW DISCIPLINE ACTIVITY

COLLABORATION
AMSI STRENGTHENS THE DISCIPLINE THROUGH COLLABORATION WITH MEMBERS AND STAKEHOLDERS

To deliver our mission, we will

Advocate for the role of the mathematical sciences

Engage with stakeholders and build partnerships

Enhance mathematical sciences education and research

Strengthen mathematical sciences skills in the community

Influence policy makers that affect the mathematical sciences

By

Promoting the benefits of mathematical sciences capabilities

Delivering programs and services for all our stakeholders across disciplines and sectors

Attracting investment and sustainable funding

Building engagement and partnerships with schools, universities, industry, government and philanthropic entities to deliver our programs effectively

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