AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

Research Report

ANNUAL
2017 -18

AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

ABOUT **AMSI**

The Australian Mathematical Sciences Institute (AMSI) is a national collaborative venture of Australia's leading universities, professional societies and government agencies.

The central voice for the Australian mathematical sciences, AMSI drives a strong policy and advocacy agenda to radically improve the effective and efficient delivery of mathematical and statistical capability and capacity to education, research and industry.

AMSI runs significant national programs to improve mathematical sciences outcomes within research, higher education, industry engagement and schools. Our activities include scientific workshops, distinguished visiting lectureships, short courses, research training events, PhD industry research internships, professional development for teachers, and industry liaison.

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RMIT University
The Australian National University
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The University of Newcastle
The University of Queensland
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The University of Adelaide
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AMSI and its members acknowledge the significant contribution of The University of Melbourne as our Lead Agent and host

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Australian and New Zealand Industrial and 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)

Member list as of July 2018

Cover image: *Sand painting 2* by Dr Marcus Volz, The University of Melbourne
The image shows the trajectories of a number of particles whose movements are governed by a simple generative algorithm. Linear interpolation is used to transition between the paths, and each path is then replaced by a large number of randomly scattered points to achieve a sandy texture.
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Editorial team: Melissa Trudinger and Laura Watson
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DELIVERING TRULY **NATIONAL** & **COOPERATIVE** PROGRAMS

PHOTO: JENNY CUEREL

AMSI and its members have collaborated to deliver another year of exciting achievements in research and research training. Our goals are to provide enhanced experiences for all our students through our flagship schools and scholarships program and to build international collaborations and research opportunity for our mathematical scientists. Australia's schools of mathematical sciences and its scientific agencies vary enormously in size, character and resourcing. So, in an intensely competitive university sector, AMSI's role is particularly important in delivering truly national and cooperative programs.

In the year from July 2017 to June 2018 AMSI supported **21** workshops, partially in partnership with the Australian Mathematical Society. These events attracted more than **850** participants, of whom **38%** were international visitors, more than **40%** were postgraduates or early career researchers (ECRs) and **22%** were female. We sponsored **112** keynote speakers of whom **93%** were international and **24%** were female.

I thank the members of our Scientific Advisory Committee (SAC), in particular chairs Terry Speed (till January 2018) and Phil Broadbridge, for their leadership, wisdom and diligence.

The female participation in the workshop program continues to give concern although there have been increases over previous years. Our SAC believes that its strong insistence on female participation strategies is paying dividends and we are studying workshop attendance data to identify positive and negative factors affecting participation by women. On the plus side, 47 per cent of those postgraduate and ECRs whose attendance we supported through our Member Travel Grant scheme were female.

Our flagship schools and scholarship program were particularly successful this year and the trend indicates greater success in the 2018-19 year. With attendance at a record 551 we saw 41 per cent female students and 35 per cent female lecturers and speakers out of a total of 98. It was particularly pleasing to support many female students through the Choose Maths travel grants, supported by the BHP Foundation.

Our PhD Industry Internship program, APR.Intern, is growing rapidly, placing 82 interns from 14 disciplines with 45 industry partners across 9 industry sectors from July 2017 to June 2018. Although it services all academic discipline areas, there continues to be a particularly strong demand for the mathematical sciences, especially in statistics, optimisation and cyber security.

In June 2018, the University of Melbourne hosted the second AMSI Optimise event with operational support provided by AMSI. This event has created a valuable industry engagement opportunity, moving next year to Curtin University in Western Australia on the themes of mining, oil and gas. The success of AMSI Optimise is a credit to both the optimisation community and AMSI's Research and Higher Education team. On behalf of AMSI's membership I congratulate Program Manager Chloe Pearse, Angela Coughlin, Anna Muscara, Francesca Hoban Ryan and Liam Williamson for the flawless delivery of these programs so essential to AMSI's identity.

Finally, I acknowledge our major funding partner, the Commonwealth Department of Education and Training. It is heartening to see bipartisan recognition and support of the fundamental place that the mathematical sciences have in our social, economic and intellectual lives.

Professor Geoff Prince
Director

AMSI Milestones

2002

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

AMSI Summer School established

2003

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

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

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

100th Vacation Research Scholarship awarded

AMSI Winter School established

2005

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

Annual AMSI Lecture Tour established

2006

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

2007

AMSI sponsors 100th Scientific Workshop

2008

2009

AMSI Intern program is established

Group photo at the AMSI Summer School 2018

PHOTO: MATHS AT MONASH

2010

AMSI Intern program is expanded through $1.7m government grant

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 held

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

Choose Maths launched with $22 million from BHP Foundation

2015

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

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

2016

15th AMSI Summer School held

AMSI Optimise launches in Melbourne

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

AMSI Intern relaunched as APR.Intern

AMSI places 200th intern

2017

AMSI sponsors 250th Scientific Workshop

AMSI places 250th intern

1400 mathematicians and statisticians attend AMSI-sponsored events in 2017/18

2018

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 (R&HE) 2017–2018

The R&HE Committee monitors mathematical sciences research across Australia and provides strategic advice to the AMSI Board and Executive.

Prof. Markus Hegland, MSI, The Australian National University (Chair)
Dr Nicola Armstrong, Murdoch University
Prof. Nigel Bean, The University of Adelaide (from July 2017)
Tom Dyer, University of Wollongong (Student representative)
Prof. Anthony Henderson, The University of Sydney
Dr Phillip Isaac, The University of Queensland
Assoc. Prof. Inge Koch, Executive Director, Choose Maths
Chloe Pearse, AMSI Research and Higher Education Program Manager
Prof. Geoff Prince, AMSI Director
Prof. Aidan Sims, University of Wollongong
Prof. Scott Sisson, The University of New South Wales
Prof. Kate Smith-Miles, The University of Melbourne
Prof. Terry Speed, The Walter and Eliza Hall Institute of Medical Research (until January 2018)
Maaike Wienk, ACE Network, AMSI
Anna Muscara, AMSI (Co-secretary)
Angela Coughlin, AMSI (Co-secretary)

Scientific Advisory Committee (SAC) 2017–2018

The SAC provides scientific advice for AMSI Research activities and reviews, as well as AMSI Scientific Workshops.

Prof. Philip Broadbridge, La Trobe University (Chair, from May 2018)
Prof. Terry Speed, The Walter and Eliza Hall Institute of Medical Research (Chair, until January 2018)
Prof. Geoff Prince, AMSI Director (acting Chair, from January–May 2018)
Prof. Ben Andrews, The Australian National University
Prof. Andrew Barbour, University of Zurich (from November 2017)
Prof. Darren Crowdy, Imperial College London
Prof. Ezra Getzler, Northwestern University
Prof. Elizabeth Mansfield, University of Kent
Prof. Mary Myerscough, The University of Sydney (from November 2017)
Prof. Terry Tao, UCLA; Clay Mathematics Institute, USA
Prof. Ole Warnaar, The University of Queensland
Assoc. Prof. Lesley Ward, University of South Australia (from November 2017)
Francesca Hoban Ryan, AMSI (Secretary)
Chloe Pearse, AMSI Research and Higher Education Program Manager (Ex-officio)

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 provided are not intended as endorsements of views or information but are provided for the convenience of the reader.

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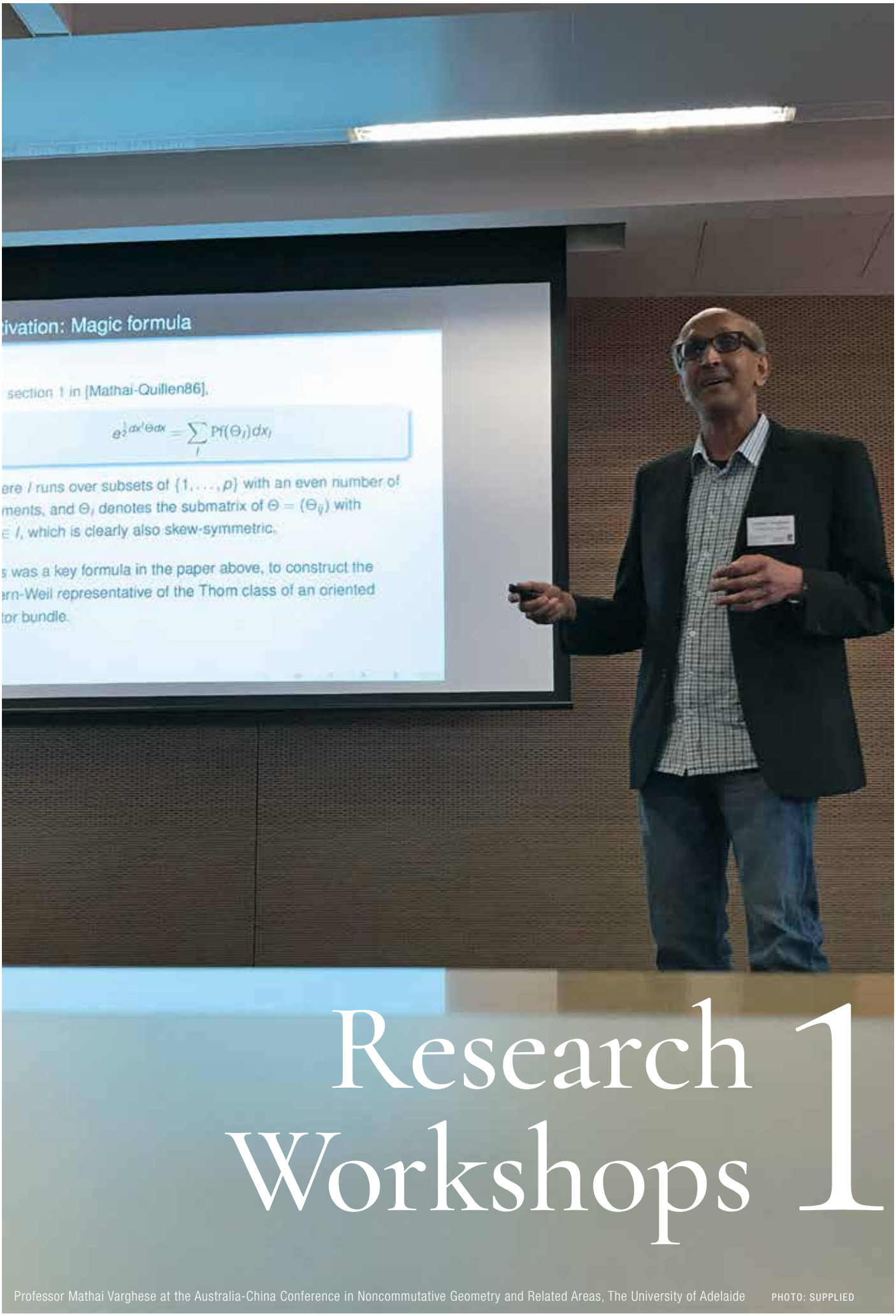


Research Workshops 1

Professor Mathai Varghese at the Australia-China Conference in Noncommutative Geometry and Related Areas, The University of Adelaide PHOTO: SUPPLIED

1 RESEARCH WORKSHOPS

AMSI's program of scientific workshops is internationally recognised. Nurturing 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 2017–18 AMSI sponsored **21 workshops and conferences** through the Scientific Workshops Program

AMSI-sponsored workshops and conferences attracted **855 participants** from academia, industry and government

38% of participants were **international visitors**

Women made up **22%** of the participants

23% of participants were **postgraduate students**, and another **16%** were **early career researchers (ECRs)**

Of **360 speakers** total:

- **24%** speakers were **women**
- **46%** speakers were **international**

AMSI sponsored **112 speakers,** of whom **93%** were **international**

20 students and early career researchers were awarded AMSI travel funding **to attend** research workshops

1.01 HARMONIC ANALYSIS AND PDE

Macquarie University, 17–21 July 2017

Bringing together global and national field leaders, this conference provided a fertile ground to explore new developments and collaborative opportunities within harmonic analysis and partial differential equations (PDEs).

Playing an important role in fundamental and applied mathematical discovery, harmonic analysis and PDEs have extensive applications within other research fields such as complex analysis, mathematical modelling, signal processing and medical imaging. Organised to mark the 60th birthday of Macquarie University's Professor Xuan Duong, this conference examined the most significant recent achievements in harmonic analysis and PDEs, with a focus on future directions of the research.

The key research themes included harmonic analysis and partial differential equations, in particular sharp weighted bounds, Riesz transforms on manifolds, function spaces, commutators, elliptic partial differential equations and homogenisation.

Among the many highlights, a lecture from Professor Jill Pipher provided insight on an excellent recent result on elliptic PDEs which appeared in the *Journal of the American Mathematical Society*. Professor Michael Lacey also opened up some recent techniques in harmonic analysis that will have far-reaching consequences for future work.

With an impressive representation from the global and Australian research communities, students and early career researchers benefited from access to established field experts. Importantly the event has raised the Australian mathematics research profile and seeded collaboration between Australian and international research teams.

Excitingly, Associate Professor Lesley Ward and her two PhD students (Stefanie Mills and Trang Nguyen) have had discussions with Professor Jill Pipher, while Professor Virginia Naibo is exploring possible joint work with several Australian and international researchers. Also as a result of the conference, Associate Professor Soonsik Kwon had a one-week visit at Monash to collaborate with Professor Zihua Guo after the conference; and Professors Chin-Cheng Lin (National Central University, Taiwan) and Hong-quan Li (Fudan University) stayed longer at Macquarie to collaborate with Professors Xuan Duong and Ji Li.

The program also included extra opportunities such as the Women in Mathematics luncheon for the female participants, along with other researchers at Macquarie University.

"The variety of talks was good. The long lunch breaks were helpful for discussions and collaboration work."

Participant

Organisers

Assoc. Prof. Zihua Guo, Monash University
Dr Ji Li, Macquarie University
Assoc. Prof. Lesley Ward, University of South Australia

Special Presenters

Assoc. Prof. Soonsik Kwon, Korea Advanced Institute of Science and Technology, South Korea
Research Interests: analysis of PDE, nonlinear dispersive equations
Prof. Michael Lacey, Georgia Institute of Technology, USA
Research Interests: harmonic analysis, probability, ergodic theory
Prof. Chin-Cheng Lin, National Central University, Taiwan
Research Interests: harmonic analysis
Prof. Virginia Naibo, Kansas State University, USA
Research Interests: harmonic analysis, PDEs
Prof. El Maati Ouhabaz, Institut de Mathématiques de Bordeaux, France
Research Interests: PDEs and harmonic analysis, evolution equations and heat kernels, spectral theory, Schrödinger operators
Prof. Jill Pipher, Brown University, USA
Research Interests: harmonic analysis, elliptic PDE, cryptography
Prof. Zhongwei Shen, University of Kentucky, USA
Research Interests: analysis and PDEs
Prof. Brett Wick, Washington University, USA
Research Interests: function theory, harmonic analysis, several complex variables, operator theory

MathSciNet Classification

42 Fourier Analysis, 35 Partial Differential Equations

Web Links

mq.edu.au/about/about-the-university/faculties-and-departments/faculty-of-science-and-engineering/departments-and-centres/department-of-mathematics-and-statistics/news-and-events/2017-harmonic-analysis-and-pde-workshop

Other Sponsors

AustMS, Macquarie University (Department of Mathematics), Monash University (School of Mathematical Sciences), University of South Australia (School of Information Technology and Mathematical Sciences)

Key Contact

Dr Ji Li, Macquarie University, ji.li@mq.edu.au

WORKSHOP PARTICIPATION

50	Attendees
9	Postgraduate students
4	Early career researchers
6	Women
18	International participants

1.02 INTERACTIONS BETWEEN SEMIGROUPS AND OPERATOR ALGEBRAS

The University of Newcastle, 24–27 July 2017

Seeding exciting new collaborations, this event opened avenues for Australian early career researchers to engage with world experts on the theory of semigroups and their relationships to other fields of mathematics such as operator algebras and totally disconnected locally compact groups.

Recently reinvigorated through Dr Xin Li's construction of semigroup C*-algebras, operator algebras associated to semigroups can be traced back to Coburn's famous 1960s theorem. Li's construction has introduced new and interesting classes of C*-algebras, which have deep connections to number theory and dynamical systems. Focusing on the interplay between semigroups and operator algebras, discussion at this event centred on a new construction generalising group C*-algebras defined using left-cancellative semigroups. Many speakers explored the connections between structural properties of C*-algebras and combinatorial properties of the semigroups defining them. One connection that was thoroughly explored through this meeting is that to the representation theory of totally disconnected locally compact groups.

Among the highlights were Dr Xin Li's four one-hour lectures, beginning with the basic definition of a semigroup C*-algebra, and giving a number of examples including some with deep connections to number theory. He also gave an overview of the state of the art through a selection of his own results from the past five years.

Professor Nadia Larsen from the University of Oslo gave two one-hour lectures outlining the theory of product systems of C*-modules indexed by semigroups, including semigroup C*-algebras as a particular example. Her recently proven uniqueness theorems, an essential feature for C*-algebras defined using some combinatorial data such as semigroups, were particularly exciting.

Professor Jacqui Ramagge from the University of Sydney rounded out the invited speakers, giving two one-hour lectures focusing on a particular example of semigroup C*-algebra defined using group actions on homogeneous trees. She outlined a generalisation to group actions on more general graphs, and also explored the natural dynamics which these algebras exhibit and presented a classification for equilibrium states exhibited by the dynamics.

The program also featured contributed talks by both established and early career researchers as well as ample time for collaboration. As a result, many new links were formed including collaborations between Dr Xin Li (Queen Mary University of London), Dr Tron Omland (University of Oslo) and Associate Professor Jack Spielberg (Arizona State University), and also between Dr Zahra Afsar (University of Wollongong), Becky Armstrong (The University of Sydney) and Dr Nathan Brownlowe (The University of Sydney). One example of a tangible research outcome was made through the work of Dr Li and Associate Professor Spielberg. In particular, Li used Spielberg's work on Baumslag-Solitar monoids to provide the first known example of a monoid which embeds into a group, for which the universal group embedding is not Toeplitz.

"The workshop triggered several fruitful discussions with the potential of leading to new interesting research projects. The participants were encouraged and given many excellent opportunities to initiate new collaborations, which was beneficial for everyone."

Dr Xin Li, Queen Mary University of London

Organisers

Dr Nathan Brownlowe, The University of Sydney
Dr David Robertson, The University of Newcastle

Special Presenters

Prof. Nadia Larsen, University of Oslo
Research interests: operator algebras
Dr Xin Li, Queen Mary University of London
Research Interests: operator algebras, dynamical systems, geometric group theory, number theory
Prof. Jacqui Ramagge, The University of Sydney
Research Interests: group theory, functional analysis, geometric analysis, operator algebra

MathSciNet Classification

20 Group Theory and Generalisations,
46 Functional Analysis

Web Links

carma.newcastle.edu.au/meetings/semigroups/

Other Sponsors

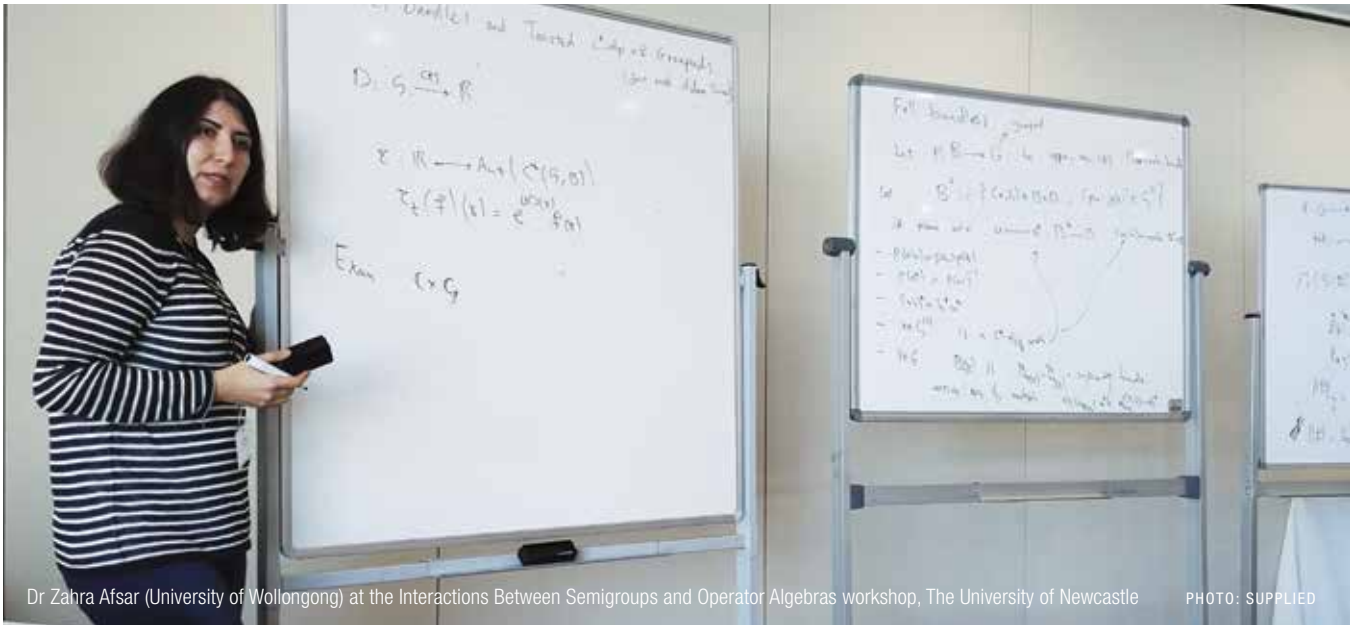
AustMS, The University of Newcastle (School of Mathematical and Physical Sciences), CARMA (Computer-Assisted Research Mathematics and its Applications)

Key Contact

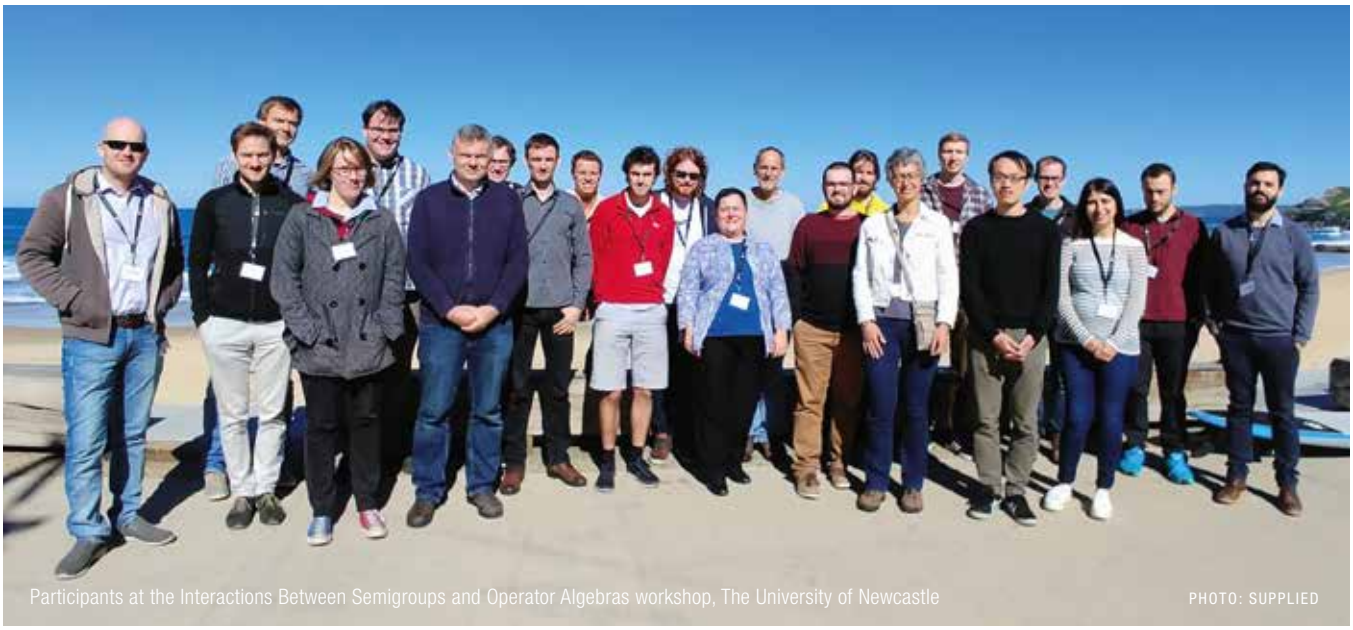
Dr David Robertson, The University of Newcastle,
d.robertson@newcastle.edu.au

WORKSHOP PARTICIPATION

23 Attendees
8 Postgraduate students
3 Early career researchers
4 Women
8 International participants



Dr Zahra Afsar (University of Wollongong) at the Interactions Between Semigroups and Operator Algebras workshop, The University of Newcastle PHOTO: SUPPLIED



Participants at the Interactions Between Semigroups and Operator Algebras workshop, The University of Newcastle PHOTO: SUPPLIED

Participants at the String Geometries and Dualities workshop, The University of Adelaide PHOTO: SUPPLIED

1.03 STRING GEOMETRIES AND DUALITIES

The University of Adelaide, 11–15 September 2017

Mathematical dualities of physical theories have gained a tremendous amount of interest in the last few years. Positioning Australia as a strong centre for research in this area, the workshop provided valuable networking opportunities between international and local researchers.

Common mathematical structures underpin contemporary developments in string geometries and dualities in high-energy physics, string theory, and related areas. With a focus on new applications in the areas of mathematics and condensed-matter physics, this workshop attracted a strong community of mathematical physicists with interests in the application of generalised geometry, K-theory, topology, representation theory, index theory and modular tensor categories.

The interdisciplinary nature of the workshop also gave a rare opportunity for mathematicians from several different fields to interact and discuss new research directions with string geometries and dualities as a unifying theme. Ample time was provided for discussions and networking to foster new collaborations and future workshops. Students and early career researchers at the conference were also given the opportunity to present their research and network with more established researchers in the field.

The area of vertex operator algebras and conformal field theories was covered in detail by speakers such as Dr Kazuya Kawasetsu, Dr David Ridout, Tianshu Liu (all from the University of Melbourne), Professor Maxim Zabzine (Uppsala University) and Michael Cromer (The Australian National University).

Highlights included two speakers, Dr Zsuzsanna Dancso (The University of Sydney) and Dr Pedram Hekmati (University of Auckland), who both spoke about the Dufflo isomorphism, but motivated from very different starting points.

Several variants of T-duality were also covered by Professor Peter Bouwknegt (The Australian National University), Associate Professor Jarah Evslin (Chinese Academy of Sciences), Dr Keith Hannabuss (University of Oxford), Professor Machiko Hatsuda (Juntendo University), and Mark Bugden (The Australian National University) and some possible applications of real K-theory results were outlined by Chi-Kwong Fok.

A new paper on T-duality in a background H-flux was completed by participants Assistant Professor Fei Han (National University of Singapore) and Professor Mathai Varghese (The University of Adelaide) and subsequently published in the journal *Communications in Mathematical Physics* (arxiv.org/abs/1710.07274).

New research links were forged between researchers from Singapore and Japan, and some existing connections with researchers from Sweden, New Zealand and the United Kingdom were enhanced.

"All great! Ample time and opportunities for discussion! Mixed people of different backgrounds together."

Workshop participant

Organisers

Dr David Baraglia, The University of Adelaide
Prof. Peter Bouwknegt, The Australian National University
Dr Guo Chuan Thiang, The University of Adelaide
Prof. Mathai Varghese, The University of Adelaide

Special Presenters

Assoc. Prof. Jarah Evslin, Chinese Academy of Sciences, China
Research Interests: string theory, T-duality, AdS/CFT correspondence, nonabelian vortices and confinement in supersymmetric gauge theories
Dr Keith Hannabuss, University of Oxford, UK
Research Interests: representation theory, T-duality, quantum theory and operator algebras
Prof. Machiko Hatsuda, Juntendo University, Japan
Research Interests: string theory, quantum field theory, T-dualities, Lie algebras
Prof. Meng-Chwan Tan, National University of Singapore
Research interests: M-theory, string theory, quantum field theory, geometric Langlands and its extensions and applications to string theory
Prof. Maxim Zabzine, Uppsala University, Sweden
Research interests: string theory, mathematical methods in physics

MathSciNet Classification

81T30, 81T40, 81T45

Web Links

iga.adelaide.edu.au/workshops/WorkshopSep2017/

Other Sponsors

Institute for Geometry and its Applications (The University of Adelaide), AustMS

Key Contact

Dr Guo Chuan Thiang, The University of Adelaide, guochuan.thiang@adelaide.edu.au

WORKSHOP PARTICIPATION

34 Attendees
13 Postgraduate students
7 Early career researchers
7 Women
13 International participants

1.04 AUSTRALIAN-JAPANESE WORKSHOP ON REAL AND COMPLEX SINGULARITIES

The University of Sydney, 25–29 September 2017

When applied to computational logic, singularity theory has implications for the development of artificial intelligence and computational methods for decision theory. This workshop strengthened linkages between Australian and Japanese mathematicians and applied researchers in the fields of computer science and complex systems engineering.

The Australian-Japanese Workshop on Real and Complex Singularities focused on the application of geometry and algebra of singularities in two types of complex systems: development of artificial intelligence for mathematical problem solving and machine learning and computational methods developed in connection with decision making in complex economic and natural systems.

Importantly this event nurtured scientific dialogue between mathematicians and applied computer science and complex systems engineering researchers in the field of singularity theory.

Key themes included application of singularity theory to computational logic, accurate and efficient prediction of tipping points in economic and natural systems using singularity and catastrophe theories, pure and computational aspects of singularities, and the deep connections between singularity theory and Lie theory. Highlights from the keynote speakers included:

- Professor Dr Hirokazu Anai's overview of basic and applied research underway in Fujitsu Japan's Artificial Intelligence (AI) Laboratory. With a focus on the mathematical technologies being developed at Fujitsu, the use of efficient computational logic techniques involving singularity theory and other mathematics in various industrial applications was outlined. Perhaps most striking for the audience was to hear about significant progress in the development of an AI system that could pass the University of Tokyo (Todai) entrance examination.
- Professor Shihoko Ishii spoke about singularities with respect to Mather-Jacobian discrepancies. She explained the usefulness of such discrepancies in the study of the positive characteristic situation.
- Dr Tzee-Char Kuo delighted and inspired the participants with stories, reminiscences and advice drawn from his long and illustrious mathematical career.
- Professor Geordie Williamson stimulated workshop attendees with a lively and insightful presentation about the singularities of Schubert varieties, and their deep connections with Lie theory.
- Professor Stephen Yau addressed a long-standing conjecture about the non-existence of negative weight derivations of isolated singularities.

In addition to the keynote lectures, a generous program of presentations by local and international participants was complemented by ample time for discussions.

The workshop has resulted in several tangible outcomes, including a proposal for further cooperation between Fujitsu Labs Japan and two Australian universities (Sydney and Macquarie), aiming to enhance progress in mathematical technologies and machine learning in both countries. In addition, a number of papers have been written for the JARCS Proceedings including one on the role played by the mathematics of singularities in predicting tipping points in climate, ecological and economic systems.

"Wonderful conference!"

Professor Shihoko Ishii, Tokyo Woman's Christian University, Japan

Organisers

Dr Florica Cirstea, The University of Sydney
Prof. Toshizumi Fukui, Saitama University, Japan
Dr Michael Harre, The University of Sydney
Dr Adam Harris, University of New England
Prof. Alexander Isaev, The Australian National University
Prof. Satoshi Koike, Hyogo University of Teacher Education, Japan
Dr Scott McCallum, Macquarie University
Prof. Laurentiu Paunescu, The University of Sydney

Special Presenters

Prof. Dr Hirokazu Anai, Fujitsu Labs, Japan
Research Interests: computational algebra
Prof. Shihoko Ishii, Tokyo Woman's Christian University, Japan
Research Interests: algebraic geometry, singularity theory, arc spaces, jet schemes, multiplier ideals
Dr Tzee-Char Kuo, The University of Sydney
Research Interests: geometry, topology, analysis
Prof. Geordie Williamson, The University of Sydney
Research Interests: algebra, geometry, representation theory
Prof. Stephen Yau, Tsinghua University, China
Research Interests: differential geometry, geometric analysis

MathSciNet Classification

14B05, 68A40, 91B06

Web Links

maths.usyd.edu.au/u/laurent/RCSW/

Other Sponsors

The University of Sydney, Mathematical Sciences Institute at The Australian National University (MSI), AustMS

Key Contact

Prof. Laurentiu Paunescu, The University of Sydney, laurent@maths.usyd.edu.au

WORKSHOP PARTICIPATION

31 Attendees
3 Postgraduate students
3 Early career researchers
3 Women
12 International participants

1.05 WORKSHOP ON APPLICATIONS IN NATURAL RESOURCE MATHEMATICS

The University of Queensland, 3–5 October 2017

Attracting a diverse group of university and government agency researchers, this workshop ignited discussion on the application of mathematical and statistical tools to model natural resources such as fisheries and forests.

In recent years growing numbers of mathematical scientists have been working to develop and apply mathematical and statistical theory to produce tools that will have direct impact in the management of fisheries, forestry, water security, conservation, pest and disease management, and adaptation to global changes. Their efforts have already had major impact on our understanding of important phenomena such as dynamics of ecosystems, sustainable fisheries, wildlife trafficking and bushfires.

This workshop provided a platform for Australian field leaders to engage with eminent international experts, early career researchers and PhD and Honours students. As well as reporting on their latest findings, attendees exchanged ideas on important future developments. It was also a valuable forum for early career researchers keen to showcase and workshop their work with leading researchers in their field. Importantly, participants gained insights into the open challenges within the broader area of natural resource mathematics.

The program included both invited and contributed presentations on topics including ecosystem modelling, bushfire modelling, mathematical and computational statistical modelling, and fisheries research, with plenty of time for participant discussion. There was a strong focus on students and early career researchers, including presentations and a panel discussion on career pathways in natural resources modelling.

Key outcomes of the conference included an increased awareness among the ecologists and environmental scientists of the vast array of sophisticated mathematical and statistical tools to capture the many complexities of natural resource phenomena in modelling. Conversely, mathematical scientists and statisticians were exposed to the inherent complexity of natural resource problems such as fisheries, or bushfires, or marine ecosystems.

All benefited from in-depth discussion on the shortcomings of existing modelling methodologies in view of the limitations of (a) understanding of the scientific domain of the underlying problems, and (b) available data and its quality.

A number of papers by selected conference participants have been submitted to a special issue of *Environmental Modeling and Assessment*, a journal edited by Professor Jerzy Filar. Guest editors on the special issue include a number of the conference organising committee including Dr Sharon Lee, Dr Wen-Hsi Yang, Dr Matthew Holden and Dr Clare McGrory

WORKSHOP PARTICIPATION

56 Attendees
16 Postgraduate students
15 Early career researchers
26 Women
4 International participants

Organisers

Dr Clare McGrory, The University of Queensland (conference director)
Prof. Jerzy Filar, Centre for Applications in Natural Resource Mathematics (CARM), The University of Queensland
Prof. John Hearne, RMIT University
Assoc. Prof. Joshua Ross, The University of Adelaide
Dr Wen-Hsi Yang, CARM, The University of Queensland
Dr Sharon Lee, The University of Queensland
Dr Matthew Holden, CARM & CEED, The University of Queensland
Roxanne Jemison, CARM, The University of Queensland

Special Presenters

Prof. Michel De Lara, École des Ponts ParisTech, France.
Research Interests: optimisation theory, stochastic processes, control theory
Dr Deborah R. Hart, NOAA/Northeast Fisheries Science Center, USA
Research Interests: marine ecology, fisheries management, ecosystem modelling, fish population dynamics
Prof. Richard Barker, University of Otago, NZ
Research Interests: statistical theory, methods and analysis for applications in fisheries and wildlife ecology, and climate change, Bayesian inference
Dr Roger Cropp, Griffith University, QLD
Research Interests: ecosystem modelling, environmental science, marine ecology, dynamical systems
Assoc. Prof. Jason Sharples, The University of New South Wales, ACT
Research Interests: bushfire risk management, geometry, mathematical physics
Dr George Leigh, Department of Agriculture and Fisheries, Brisbane, QLD
Research Interests: image analysis, stochastic models, statistical theory and analysis, mineral textures, geometallurgy, wavelet analysis, mathematical morphology, fishery population dynamics, expert programming
Dr John Norbury, University of Oxford, UK
Research Interests: applied mathematics, differential equations
Dr Trevor Hutton, CSIRO, Brisbane, QLD
Research Interests: marine ecology, fisheries science, biodiversity
Dr Éva Plagányi, CSIRO, Brisbane, QLD
Research Interests: ecosystem modelling, marine systems management, ecosystem modelling

MathSciNet Classification

62 Statistics, 90 Operations Research and Mathematical Programming, 92 Biology and Other Natural Sciences

Web Links

uq.edu.au/events/event_view.php?event_id=13096

Other Sponsors

AustMS, Global Change Institute (UQ), Centre for Natural Resource Mathematics (CARM)

Key Contact

Roxanne Jemison, CARM, The University of Queensland, roxanne.jemison@uq.edu.au

PHOTO: BERNARD DUPONT

NATURAL RESOURCE **MATHEMATICS**

By Professor Jerzy Filar and Dr Matthew Holden

The biggest challenge facing Australia and, indeed, our planet is how to maintain and manage our natural systems such as fisheries, forestry and biodiversity in the face of habitat destruction, climate change, pollution and over-harvesting. Natural Resource Mathematics is the field of mathematics which seeks to develop new theory and quantitative tools to better understand and manage our natural world, with an aim to help us overcome this grand challenge.

It is an eclectic field, lying at the interface of three branches of mathematics: (1) **Dynamical systems**, which provide us the tools to study the evolution of population trajectories over time under different scenarios, (2) **Applied Probability & Statistics**, which allow us to assess the state of natural resources and quantify key uncertainties, and (3) **Operations Research**, which can inform the most cost-effective actions to achieve environmental objectives.

This workshop brought together national and international experts using these branches of mathematics to understand and aid the management of natural resources. Researchers from around the world talked about applications as diverse as invasive species control, fire management and fisheries.

CASE STUDY 1: IMPROVING THE SUSTAINABLE HARVEST OF SCALLOPS

In a plenary talk, Dr Deborah Hart from the National Oceanic and Atmospheric Administration (NOAA, USA), demonstrated new methods being used to quantify uncertainty of scallop abundance (and more generally, any species) given the issue of spatial scale. One way to reduce uncertainty is through incorporating data from photographic surveys of the ocean's floor, which can be used to estimate absolute measures of abundance without any assumptions regarding natural mortality and catch.

PHOTO: PIXABAY

Several other talks focused on the scallop fishing industry and its management. As discussed by Dr Wen-Hsi Yang from the University

of Queensland, in 2017, the Queensland Government chose to partially close the fishery due to overfishing. The latter was revealed by state-of-the-art statistical analyses. However, trying to estimate the abundance of a population is actually quite challenging. Dr Yang provided strong statistical evidence that scallop abundance in Queensland was at an all-time low.

CASE STUDY 2: THE FATE OF POPULATIONS UNDER ILLEGAL HARVEST

A well-known theory in ecology postulates that species' populations above some minimal threshold size tend to increase, and below that threshold tend to decrease towards extinction. In 2008 it was proposed that harvest by humans can also induce such thresholds. The theory assumes that if consumers are willing to pay high prices for rare species, small populations are destined to extinction because poachers are willing to exert high effort to capture the rare prize and receive the big payout (see fig. a). Dr Matthew Holden from the University of Queensland addressed this issue using dynamical systems theory. He showed that the fate of illegally harvested species can be even worse than what was previously thought in this theory. Consider a population of size x that grows at rate r. It is harvested at a rate proportional to the number of poachers, y, and animals, x. Poachers increase their effort proportionally to profit, where price is a function of population size. These assumptions can be summarised as the coupled differential equations:

$$\frac{dx}{dt} = rx - qxy$$
$$\frac{dy}{dt} = \delta\left[p(x)qxy - cy\right].$$

Large initial population sizes can cross hypothesized thresholds, on a predestined path towards extinction, through the existence of a two-dimensional extinction barrier. This barrier is actually a "homoclinic orbit" from dynamical systems theory (see fig b). Because past theory, ignoring this two-dimensional complexity, has been used to conceptualize extinction risk of many harvested species, modifying it is essential so as not to underestimate the risk of illegal harvest. Dr Holden then showed how the theory could be used to protect African elephants from poaching.

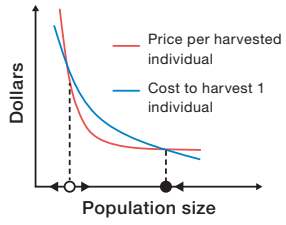


Fig a. The classic argument: if price is higher than poacher costs, the population declines through increased harvest. This leads to a hypothesised small extinction threshold (open circle).

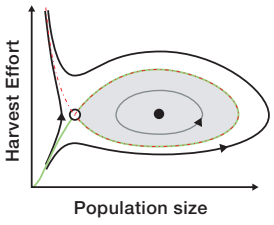


Fig b. Analysis demonstrates the population dynamics in two-dimensional phase space (harvesters vs population) given by the curves in (a). Populations to the right of the black dot in (a) can go extinct by cycling around the grey region in (b), via the green curve.

FUTURE DIRECTIONS

Much of the workshop centred on new ways of calculating and incorporating uncertainty to aid decision making. From uncertainty in population abundance estimates, to the effect of price on poaching, to the spread of wildfires, to bi-stability and the prediction of tipping points, uncertainty is a major component of environmental risks. In the next decade uncertainty quantification and its inclusion in decision science will play an increasingly important role. It is evident from this workshop that, from advances in viability theory techniques, presented by Professor De Lara, to new ways to approximately solve partially observable markov decision processes, discussed by Dr Iadine Chades and Martin Peron, mathematicians are developing new and clever ways of incorporating uncertainty in mathematical frameworks to aid natural resource management decisions.

A special issue of Springer's *Environmental Modeling and Assessment* inspired by this workshop is currently in preparation. It is expected to appear in 2019.

Prof. Jerzy Filar *is the Director of the Centre for Applications in Natural Resource Mathematics (CARM), within the School of Mathematics and Physics at the University of Queensland.*
Dr Matthew Holden *is a lecturer and research fellow at the University of Queensland with joint appointments in the Centre for Applications in Natural Resource Mathematics (CARM) and the ARC Centre of Excellence for Environmental Decisions (CEED).*

INTERNATIONAL PLENARY SPEAKER PROFILES

Professor Michel De Lara

Michel De Lara is a professor at the French applied mathematics research centre CERMICS, at the École des Ponts ParisTech, specialising in control theory and stochastic optimisation. In particular, he has developed new quantitative methods for the sustainable management of natural resources, with an emphasis on biodiversity and energy.

Dr Deborah R. Hart

Deborah (Dvora) Hart received her PhD in mathematics from the California Institute of Technology and has published in a number of fields, including pure and applied mathematics, mathematical and theoretical ecology and fisheries. Since 1999 she has worked at the Northeast Fisheries Science Center in Woods Hole, Massachusetts (USA) where she is a member of the stock assessment methods group that develops new methods for assessment of fish and invertebrate stocks off the North-Eastern US coast. She has been particularly involved with assessment and management of the Atlantic sea scallop fishery. She developed a theory of rotational fisheries that was the basis of a rotational fisheries management plan for sea scallops that helped rebuild this fishery and made it one of the most valuable fisheries in the US.

Professor Richard Barker

Richard Barker is a professor, and Chair in Statistics, within the Department of Mathematics and Statistics at the University of Otago (New Zealand), and is currently Pro-Vice-Chancellor of the Division of Sciences. He began his career as a Fish and Game officer before working at the Patuxent Wildlife Research Centre in the United States in the early 1990s, prior to earning his PhD in Statistics at Massey University. He specialises in Bayesian inference, hierarchical models, ecological statistics and mark-recapture models.

1.06 ELLIPTIC PDES OF 2ND ORDER: CELEBRATING 40 YEARS OF GILBARG & TRUDINGER'S BOOK

MATRIX, Creswick, 16–28 October 2017

Celebrating the 40th anniversary of the publication of David Gilbarg and Neil Trudinger's book, *Elliptic Partial Differential Equations of Second Order*, this MATRIX workshop examined developments and new trends in the area, giving students and early career researchers an introduction to the key research themes of the field.

This event—the first in a pair of MATRIX workshops—gave advanced graduate students and early career researchers a concise introduction to key themes in elliptic and parabolic partial differential equations. For many students this provided insight from global leaders and a very useful introduction to the field and its many applications to their own research in the field and related areas.

The workshop consisted of a series of lectures given by three prominent researchers:

- Particularly well known for his work in the field of nonlinear elliptic partial differential equations, Professor Neil Trudinger spoke on the classical topics and recent results in the elliptic partial differential equations at the core of his book.
- Dr Valentina Wheeler spoke about the parabolic analogues of this theory with particular attention to mean curvature flow.
- Dr Connor Mooney, a postdoctoral researcher at ETH Zurich, discussed some classical results of the regularity for minimisers of convex functionals in the calculus variations, as well as some more recent results and open questions when the functional is degenerate convex, or the minimiser is vector-valued. His counterexample to higher regularity in low-dimensional parabolic systems, which he linked to the classical results of Bombieri, Giusti et al., was a highlight of the week.

Rounding out the program were a series of Research Spotlights—short talks by participants on their current research. The Graduate Lecture series was followed by a second week of research talks.

Note: *AMSI sponsored the Graduate Lecture Series held during the first week (from 16–20 October) of this two-week long MATRIX event.*

> *"As far as research is concerned, the stay was a continuous opportunity for cross-discipline communication, allowing me to share ideas from General Relativity with those studying other problems, drawing useful parallels where possible and indicating possible applications for the mathematical research being conducted by other participants."*
>
> **Dr Calum Robertson, Monash University**

Organisers

Dr Julie Clutterbuck, Monash University
Prof. Lucio Boccardo, Sapienza Università di Roma, Italy
Assoc. Prof. Florica-Corina Cîrstea, The University of Sydney
Prof. L. Craig Evans, University of California, Berkeley, USA
Prof. Enrico Valdinoci, The University of Melbourne
Dr Paul Bryan, The University of Queensland

Special Presenters

Prof. Neil Trudinger, The Australian National University
Research Interests: nonlinear elliptic PDEs, applied and nonlinear analysis
Dr Valentina Wheeler, University of Wollongong
Research Interests: geometric analysis, PDEs, differential geometry, calculus of variations
Dr Connor Mooney, ETH Zurich
Research Interests: PDEs

MathSciNet Classification

35JClose

Web Links

matrix-inst.org.au/events/elliptic-differential-equations-of-second-order/

Other Sponsors

MATRIX, Monash University

Key Contact

Dr Julie Clutterbuck, Monash University, julie.clutterbuck@monash.edu

WORKSHOP PARTICIPATION

16	Attendees
10	Postgraduate students
1	Early career researchers
7	Women
5	International participants

1.07 COMBINATORICS, STATISTICAL MECHANICS AND CONFORMAL FIELD THEORY

MATRIX, Creswick, 6–10 November 2017

Leading to several new research collaborations, this workshop nurtured new and ongoing collaborations and raised Australia's international profile as a leader in research overlapping statistical mechanics, integrability, conformal field theory and combinatorics.

This workshop was embedded in a three-week MATRIX program (29 October – 18 November 2017) whose primary aim was to provide a collaborative platform for experts in integrable systems, statistical mechanics and combinatorics to explore problems lying on the interface of these fields. A particular goal was to deepen understanding of the connections between integrable spin chains at the so-called combinatorial point and combinatorial problems in alternating sign matrices as well as scaling limits of such connections.

As part of the MATRIX program, the workshop was preceded by a week of introductory lectures and research seminars and followed by a week of research seminars. The workshop itself had several presentations every morning, with the afternoons kept for discussions and collaborations.

Key workshop presentations included:

- Professor Bernard Nienhuis's talk about universality in the hyperbolic plane where he discussed critical properties and scaling of two-dimensional models in the hyperbolic plan using Monte-Carlo and corner transfer matrix renormalisation group methods.
- Professor Philippe Ruelle reviewed recent developments concerning the combinatorics of spanning trees, spanning forests and other related geometric structures with applications to SLE and sandpile models.
- Associate Professor Robert Weston presented research on lattice supersymmetry in the open XXZ model using algebraic Bethe ansatz to study lattice SUSY operators.
- Associate Professor Paul Zinn-Justin discussed integrable tiling models and motivated by "puzzles" in Schubert calculus, introduced their higher-rank generalisations.

Abundant discussion sessions provided a creative and relaxing atmosphere for researchers to discuss different aspects of the mathematical structure of integrable systems and their applications to combinatorics, conformal field theory, representation theory, symmetric polynomials, and other topics.

Participants discussed many different problems, possible proofs and, in particular, supersymmetric extensions of the currently known connections between integrability, combinatorics and geometry. Several new collaborations between groups from different countries were initiated. There was a significant interest in the supersymmetric quantum spin chains with a lot of discussions by Professor Nienhuis, Dr Christian Hagendorf (Catholic University of Louvain), Associate Professor Weston, and the University of Melbourne's Professor Jan De Gier, Dr Alexandr Garbali, Dr Thomas Quella and Dr Michael Wheeler resulting in further collaborations.

Professor Atsuo Kuniba (Tokyo University) and Dr Vladimir Mangazeev continued their joint project on high genus solutions of the Yang-Baxter equation and discussed with Associate Professor Jon Links (The University of Queensland) possible connections to classical solutions of the YBE. Professor Paul Pearce (The University of Melbourne), Associate Professor Jorgen Rasmussen (The University of Queensland) and Dr David Ridout (The University of Melbourne) discussed scaling properties of critical dense polymers and logarithmic conformal field theories.

A further highlight of the program was the open-problem sessions chaired by Professor Nienhuis where the participants could present open problems for immediate feedback and live discussions. The workshop certainly met its objectives, with plenty of fruitful discussions and collaborations on all key research topics.

"It was a significant and successful event with involvement of leading experts in the field."

Prof. Vladimir Bazhanov, ANU

Organisers

Prof. Vladimir Korepin, Stony Brook University, USA
Dr Vladimir Mangazeev, The Australian National University
Prof. Bernard Nienhuis, University of Amsterdam, The Netherlands
Assoc. Prof. Jorgen Rasmussen, The University of Queensland

Special Presenters

Prof. Bernard Nienhuis, University of Amsterdam, The Netherlands
Research Interests: statistical physics, solvable statistical lattice models, quantum chains, self-avoiding walks, Bethe ansatz, colloidal systems and asymmetric exclusion models
Prof. Philippe Ruelle, Catholic University of Louvain, Belgium
Research Interests: statistical physics, spin chains, combinatorics, integrable systems, conformal field theory and representation theory
Assoc. Prof. Robert Weston, Heriot-Watt University, UK
Research Interests: integrable systems, exactly solvable statistical-mechanical models and integrable quantum field theory
Assoc. Prof. Paul Zinn-Justin, The University of Melbourne
Research Interests: integrable systems, combinatorics, applications in algebraic geometry, symmetric polynomials

MathSciNet Classification

81T40, 82A15, 82B23

Web Links

matrix-inst.org.au/events/combinatorics-statistical-mechanics-and-conformal-field-theory/

Other Sponsors

MATRIX, AustMS

Key Contact

Assoc. Prof. Jorgen Rasmussen, The University of Queensland, j.rasmussen@uq.edu.au

WORKSHOP PARTICIPATION

24 Attendees
4 Postgraduate students
3 Early career researchers
4 Women
7 International participants

1.08 WORKSHOP ON MATHEMATICAL MODELLING OF RISK AND CONTIGUOUS TOPICS

MATRIX, Creswick, 27 November – 1 December 2017

This workshop saw leading researchers from Australia and overseas join forces to address key topics in mathematical analysis of risk modelling.

The need for quantitative risk modelling has, in recent years, attracted enormous worldwide attention. The risk related to both extreme and non-extreme events is generating a vast research activity, a pursuit that is international by its very nature. Moreover, there is also an international regulatory aspect to what concerns mathematical modelling of financial risks. One of the key elements of the current version of the Basel accord is the emphasis on responsible use of mathematical models, in particular those developed by financial institutions. Outside of this, there are academics working in the interest of public good trying to mathematically analyse stability of the financial system, and there are many other sources of risk that are of profound interest and can be analysed mathematically.

Part of a broader MATRIX research program, this event provided in-depth introductory workshop sessions as well as dedicated time for developing research collaborations. Discussion addressed the key topics arising in mathematical analysis of risk and contiguous areas, attracting both local and international researchers to the event.

The keynote presentations included:

- Professor Kostya Borovkov, who gave a talk on the large deviation probabilities in a multivariate boundary-crossing problem motivated by a two-dimensional ruin problem. For a multivariate random walk with i.i.d. jumps satisfying the Cramer moment condition and having mean vector with at least one negative component, the exact asymptotics were derived for the probability of ever hitting the positive orthant that is being translated to infinity along a fixed vector with positive components.
- Professor Marie Kratz's talk on risk aggregation focused on studying the local behaviour of (extreme) quantiles of the sum of heavy-tailed random variables, to infer on risk aggregation, and thus on the behaviour of diversification benefit. The main contribution was to investigate the non-asymptotic case (i.e. for any threshold), providing analytical results on the risk aggregation for copula models that are used in practice and comparing them with results obtained via Monte Carlo method.
- Professor Yuri Kabanov discussed a model describing the evolution of capital of a venture company selling innovations and investing its reserve into a risky asset with the price given by a geometric Levy process. It was proved that, under some natural conditions on the model, the company's ruin probability decays as a power function of the initial capital.
- Assistant Professor Martin Larsson's talk introduced affine Volterra processes, defined as solutions of certain stochastic convolution equations with affine coefficients. Classical affine diffusions constitute a special case, but affine Volterra processes are neither semimartingales, nor Markov processes in general. Nonetheless, their Fourier-Laplace functionals admit exponential-affine representations in terms of solutions of associated deterministic integral equations, extending the well-known Riccati equations for classical affine diffusions.

Boosting research potential of Australian researchers, the event led to new collaborations and international connections to further risk modelling and related areas. Participants included postgraduate students and early career researchers in addition to more established academics and industry specialists, and there were many fruitful discussions around the talks.

The outcomes of the conference can also be viewed and understood in the broader context of the three-week long MATRIX research program. During the program, several groups of collaborators started working on a number of new projects, and as a result, several joint papers have been submitted for publication in the MATRIX proceedings.

Note: *AMSI sponsored this Mathematics of Risk workshop, held as part of a longer Mathematics of Risk research program at MATRIX.*

"Everything was great. For me the most important thing was the possibility to cooperate with strong mathematicians."

Workshop particIpant

Organisers

Prof. Konstantin Borovkov, The University of Melbourne
Assoc. Prof. Kais Hamza, Monash University
Prof. Masaaki Kijima, Tokyo Metropolitan University
Prof. Alex Novikov, University of Technology Sydney
Prof. Peter Taylor, The University of Melbourne

Special Presenters

Prof. Konstantin Borovkov, The University of Melbourne
Research Interests: functional limit theorems of probability theory, branching processes, Poisson approximation, theory of records, Markov chain Monte Carlo, applications of stochastic models
Prof. Marie Kratz, Ecole Supérieure des Sciences Economiques et Commerciales, France
Research Interests: quantitative risk analysis, extreme risks; extreme value theory, gaussian processes (nonlinear functionals), stochastic geometry, point processes, time series, dynamical systems
Prof. Yuri Kabanov, University of Franche-Comté – Besançon, France
Research Interests: mathematical finance, stochastic calculus, statistics of random processes, nonlinear filtering, applied statistics, regression analysis, econometrics, mathematical economics, statistical software
Asst. Prof. Martin Larsson, ETH Zurich, Switzerland
Research Interests: probability theory, stochastic processes, and applications in mathematical finance and financial engineering

MathSciNet Classification

60G70, 60H30, 91G80, 91B30, 91B74

Web Links

matrix-inst.org.au/events/mathematics-of-risk-conference/

Other Sponsors

MATRIX, ACEMS, UTS, Monash University, ANU

Key Contact

Prof. Konstantin Borovkov, The University of Melbourne, borovkov@unimelb.edu.au

WORKSHOP PARTICIPATION

36 Attendees
9 Postgraduate students
2 Early career researchers
6 Women
14 International Participants

1.09 GAUGE THEORY AND HIGHER GEOMETRY

The University of Adelaide, 28 November – 1 December 2017

Honouring mathematician Michael Murray's contributions to gauge theory and higher geometry, this interdisciplinary conference fostered collaboration between geometry and mathematical physics leaders to further Australian research impacts.

The subjects of higher geometry and gauge theory are essential components of modern approaches to problems in mathematical physics. Celebrating Australia's important contribution to these subjects, this conference acknowledged both Professor Michael Murray's contributions to geometry and gauge theory and the benefits of strengthening global collaboration. As well as Australian research connections, the program acknowledged ties with researchers in New Zealand, the United Kingdom, Finland and Japan.

Inspired by mathematical physics, the meeting's theme was the elucidation of higher structures in differential geometry and gauge theory. A broad selection of topics lying at the interface between geometry and mathematical physics was covered, including higher category theory and gerbes, twisted K-theory, moduli spaces of surfaces and operads, twisted Donaldson invariants, and Lagrangian-Floer theory, as well as more traditional differential geometric topics such as Sasaki-Einstein geometries, and topics of a more algebraic flavour, such as Lie superalgebras.

Dame Frances Kirwan's talk was a highlight. The 20th Savilian Professor of Geometry at Oxford's Balliol College, she spoke on moduli spaces of surfaces (complex curves) and specifically her important recent work extending methods from the setting of stable curves to allow the construction of moduli spaces of unstable curves.

Another standout talk was given by Dr Hang Wang, from the University of Adelaide, who spoke on her work (joint with Kato and Sasahira) on twisted Donaldson invariants. This work is highly significant in manifold theory because it heralds a technical breakthrough in linking Donaldson invariants, up until now defined for simply-connected 4-manifolds, with Novikov's higher signatures which are higher invariants coming from the fundamental group. The outcome, distinguishing infinitely smooth structures on non-simply connected 4-manifolds is a new and exciting development.

Dr Marcy Robertson (The University of Melbourne) gave a talk describing the profinite Grothendieck-Teichmueller group in terms of the homotopy automorphisms of a certain Teichmueller tower, on which she is collaborating with de Brito and Horel.

There were also significant results presented in the theory of bundle gerbes and twisted K-theory. Professor Jouko Mickelsson presented progress in understanding global anomalies in the setting of the moduli space of gauge connections in dimension 3 and Professor Alan Carey reported on recent developments related to Bai-Ling Wang's constructions of geometric cycles in twisted K-homology. Dr Alexander Campbell (Macquarie University) gave a talk on the more abstract aspects of higher geometry, describing his work on higher category theory and non-abelian cohomology.

In addition to seeding many collaborative discussions, the workshop gave opening speaker Professor Rod Gover (University of Auckland) and workshop participant Dr Thomas Leistner (The University of Adelaide), the opportunity to work on a joint paper *Invariant prolongation of the Killing tensor equation*, which has been accepted for publication in *Annali di Matematica* (link.springer.com/article/10.1007%2Fs10231-018-0775-3).

"It was an excellent conference with many interesting talks, I enjoyed it very much."

Bai-Ling Wang, The Australian National University

Organisers

Assoc. Prof. Diarmuid Crowley, The University of Melbourne
Dr Pedram Hekmati, University of Auckland, NZ
Dr Danny Stevenson, The University of Adelaide
Dr Melissa Tacy, University of Otago, NZ
Dr Guo Chuan Thiang, The University of Adelaide
Dr Raymond Vozzo, The University of Adelaide

Special Presenters

Prof. Dame Frances Kirwan, University of Oxford
Research Interests: Algebraic and symplectic geometry
Prof. Jouko Mickelsson, University of Helsinki
Research Interests: anomalies and current algebra, representations of Lie algebras, extensions of infinite dimensional groups arising in quantum field theory, gerbes and twisted K-theory
Prof. Peter Bouwknegt, The Australian National University
Research Interests: mathematical physics, quantum field theory, conformal field theory
Prof. Alan Carey, The Australian National University
Research Interests: mathematical physics, twisted K-theory, index theory and geometric questions in quantum field theory
Prof. Michael Eastwood, The University of Adelaide
Research Interests: differential geometry, conformal geometry
Prof. Ashwin Rod Gover, University of Auckland
Research Interests: differential geometry, twistor theory and mathematical physics
Dr Kiyonori Gomi, Shinshu University, Japan
Research Interests: K-theory, mathematical physics
Dr Peter Jarvis, University of Tasmania
Research Interests: quantum field theory and integrable models

MathSciNet Classification

53C08, 53C80, 57R22

Web Links

iga.adelaide.edu.au/workshops/MKM60/

WORKSHOP PARTICIPATION

40 Attendees
10 Postgraduate students
4 Early career researchers
5 Women
8 International participants

Other Sponsors

AustMS, Institute of Geometry and its Applications (The University of Adelaide), School of Mathematical Sciences (The University of Adelaide)

Key Contact

Assoc. Prof. Diarmuid Crowley, The University of Melbourne, dcrowley@unimelb.edu.au
Dr Danny Stevenson, The University of Adelaide, daniel.stevenson1971@gmail.com

1.10 FUTURE DIRECTIONS IN REPRESENTATION THEORY

The University of Sydney, 4–8 December 2017

This conference attracted some of the most prominent local and international researchers in the field, and consolidated Australia's place as a world leader in representation theory.

The most significant Australian representation theory workshop in a decade, this event consolidated Australia's positioning as a global field leader field (following a recent wave of hiring by several Australian universities). Featuring 22 invited speakers including 14 international experts, it proved a powerful platform to familiarise many of the younger generation of international researchers with the Australian scene.

Chosen to reflect key areas of representation theory, conference themes and invited speakers illustrated the area's connections with other emerging growth fields of pure mathematics and mathematical physics, including:

- symplectic and gauge theories
- categorification and categorical actions
- topological methods in representations of finite and p-adic groups
- parity sheaves on flag manifolds

In keeping with the conference's emphasis on youth, many of the invited speakers were early and mid-career researchers who had already made spectacular contributions to the field. Notably, almost half of the invited international speakers at the conference were women, demonstrating that internationally at least, there is no longer a significant gender imbalance.

The discovery of connections between the talks of different speakers was a highlight throughout the week. To illustrate, the opening address of Professor Hiraku Nakajima set a theme that several later talks responded to: Associate Professor Ben Webster from the Perimeter Institute in Canada, speaking just a couple of hours afterwards, modified his talk to explain a convincing program to prove one of the conjectures Nakajima had stated; and Assistant Professor Emily Cliff described a potentially broader framework for related ideas, which has resulted in a new collaboration with Nakajima. Similarly, the talks of Professor Gunter Malle and Dr Olivier Dudas on the representations of finite groups of Lie type found a response in the talks of Dr Jessica Fintzen and Charlotte Chan on the representations of p-adic groups, opening a new conversation on the generalisations of Deligne-Lusztig theory.

In addition to the invited speakers, students and early career researchers attending the conference also had the opportunity to present posters about their work. Times for discussion were built into the program and plenty of opportunities for discussions and networking were provided including a gender diversity dinner.

Several international participants in the workshop extended their stay in Sydney to attend the AustMS conference in the following week, where they contributed talks to the special session in representation theory. The success of the workshop as a showcase for Australian representation theory has also resulted in widespread interest in upcoming postdoctoral positions in this field in Sydney and Queensland, and in the MATRIX program on geometric and categorical representation theory in December 2018.

WORKSHOP PARTICIPATION

88 Attendees
20 Postgraduate students
27 Early career researchers
23 Women
44 International participants

PHOTO: SUPPLIED

Group Photo: left to right: David Baraglia, Csaba Nagy, Kiyonori Gomi, Bai-Ling Wang, Chi-Kwong Fok, Matthew Randall, Guo Chuan Chiang, Raymond Vozzo, Juoki Michelson, Danny Stevenson, Michael Murray, Diarmuid Crowley, Kelli Francis-Staite, Alexander Campbell, David Roberts, Marcy Robertson, Peter Jarvis, Paul Norbury, Michael Vaughn, Peter Bouwknegt.

"This was a top-level representation theory conference, with an outstanding and broad collection of speakers making it one of the best conferences I've been to in several years"

Prof. Jonathan Brundan, University of Oregon

Organisers

Prof. Anthony Henderson, The University of Sydney (Chair)
Prof. Pramod Achar, Louisiana State University, USA
Dr Zsuzsanna Dancso, The University of Sydney
Dr Masoud Kamgarpour, The University of Queensland
Prof. Geordie Williamson, The University of Sydney
Dr Oded Yacobi, The University of Sydney

Special Presenters

Prof. Jonathan Brundan, University of Oregon, USA
Research Interests: algebraic groups, combinatorial representation theory, Lie superalgebras
Charlotte Chan, University of Michigan, Ann Arbor, USA
Research Interests: representation theory, number theory and algebraic geometry
Asst. Prof. Emily Cliff, University of Illinois, Urbana-Champaign, USA
Research Interests: geometric representation theory, chiral and factorisation algebras
Dr Kevin Coulembier, The University of Sydney
Research Interests: Lie (super)algebras, quasi-hereditary and cellular algebras, homological algebra, BGG category O, primitive ideals, modular representation theory
Dr Olivier Dudas, Université Paris Diderot, France
Research Interests: modular representation theory of finite reductive groups
Dr Michael Ehrig, The University of Sydney
Research Interests: representation theory, algebraic combinatorics, low dimensional topology, algebraic geometry
Dr Inna Entova-Aizenbud, Ben Gurion University, Israel
Research Interests: representation theory, monoidal categories (particularly Deligne categories), categorical actions, superalgebras and algebraic combinatorics
Asst. Prof. Jessica Fintzen, Institute of Advanced Study/University of Michigan/University of Cambridge, USA/UK
Research Interests: number theory, representation theory, p-adic groups
Dr Peter Hochs, The University of Adelaide
Research Interests: index theory, geometric quantisation, noncommutative geometry, differential geometry and geometric analysis, Lie theory, links between K-theory, K-homology and representation theory
Dr Anthony Licata, The Australian National University
Research Interests: geometric representation theory and categorification
Prof. Gunter Malle, University of Kaiserslautern, Germany
Research Interests: group and representation theory, number theory
Dr Peter McNamara, The University of Queensland
Research Interests: algebra and number theory, geometric and categorical representation theory, combinatorics
Prof. Hiraku Nakajima, Kyoto University, Japan
Research Interests: representation theory, geometry
Prof. Arun Ram, The University of Melbourne
Research Interests: combinatorial representation theory
Prof. Simon Riche, Université Clermont Auvergne, France
Research Interests: geometric theory of representations, algebraic groups and their Lie algebras, geometry of some associated varieties
Asst. Prof. Laura Rider, University of Georgia, USA
Research Interests: geometric representation theory
Prof. Peng Shan, Tsinghua University, China
Research Interests: representation theory, algebraic geometry
Prof. Monica Vazirani, University of California, Davis, USA
Research Interests: representation theory, combinatorics, discrete math, Hecke algebras, crystal graphs, DAHA, KLR algebras, parking functions
Assoc. Prof. Ben Webster, University of Waterloo/Perimeter Institute, Canada
Research Interests: representation theory, mathematical physics, geometry and topology, including knot homology, the geometry of symplectic singularities and categorification
Dr Ting Xue, The University of Melbourne
Research Interests: algebra, number theory, representation theory, geometry, topology
Dr Yaping Yang, The University of Melbourne
Research Interests: integrable systems, Lie algebras, geometric representation theory, motivic homotopy theory and the related geometry and topology
Prof. Xinwen Zhu, California Institute of Technology, USA
Research Interests: geometric representation theory

MathSciNet Classification

20 Group Theory and Generalisations, 24 Algebraic Geometry, 82 T Quantum Theory

Web Links

sites.google.com/site/ausreptheory/conference2017

Other Sponsors

The University of Sydney (School of Mathematics and Statistics), The University of Queensland (School of Mathematics and Physics), National Science Foundation (USA), AustMS

Key Contact

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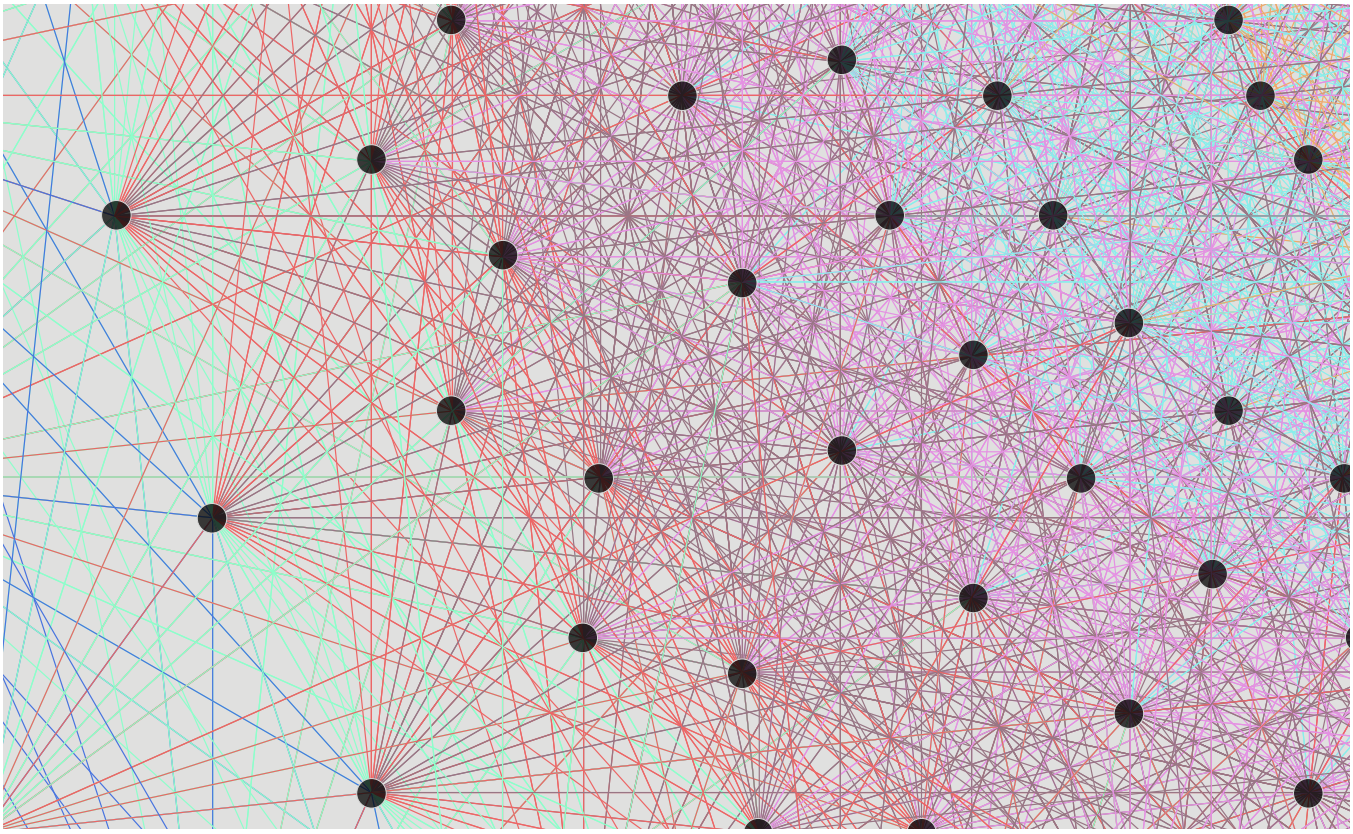


IMAGE: WIKIMEDIA

FUTURE DIRECTIONS IN **REPRESENTATION THEORY**

By Prof. Anthony Henderson

Representation theory is the abstract study of the possible types of symmetry in all dimensions. A key use for representation theory is to decompose a complicated situation into a sum of simple ones, thus making it easier to understand. For example, the decomposition of a sound wave into its Fourier components uses the representation theory of the rotational symmetry group of a circle; the decomposition of the wave-function of an elementary particle into its pure modes uses the representation theory of the rotational symmetry group of a sphere.

In recent years, the field has evolved beyond these classical questions. The problems which remain unsolved tend to involve infinite-dimensional spaces, or number systems of finite characteristic (for instance, where $1+1+1=0$). What makes these contexts more challenging is that one can no longer decompose a complicated representation as a sum of simple representations; instead more subtle notions of decomposition are required.

This workshop brought experts and beginners in the field together to discuss recent discoveries and begin collaborating on the next frontier of problems.

The opening address of Hiraku Nakajima described his new construction of representations of Kac-Moody algebras using the Coulomb branches predicted by quantum field theory. It is remarkable that an idea which arose from physics has turned out to be the solution to a purely algebraic problem. Several later talks in the workshop carried on this theme; most notably Ben Webster explained a convincing program to prove one of the conjectures Nakajima had stated. Emily Cliff's talk on factorisation algebras and Xinwen Zhu's talk on the categorical trace of the Satake category explored a broader framework for the same ideas.

Another prominent theme was the unifying role played by geometry, in particular the class of spaces known as Deligne-Lusztig varieties and their variants. The talks of Gunter Malle and Olivier Dudas highlighted the importance of these spaces for the representation theory of finite groups of Lie type; this is well known over the complex numbers, but their new results apply to more general contexts. The theme found a pleasing counterpoint in the talks of Jessica Fintzen and Charlotte Chan on the representation theory of p-adic groups, where similar spaces arise.

FUTURE DIRECTIONS

The workshop explicitly focused on future directions in the field, and the invited speakers included many early career researchers for whom the organisers predict great things. Their talks suggest a vision of the field in ten years' time in which the role previously played by algebraic structures such as groups and Lie algebras will instead be played by geometric structures such as symplectic varieties, and the focus will have shifted from multiplicities and character formulas to categories and cohomology theories. The "rising tide" philosophy of

Grothendieck, which transformed algebraic geometry in the late 20th century, is now visibly dominant in representation theory as well: in a nutshell, this philosophy is that hard problems are more often solved by building more comprehensive categorical foundations than by quixotic tours de force.

Anthony Henderson *is a Professor of Mathematics in the School of Mathematics and Statistics at the University of Sydney.*
Geordie Williamson *is a Professor of Mathematics in the School of Mathematics and Statistics at the University of Sydney.*

KEYNOTE SPEAKER

Professor Hiraku Nakajima

Hiraku Nakajima is one of the most distinguished Japanese mathematicians of our time. He is currently a Professor at the Kavli Institute for the Mathematics and Physics of the Universe in Tokyo; at the time of the workshop, he was at the Research Institute for the Mathematical Sciences in Kyoto. He was a plenary speaker at the 2002 International Congress of Mathematicians, and won the 2003 Cole Prize of the American Mathematical Society and the 2014 Japan Academy Prize. This workshop was his first research visit to Australia.

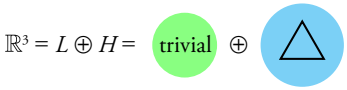
Nakajima has revolutionised representation theory by his introduction of ideas from differential geometry and mathematical physics. The Nakajima quiver varieties he introduced in the 1990s are now a central object of study: that phrase alone records over 3000 hits on Google. He and his collaborators have recently discovered the long-sought mathematical construction of the Coulomb branches predicted by physicists working in quantum field theory.

PHOTOS: JAYNE ION

CASE STUDY: SIMPLE REPRESENTATIONS IN GEOMETRY

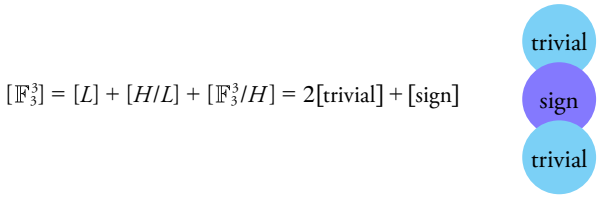
Simple Representations

Consider the symmetric group S_3 of permutations of the set {1,2,3}. It acts on three-dimensional space V via permutation of the coordinates. There are two invariant subspaces: the line L consisting of points whose coordinates are all equal, and the plane H consisting of points whose coordinates sum to zero. If we are working with real numbers, then V is the direct sum of L and H; this is an example of a representation being decomposed as a sum of simple representations.



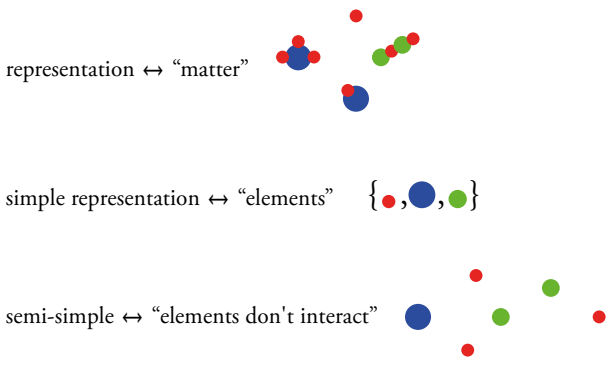
Jordan-Hölder Theorem

By contrast, if we are working with a number system in which 1+1+1=0, then L is contained in H, so V can no longer be decomposed as a sum: instead it decomposes in a looser sense into the simple representations L, H/L and V/H. This is a first example of the intriguing phenomena arising in representation theory in finite characteristic, which we are only now beginning to understand more systematically.



Simple Representations—an analogy

One can think of the simple representations as elements and the task in representation theory is to decompose representations into simple representations, just as one tries to understand matter in terms of its composite elements. The most important questions concern the simple representations.



1.11 STATISTICAL CHALLENGES IN ASTRONOMY

The University of New South Wales, 7–8 December 2017

This interdisciplinary workshop fostered collaboration between statisticians and astronomers leading to the development and use of advanced statistical tools for astrophysical data.

Galactic archaeology is a growing field in astronomy, with an overall goal of using detailed data about stars in the Milky Way to unwind its history of star formation and chemical enrichment. Large-scale surveys such as the Australian-led GALAH (Galactic Archaeology with HERMES) survey and the European-based Gaia-ESO survey are collecting large quantities of high quality data for 105-106 stars in order to answer important questions about the formation of our galaxy. Future projects like WEAVE and 4MOST will be even larger.

Sophisticated statistical and computational methods are needed to extract the most useful information from the observational data. Data visualisation in high dimensions will play a very important role as an exploratory tool, as well as a validation tool for the data analysis.

This two-day workshop brought together experts in statistics and astrophysics, in an attempt to identify the more important scientific goals and research tools for future collaborative research. The field of galactic archaeology is relatively young and developing strong cross-disciplinary skills and partnerships will be extremely valuable for making the most of Australia's investment in big astronomical data.

With the first day focused on astronomy talks and the second on statistics, the workshop provided unique insights into the two areas, identifying statistical research tools needed by astronomers and highlighting the latest developments in statistical methodology. As well as providing attendees with time to interact and discuss projects, tutorial-style workshops on statistical software and data visualisation were provided to introduce the latest statistical and computational tools from the statistical community to the astronomers.

Keynote speaker Dr Dan Foreman-Mackey, from the Flatiron Institute's Center for Computational Astrophysics, spoke about Gaussian processes and their importance in astronomy. Associate Professor Inge Koch, from the University of Adelaide and AMSI, spoke about the use of histograms for high-dimensional clustering in the second keynote session.

Other invited talks of the workshop included the use of Bayesian hierarchical models in astronomy by Dr Sanjib Sharma from the University of Sydney, scalable Markov chain Monte Carlo methods by Dr Minh-Ngoc Tran, and Bayesian modelling with STAN by Dr John Ormerod. Associate Professor Tomasz Bednarz, director of visualisation from UNSW Art & Design and CSRIO Data61, showcased recent developments in data visualisation and its potential for data science, making this workshop a truly interdisciplinary affair.

One of the highlights of the event was the group project session. Attendees were asked to bring a project that they would like help on and give a brief description of their goals. Over 30 projects were presented, and attendees spent some time during the workshop in groups to work on these problems. It is anticipated that some new collaborations have come out of this, and possibly new papers.

WORKSHOP PARTICIPATION

75	Attendees
22	Postgraduate students
11	Early career researchers
12	Women
1	International participants

"This is great, I didn't know the astronomers were using so much statistics"

Workshop participant

Organisers

Dr Yanan Fan, The University of New South Wales
Dr Sarah Martell, The University of New South Wales
Dr Andrew Casey, Monash University
Dr John Ormerod, The University of Sydney
Assoc. Prof. Catherine Greenhill, The University of New South Wales

Special Presenters

Dr Daniel Foreman-Mackey, Flatiron Institute, USA
Research Interests: application of probabilistic data analysis techniques to astronomy
Assoc. Prof. Inge Koch,
The University of Adelaide, AMSI
Research Interests: data mining, analysis of multivariate and high-dimensional data
Dr Sanjib Sharma, The University of Sydney
Research Interests: astronomy
Assoc. Prof. Tomasz Bednarz, The University of New South Wales/CSIRO Data61
Research Interests: data visualisation, computer graphics, virtual reality and related simulation, image processing, simulation and modelling
Dr Minh Ngoc Tran, The University of Sydney
Research Interests: Bayesian methodology, statistical machine learning

MathSciNet Classification

62 Statistics, 85 Astronomy and Astrophysics

Web Links

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Other Sponsors

ACEMS (ARC Center of Excellence for Mathematical and Statistical Frontiers), School of Mathematics and Statistics, UNSW

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PHOTO: PIXABAY

STATISTICAL CHALLENGES IN ASTRONOMY

By Dr Sarah Martell and Dr Yanan Fan

Astrostatistics is a growing field of research, driven by an increasing complexity in astronomical data sets and the development of new mathematical methods for data analysis and model fitting. There are particular types of astronomy research that are well suited to an astrostatistics approach. These include fitting complex models (for example, parameter estimation and uncertainty quantification for the spatial distribution and velocities of stars in the Milky Way), time series analysis (for example, searching for the periodic Doppler-shift signal of a planet in irregularly-spaced radial velocity measurements of its host star), and morphological classification (for example, classifying star clusters in images as symmetric, asymmetric, or not really clusters).

Astrostatistics focuses on the topics in astronomy that benefit most from statistical analysis, and astronomers tend to be enthusiastic about new statistical techniques and tools. Bayesian and Monte Carlo methods are commonly used for model fitting, Principal Component Analysis is standard for dimensionality reduction, and a number of methods including k-means, DBSCAN and Gaussian mixture modelling are popular for clustering analysis. More recent additions to the astronomical repertoire include t-distributed Stochastic Neighbour Embedding for dimensionality reduction, and phylogenetic classification, convolutional neural networks, and random forest algorithms for classification.

Large survey science is increasingly important in astronomy, and there are a number of ongoing and upcoming projects that will collect high-dimensional data for millions of stars and galaxies. Statisticians who specialise in topics such as dimensionality reduction, clustering algorithms and high-dimensional visualisation have a lot to offer, particularly to astronomers looking to find physically meaningful structure and unexpected outliers in extremely large data sets. The challenge is to develop new statistical tools that can scale well to the size and dimension of the data.

The workshop, *Statistical Challenges in Astronomy*, brought together both statisticians and astronomers to discuss and identify how the two disciplines could work together on the challenges in interpreting large and complex astronomical data sets.

One useful method that is not widely used in astronomy was the focus of the keynote presentation by Dr Daniel Foreman-Mackey, from the Flatiron Institute. He described the concept of Gaussian process regression, and how to use it to improve model fitting for astronomical data with correlated errors. The Gaussian process regression library George (george.readthedocs.io), which Foreman-Mackey wrote in Python, is freely available.

Using a Gaussian process, a data set is approximated with a combination of a mean model and a noise model, with a likelihood function that is a multivariate Gaussian. The covariance matrix for

the data is populated according to a "kernel" with a shape that is set by the parameters of the noise model.

The likelihood function can be written as:

$$\log p(\{y_n\}|\theta,a) = -\frac{1}{2} r_\theta^T K_a^{-1} r_\theta - \frac{1}{2} \log \det K_a - \frac{N}{2} \log(2\pi)$$

where y_n are the data, θ are the parameters of the mean model, a are the parameters of the noise model, and r_θ are the residuals between data and model.

$K_a = \sigma_n^2 \delta_{nm} + k_a(x_n, x_m)$ is the covariance matrix, where k_a is the kernel function.

This likelihood function can then be input into an optimisation algorithm to find the values for θ and a that best reproduce the data set. Scalability to large datasets with this method was also discussed.

A second method with the potential for wide application to astronomical data is the use of unsupervised learning methods such as SOPHE (Second Order Polynomial Histogram Estimator). Keynote speaker Associate Professor Inge Koch (The University of Adelaide and AMSI) described this method of constructing high-dimensional histograms, which efficiently handle problems with high dimensions and large sample sizes and can be used to detect clustering of the underlying data.

Although SOPHE was illustrated with examples from flow cytometry data, it is clear that such generic methods can be equally useful in astronomy, for example, when interest is in finding groups of stars with similar chemical properties.

The research talks from astronomers at *Statistical Challenges in Astronomy* all featured open-source software written in either R or Python, the coding languages most commonly used for data analysis. Over the past ten years, sharing data and software has come to be widely accepted as good practice in the astronomical community, and the Astrophysics Source Code Library (ascl.net/) has steadily added ~200 new freely available codes per year, contributed by researchers. Community-supported libraries like astropy have flourished, and the journals *Astronomy and Computing* (journals.elsevier.com/astronomy-and-computing) and *The Journal of Open Source Software* (joss.theoj.org/) were created to encourage the publication and citation of useful software written by the research community.

In the next ten years this trend toward sharing and transparency is expected to continue, with large survey projects producing freely available libraries of custom analysis tools for their publicly available data, as is already done by the NASA Kepler mission (keplerscience.arc.nasa.gov/software.html).

A NOVEL APPROACH TO COLLABORATION

Statistical Challenges in Astronomy included two sessions of collaborative working time, for which all participants were asked to bring a research project. The goal for these sessions was to introduce astronomers with research questions to statisticians with insight into how to approach those questions. The first session, before lunch on the first day, began with a one-minute, one-slide introduction to each project. Around 30 projects were presented, including:

- Combining tSNE and DBSCAN to identify groups of stars that are similar in their elemental abundances, presented by Chengyuan Li at Macquarie University. He was interested in discussing ways to optimise those steps to identify stars with very low abundances with minimal contamination.
- Using a combination of imaging and spectroscopic data to determine the intrinsic shapes of galaxies and their orientation relative to our line of sight, presented by Caroline Foster (The University of Sydney). She was interested in improving her algorithm to give more tightly constrained results.
- Using phase information from the Fourier transform of the spatial distribution of galaxies in the Universe. Manodeep Sinha (Swinburne University) was interested in adding this to the Fourier amplitudes, which revealed a preferred size for large-scale structure, providing a more complete mapping of that large-scale structure.

The introductory presentations were followed by unstructured time where the participants formed small groups and started to develop their projects through discussion and preliminary coding. The second session, at the end of the workshop, consisted of more working time followed by updates on projects that had interesting progress or a particularly good match between the astronomer and the statistician. *The one-slide project summaries are online at: tinyurl.com/y82r54wd*

Dr Yanan Fan *is a senior lecturer at the School of Mathematics and Statistics at the University of New South Wales.*
Dr Sarah Martell *is a senior lecturer in Astrophysics at the University of New South Wales.*

KEY PRESENTERS

Dr Daniel Foreman-Mackey

Daniel Foreman-Mackey is an Associate Research Scientist at the Flatiron Institute's Center for Computational Astrophysics (CCA) in New York (USA). His research focuses on developing novel data analysis methods and applying them to astronomical survey datasets. Recently, he has been using a combination of data-driven and physically motivated time-series models to discover and characterize new exoplanets using observations from NASA's Kepler and K2 missions. Foreman-Mackey received his PhD from New York University in 2015 and then spent two years as a NASA Sagan Postdoctoral Fellow at the University of Washington, before joining the CCA.

Associate Professor Inge Koch

Associate Professor Inge Koch completed an MSc at the University of Oxford, and a research MPhil at the University of London, and then worked for industry and the University of Aberdeen in the UK, and for the CSIRO in Canberra. She completed a PhD in statistics at the Australian National University in 1991 on theoretical problems in image analysis. Her research focus is on the statistical analysis of multivariate and high-dimensional data.

Inge is currently Executive Director of AMSI's Choose Maths initiative and holds a part-time research-only appointment at the University of Adelaide.

CASE STUDY: USING STATISTICS TO SPEED UP SPECTROSCOPIC DATA ANALYSIS

Large spectroscopic surveys are adding rich detail to our understanding of the stars in the Milky Way. In spectroscopy, the light from a star is dispersed by wavelength using diffraction gratings before being captured by a detector. The spectra of stars carry a lot of information about their physical conditions (surface temperature, surface gravity and elemental composition), and classically astronomers carry out a physical analysis of the spectrum: the strengths of individual absorption lines are used to determine the physical conditions based on a model of the structure of the stellar atmosphere. However, this process is time-consuming, and it is not practical for analysing the tens of thousands to millions of spectra acquired by current and future spectroscopic surveys. Astronomers are turning to mathematical methods to provide a non-physical analysis of the spectra that produces the same results as physical analysis much more quickly, without losing accuracy. tSNE is a dimensionality-reduction technique, and astronomers use it to group stars with similar spectra. The tSNE maps in Fig a show large groups, representing major phases of stellar evolution, and also small sets of outliers, which have spectra that are distinct from the large groups because of unusual elemental abundances or unusual physical conditions.

The tSNE method works by finding a low-dimensional (2D or 3D) coordinate system that retains as much of the information as possible from the original high-dimensional data by minimising the Kullback-Leibler divergence

$$C = \sum_i \sum_j p_{ij} \log \frac{p_{ij}}{q_{ij}} = \sum_i \sum_j p_{ij} \log p_{ij} - p_{ij} \log q_{ij}$$

between the joint probabilities p_{ij} in the high-dimensional space and q_{ij} in the low-dimensional space. Further explanation of the method, downloadable code in several programming languages, and example data sets are available at lvdmaaten.github.io/tsne/.

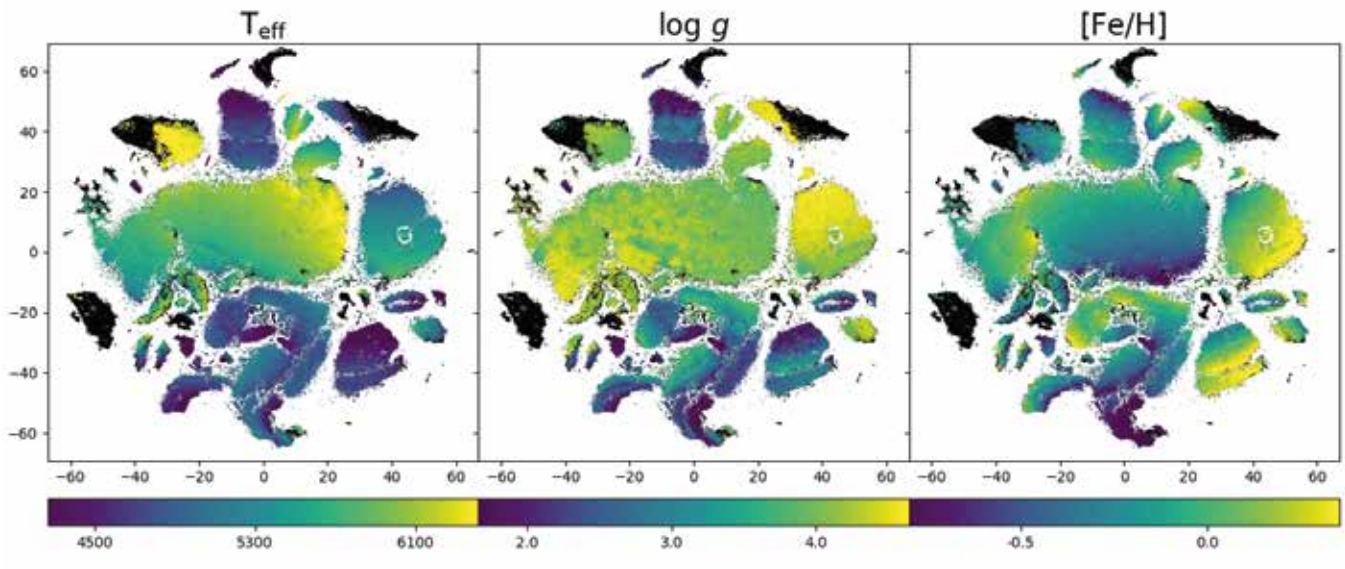

Fig a. A tSNE (t-distributed Stochastic Neighbour Embedding) map built using spectra (brightness as a function of wavelength) for 342,682 stars. The algorithm compares the spectra of the stars, and places one dot in this map for each star based on its spectral similarity to other stars. In this figure, the dots are colour-coded by surface temperature (left panel), surface gravity (centre) and heavy element abundance (right). While many stars are arranged in smooth distributions on this map, there are several smaller "islands" containing stars with spectra that are distinct in some way from the majority of stars. Figure from S. Buder et al. 2018, *Monthly Notices of the Royal Astronomical Society*, 478, p 4513 (arxiv.org/pdf/1804.06041.pdf), with data from the GALAH Survey (galah-survey.org).

1.12 THE SOUTH PACIFIC OPTIMIZATION MEETING IN WESTERN AUSTRALIA 2017

Curtin University of Technology, 8–10 December 2017

Placing local topics in an international perspective, this meeting was an ideal platform to foster idea exchange and optimisation research collaboration between Australia and the South Pacific region.

Part of a cluster of optimisation meetings and workshops organised by Curtin University in December 2017, the *6th South Pacific Optimization Meeting* attracted more than 40 local and international researchers and students. Opening new avenues for collaboration and research investigation, attendees exchanged ideas and shared research experiences centred on optimisation and its applications. This powerful exchange helped engage the Australian optimisation community more fully with its Pacific Rim and European partners.

Focusing mainly on theoretical advances in the discipline, topics covered during the three-day long program included variational analysis, optimal control theory, convex analysis, numerical optimisation, vector optimisation, stochastic optimisation, and functional analysis.

Highlights and promising outcomes from the meeting included:

- Talks by Monash University's Dr Janosch Rieger and Dr James Saunderson (on spaces of polytopes and the Lax conjecture respectively), which introduced new themes to the local theoretical optimisation community.
- A potential collaboration between Dr Hector Ramirez (University of Chile) with Professor Jerzy Filar (Director of the Centre for Applications in Natural Resource Mathematics at the University of Queensland) on the management of natural resources, specifically fisheries management.
- The commencement of a cooperation on multiobjective optimisation and optimal control with applications in machine learning and optimal choice of weights following a constructive exchange between Dr Christopher Schneider (Friedrich Schiller University Jena, Germany) and Professors Henri Bonnel (University of New Caledonia and Curtin), Yalcin Kaya (University of South Australia) and Helmut Maurer (Munster University, Germany). A paper entitled "*Optimisation over the Pareto Set: Applications in Machine Learning*", written by H. Bonnel and C. Schneider following several exchanges during and after the conference, has been submitted for publication.
- Ample opportunities to interact with experts in the field—in particular, Bui Thi Hoa (a postgraduate student at Federation University Australia) reported having insightful conversations with Professor Russell Luke on the convergence of the method of alternating projections.

There was an exceptionally strong presence of international participants taking part in the workshop, with 16 out of 30 talks given by international participants, including 4 out of 8 plenaries.

"The meeting was a complete success"

Marco Antonio Lopez Cerda, Alicante University

WORKSHOP PARTICIPATION

47	Attendees
13	Postgraduate students
5	Early career researchers
13	Women
27	International participants

Organisers

Adj. Prof. Henri Bonnel, Curtin University of Technology/University of New Caledonia, New Caledonia
Dr Honglei Xu, Curtin University of Technology
Dr C Yalçin Kaya, University of South Australia
Dr Vera Roshchina, RMIT University
Dr Christopher Schneider, Friedrich Schiller University Jena, Germany
Assoc. Prof. David Yost, Federation University, Ballarat

Special Presenters

Assoc. Prof. Regina Burachik, University of South Australia
Research Interests: optimisation theory, nonsmooth optimisation, convergence analysis
Prof. Andrew Eberhard, RMIT University
Research Interests: nonsmooth analysis, control theory, optimisation, PDE theory, economic modelling
Dr Hélène Frankowska, Institut de Mathématiques de Jussieu, University Pierre et Marie Curie, France
Research Interests: nonlinear control theory, deterministic and stochastic optimal control, differential inclusions, set-valued analysis, viability theory, hamilton-jacobi equations
Prof. Jerzy Filar, The University of Queensland
Research Interests: stochastic modelling, analytic perturbation theory and applications, operations research, optimisation, environmental modelling, graph theory, game theory
Prof. Jeya Jeyakumar, The University of New South Wales
Research Interests: global optimisation, optimisation under uncertainty, mathematical programming, convex analysis and optimisation, quadratic optimisation, polynomial optimisation
Prof. Marco Antonio Lopez Cerda, University of Alicante, Spain
Research Interests: optimisation, mathematical analysis, applied mathematics, linear programming, numerical methods, linear systems, mathematical programming, inequality
Prof. Ralph Tyrrell Rockafellar, University of Washington, USA
Research Interests: optimisation theory, convex and variational analysis, stochastic programming, optimal control, economics, finance, engineering

MathSciNet Classification

49K, 49M, 90C

Web Links

scieng.curtin.edu.au/science/mathematics-and-statistics/joc-2017/spom-in-wa-2017/

Other Sponsors

AustMS, University of New Caledonia

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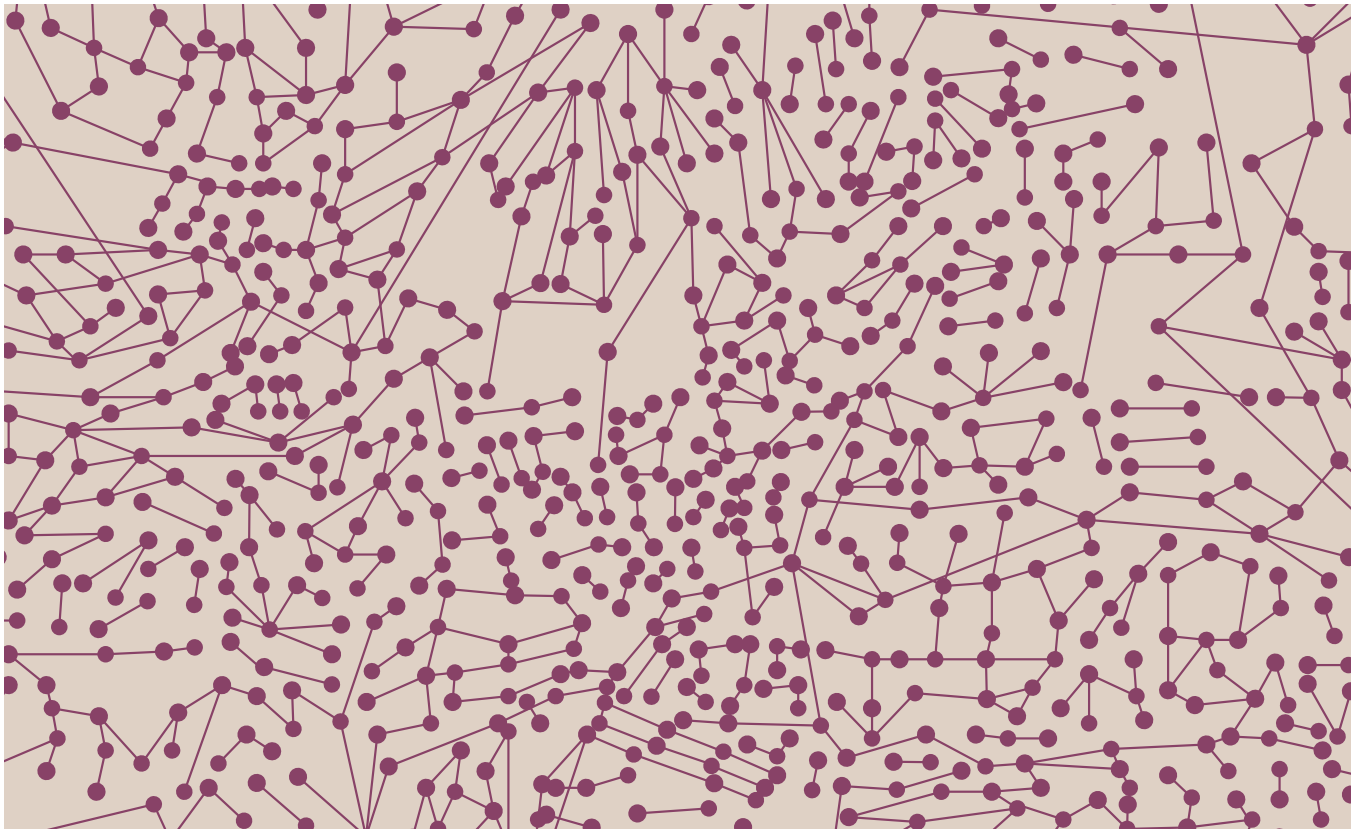


THEORETICAL ADVANCEMENTS IN **OPTIMISATION METHODS AND TOOLS**

By Prof. Henri Bonnel and Dr Vera Roshchina

It is in human nature to choose the best alternative when presented with several options, and so optimisation has been a major driver for innovation and mathematical discovery since ancient times. The development of calculus by Newton and Leibniz in the 17th century was a leap forward for the field: the task of finding an optimal solution was reduced to solving a system of equations (optimality conditions) that involved the newly invented derivative of a smooth function; this allowed the development of numerical methods. Newton's method is still one of the most popular optimisation techniques, and many algorithms employ it as a subroutine. In the 18th century, calculus of variations emerged from the work of the Bernoulli brothers on the brachistochrone problem and, thanks to Euler and Lagrange, led to the standard methods for finding optimal shapes and curves.

Throughout the 19th century the classical techniques were refined and developed further by famous mathematicians such as Weierstrass, Hamilton, Jacobi and Cauchy. Computers pushed the field to new frontiers during the 20th century. New numerical methods emerged for solving large-scale industrial problems and new mathematical theory was developed (convex analysis, optimal control, linear, conic and polynomial optimisation), building on the ideas of calculus and variational methods. Some new and old problems were solved, and many more emerged (think of the P versus NP problem for a mega-challenge!).

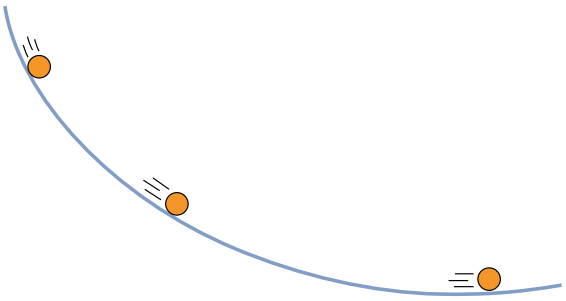


Fig 1. Brachistochrone problem—Find the shape of the curve down which a bead, starting from rest and accelerated by gravity, will slide (without friction) from one point to another in the least time.

In the 21st century, big data, machine learning, environmental challenges and hi-tech advancements in medicine are shaping our field. We also employ sophisticated tools developed within traditionally pure mathematical fields such as algebraic geometry and number theory. We can now solve hard polynomial problems using the Gröbner bases methods of computational algebraic geometry, reduce the difficulty of the problem by examining its symmetry and using group theory to implement this reduction mathematically, and sharpen the results of numerical experiments using the inverse calculator invented by number theorists.

CURRENT ADVANCEMENTS

The focus of 2017's South Pacific Optimization Meeting (SPOM) was specifically on theoretical advancements in optimisation methods and tools. The perhaps eclectic selection of topics that were discussed during the workshop ranged from epidemiology and climate models, image processing in cancer treatment and fisheries management to fine theoretical results on robustness, error bounds, duality theory and polynomial optimisation. The broad range of topics is a testament to the exciting times we are witnessing as optimisers and mathematicians, and of the depth and diversity of the Australian optimisation community.

One of the key topics that emerged during the conference was projection methods. The modern research in this area was pioneered in Australia and worldwide by the late Professor Jonathan Borwein and his team, who successfully applied the Douglas-Rachford projection algorithm to hard optimisation problems, including protein folding and solving Sudoku puzzles. It was exciting to see this work continuing and expanding: Professor Russell Luke (University of Göttingen) gave an overview talk that covered the underlying theory of projection methods as well as new applications, such as inverse problems in x-ray imaging and sub-diffraction florescence microscopy. Novel foundational ideas were presented by Dr Minh Dao (University of Newcastle) who unified the analysis of a wide range of methods, not only explaining the existing results, but also relaxing some regularity conditions and improving the estimates of linear convergence rates of projection methods. Australian PhD students Hoa Bui and Scott Lindstrom who are working in this area were able to exchange ideas with local and international participants, and we will surely see future advancements in the area coming from our junior researchers.

Another exciting theme that was well-represented at the workshop is polynomial and semidefinite optimisation. Semidefinite programming models are based on the properties of a special class of (positive semidefinite) matrices. If an optimisation problem can be modelled via semidefinite programming, it can be solved very efficiently by modern optimisation software. One of the main challenges in this field is to find a semidefinite programming formulation for a given problem. Professor Jeya Jeyakumar (University of New South Wales) gave a plenary talk on the modern techniques of semidefinite relaxations (a mathematically precise way to approximate a hard optimisation problem by a semidefinite formulation that is easier to solve). Moreover, the new result reported by Dr James Saunderson (Monash University) on the construction of hyperbolic polynomials is a strong contribution to the generalised Lax conjecture, which is one of the key open mathematical problems in the field of semidefinite programming representations.

A new collaboration on multiobjective optimisation and optimal control with applications in machine learning and optimal choice of weights emerged following a constructive exchange between Dr Christopher Schneider (Friedrich Schiller University Jena, Germany) and Professor Henri Bonnel (University of New Caledonia and Curtin), Professor Helmut Maurer (Munster University, Germany) and Dr Yalcin Kaya (University of South Australia).

In addition, Dr Hector Ramirez (University of Chile) and Professor Jerzy Filar (Director of the Centre for Applications in Natural Resource Mathematics at the University of Queensland) found common themes in their research on the management of natural resources, following Dr Ramirez' talk on fisheries management in Chile.

FUTURE DIRECTIONS IN OPTIMISATION RESEARCH

We are anticipating major advancements in the understanding of projection methods and the consolidation of results in polynomial optimisation in the next few years; we also expect to see a stronger focus on big data, machine learning and the management of natural resources. These new areas would build on the optimisation theory developed right now. It is exciting to think that the theoretical results presented at SPOM will help to treat disease, streamline data processing and make a positive impact on our environment.

Prof. Henri Bonnel *was an adjunct Professor at Curtin University until March 2018, and is also emeritus professor at the University of New Caledonia..*
Dr Vera Roshchina *is a senior lecturer at the School of Mathematics and Statistics at the University of New South Wales.*

CASE STUDY: SUBTRANSVERSALITY, GEOMETRY AND POLYHEDRAL OPTIMISATION

Hoa Thi Bui is a PhD student at Federation University Australia, working on several projects in theoretical optimisation, including the study of subtransversality and regularity of collections of sets and combinatorial properties of polytopes.

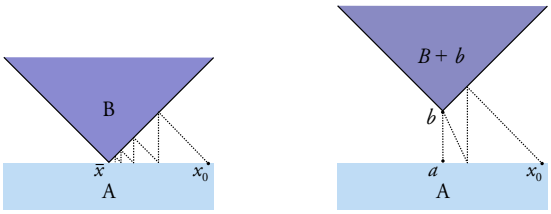


Fig 2. Subtransversality is a rigorous mathematical way of describing the geometry of relative positions of sets in space; this work has profound implications in robustness and stability issues of optimisation problems and is key in the study of the convergence of numerical algorithms, including projection methods.

Note how the geometry of the set arrangement influences the convergence of the method of alternating projections: it may take infinitely many steps or converge almost immediately, depending on the relative position of the sets.

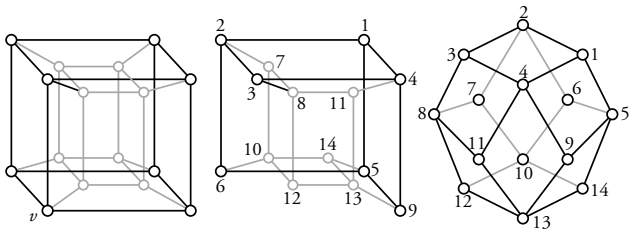


Fig 3. The study of the geometry of polytopes is crucial for our understanding of polyhedral optimisation problems, and specifically linear programming.

By using rigorous mathematical tools, high-dimensional polytopes and their properties can be represented via two-dimensional graphs and diagrams. This helps the researchers to use geometrwic approaches to solving the optimisation problems and also facilitates the communication of mathematical results.

There are very hard open problems in this field: check out the generalised Hirsch conjecture and Smale's 9th problem!

(Images provided by Hoa Thi Bui, Federation University Australia)

CASE STUDY: MAXIMALLY MONOTONE OPERATORS AND CONVEX FUNCTIONS

Regina Burachik is an associate professor in the School of Information Technology and Mathematical Sciences at the University of South Australia. Regina's interest is in theoretical and practical aspects of optimisation, including variational inequalities, maximal monotone maps, and duality theory. She publishes extensively in nonsmooth, convex and nonconvex optimisation and set-valued analysis. She recently co-authored the Springer research-level book "Set-Valued Analysis and Monotone Mappings". She is an associate editor of around 10 international journals, and regularly gives keynote and plenary talks at national and international conferences. In 2018, she was a plenary speaker at the Annual Meeting of the Australian Mathematical Society, and at the Annual Meeting of the Argentinian Mathematics Union.

The *Fenchel-Young* function highlighted at the bottom of Fig 4 is an example of a function that satisfies the same properties as above, but with respect to the maximally monotone operator given by the sub differential of a convex function.

For $T : X \rightrightarrows X^*$ max-mon, the *Fitzpatrick family* $\mathcal{H}(T)$ consists of functions $h : X \times X^* \to \mathbb{R}_{+\infty}$ convex and norm-weak* lsc, s.t.

$$h(x,v) \geq \langle x,v \rangle \quad \forall\, x \in X,\, v \in X^*$$
$$h(x,v) = \langle x,v \rangle \iff v \in Tx,$$

Fenchel-Young gives $h(x,v) := f(x) + f^*(v) \in \mathcal{H}(\partial f)$

Fig 4. Simon Fitzpatrick established a correspondence between maximally monotone operators and convex functions in a 1988 paper, in which he defined a function, now called the Fitzpatrick function. This function has the following property: it coincides with the duality product over the graph of the maximal monotone operator, and it is greater than or equal larger than the duality product everywhere else. Moreover, he defined the family of all the functions that satisfy the same property mentioned above, with respect to the graph of the operator.

(Images provided by Assoc. Prof. Regina Burachik, University of South Australia)

1.13 AUSTRALIA-CHINA CONFERENCE IN NONCOMMUTATIVE GEOMETRY AND RELATED AREAS

The University of Adelaide, 18–22 December 2017

This conference widened research communication and collaboration between Australian and Chinese mathematicians in the growing field of noncommutative geometry.

Motivated by the development of quantum theory, the introduction of operator algebras to study related mathematical questions has grown into an exciting area of modern mathematics. In particular, the fast-growing area of Connes' noncommutative geometry (NCG) has broad impacts across many areas of mathematics and physics. Spaces with nice geometric properties can be understood by classical geometry and topology. However, spaces with singularities appear often in a vast spectrum of areas, for example, spaces with symmetries or foliations in representation theory, stratified spaces in algebraic geometry and so on, are usually out of the scope of classical differential geometry and topology. NCG is an effective replacement developed from functional analysis, to extend tools in geometry, topology and analysis in these new settings.

Australia has maintained a small but very strong presence in NCG for 20 years, with research in the field now expanding rapidly in China. Establishing links between this substantial Chinese NCG community and Australian research groups is an essential investment for the future of the field.

Covering a wide spectrum of areas within noncommutative geometry, the program featured seven keynote talks and 16 research presentations by early career researchers on topics including the roles of noncommutative geometry and K-theory in topology, geometry, mathematical physics, representation theory and geometric quantisation, dynamics and operator algebras, and the classification of C*-algebras. Importantly, these sessions seeded many new directions for future research.

Keynote highlights included Professor Guihua Gong's beautiful introduction to his ground-breaking work of the last 20 years on the classification of C*-algebras, Professor Mathai Varghese's enlightening talk on spectral gap-labelling conjectures for magnetic Schrodinger operators and Professor Guoliang Yu's inspiring talk introducing higher index theorem for manifolds with boundaries.

Research talks focused on new research results and stimulated ongoing discussions and research collaborations between the Australian and Chinese mathematicians working in this field, and between the students, early career researchers and experts.

These included discussions between Professors Peter Bouwknegt and Mathai Varghese and Associate Professor Fei Han (National University of Singapore) on mathematical physics, Dr Peter Hochs (The University of Adelaide) Assistant Professor Song (Washington University, St Louis, USA) and Assistant Professor Shilin Yu (Texas A&M University) on representations and K-theory among others. Professor Guoliang Yu's talk inspired many of the participants and motivated an ongoing research collaboration between Associate Professor Bai-Ling Wang, Dr Peter Hochs and Dr Hang Wang.

Organisers

Prof. Mathai Varghese, The University of Adelaide
Prof. Guoliang Yu, Fudan University, China and Texas A&M University, USA
Prof. Alan Carey, The Australian National University
Dr Hang Wang, The University of Adelaide
Dr Guo Chuan Thiang, The University of Adelaide

Special Presenters

Prof. Peter Bouwknegt, The Australian National University
Research Interests: mathematical physics, conformal field theory, Lie algebras, representation theory, quantum groups, differential geometry, homological algebra, algebraic geometry, algebraic topology
Prof. Guihua Gong, University of Puerto Rico, USA and Hebei Normal University, China
Research Interests: functional analysis, algebra of operators, index theory, global analysis, noncommutative differential geometry
Prof. Hanfeng Li, State University of New York, Buffalo, USA
Research Interests: operator algebras, noncommutative geometry, dynamical systems
Prof. Mathai Varghese, The University of Adelaide
Research Interests: index theory of elliptic operators, secondary invariants of elliptic operators, geometric quantisation: noncompact context, noncommutative geometry.
Prof. Fedor Sukochev, The University of New South Wales
Research Interests: non-commutative functional analysis and its applications to non-commutative geometry, Banach space geometry and its applications
Prof. Guoliang Yu, Texas A&M University, USA and Shanghai Center of Mathematical Sciences (Fudan University), China
Research Interests: noncommutative geometry, K-theory of operator algebras, index theory, topology and analysis of manifolds, geometric group theory
Prof. Weiping Zhang, Chern Institute of Mathematics, Nankai University, China
Research Interests: differential geometry

MathSciNet Classification

46L87, 46L80, 19K56

Web Links

iga.adelaide.edu.au/workshops/December2017/

Other Sponsors

Australian Mathematical Society, Institute of Geometry and Applications, The University of Adelaide, Australian Research Council

Key Contact

Dr Hang Wang, The University of Adelaide, hang.wang01@adelaide.edu.au

WORKSHOP PARTICIPATION

43 Attendees
12 postgraduate students
11 Early career researchers
4 Women
18 International participants

1.14 DIOPHANTINE APPROXIMATION AND DYNAMICAL SYSTEMS

La Trobe University, 6–8 January 2018

Australian researchers and students investigating interconnected topics in Diophantine approximations, dynamical systems and ergodic theory relished this rare opportunity to engage with field experts and discuss open problems for investigation.

A connection between ergodic theory, dynamics and Diophantine approximation comes from the so-called "correspondence principle", introduced by Dani (1985), refined by Kleinbock–Margulis (1999). The correspondence principle relates the Diophantine approximation properties of a point on a quadratic variety to the dynamics of a corresponding orbit of a certain one-parameter flow on a homogeneous space. It can thus be used to deduce Diophantine theorems from dynamical ones. Kleinbock—Margulis ideas came from Ergodic theory on homogeneous flows to solve a purely number theoretic conjecture (Sprindzuk, 1965) which acted as a catalyst for most of the recent developments in Diophantine approximation.

Featuring a strongly international expert panel, the program covered the interconnected fields of Diophantine approximations, dynamical systems and ergodic theory. In particular, sessions focused on the different points of contact between the theories of Diophantine approximation and of dynamical systems.

Across the three-day long program, PhD students and experienced researchers were able to take advantage of lively discussions. Several new collaborations were initiated and progress towards long-standing conjectures was made.

Among the highlights was the resolution of the generalised Baker-Schmidt problem (1970) for hypersurfaces (arxiv.org/abs/1803.02314). Presented by Drs Mumtaz Hussain, Johannes Schleischitz and David Simmons, this research will have significant implications for the international and Australian mathematical and number theory communities.

Other links initiated during this conference included collaborations between Associate Professor Dzmitry Badziahin, Dr Schleischitz and Dr Oleg German, as well as between Dr Hussain, Professor Bing Li, Dr David Simmons and Professor Bao-Wei Wang.

At the end of the conference, several speakers stayed for another week for collaborative research on the topic *Open Problems in Diophantine approximation and dynamical systems*. A monograph is in preparation.

WORKSHOP PARTICIPATION

22	Attendees
3	Postgraduate students
5	Early career researchers
3	Women
13	International participants

"The best targeted research focused conference in Diophantine approximation and dynamical systems I ever attended"

Prof. Michel Waldschmidt, Pierre and Marie Curie University Paris VI, France

Organisers

Dr Mumtaz Hussain, La Trobe University
Assoc. Prof. Dzimitry Badziahin, The University of Sydney

Special Presenters

Assoc. Prof. Dzmitry Badziahin, The University of Sydney
Research Interests: analytical number theory, Diophantine approximation
Prof. Yitwah Cheung, San Francisco University, USA
Research Interests: ergodic theory, rational billiards, dynamics on Lie groups, Diophantine approximation
Dr Oleg German, Moscow State University, Russia
Research Interests: Diophantine approximation
Prof. Andy Hone, Kent University, UK
Research Interests: discrete and continuous integrable systems, cluster algebras, dynamics over finite fields, coherent structures in PDEs, painlevé equations, solvable models in physics and biology
Dr Oleg Karpenkov, The University of Liverpool, UK
Research Interests: continued fractions, knot theory, geometry, singularity theory
Assoc. Prof. Simon Kristensen, Aarhus University, Denmark
Research Interests: ergodic theory, small denominator problems, Diophantine approximation, metric number theory
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, geometric group theory
Dr Johannes Schleischitz, The University of Ottawa, Canada
Research Interests: Diophantine approximation
Dr David Simmons, University of York, UK
Research Interests: Diophantine approximation, fractal geometry, dynamical systems
Prof. Michel Waldschmidt, Pierre and Marie Curie University Paris VI, France
Research Interests: number theory, Diophantine approximation
Prof. Bao-Wei Wang, Huazhong University of Science and Technology, China
Research Interests: number theory, mathematical analysis

MathSciNet Classification

37A17, 11K60

Web Links

ntdu.mathsig.org/dads/

Other Sponsors

AustMS, La Trobe University

Key Contact

Dr Mumtaz Hussain, La Trobe University, m.hussain@latrobe.edu.au

1.15 CONFERENCE ON GEOMETRIC AND NONLINEAR PARTIAL DIFFERENTIAL EQUATIONS

Murramarang Resort, NSW, 5–9 February 2018

The second of two major events organised as part of ANU's Special Year on Geometric Analysis and Nonlinear Partial Differential Equations (PDEs), this workshop demonstrated and strengthened connections between geometric analysis and nonlinear PDEs, focusing on new advances in the field.

Techniques stemming from the rich interplay between geometry and nonlinear PDEs are used in solving geometric problems, and their development and application in geometry. The study of geometric and nonlinear PDEs has also had a tremendous impact on diverse fields that include mathematical physics, material science, image processing, meteorology and optimisation to name a few.

Over the past two decades, Australia has helped lead resolution of several longstanding famous problems in these areas. Notable achievements include Neil Trudinger and Xu-Jia Wang's resolution of Chern's conjecture in affine geometry, proof of the fundamental gap conjecture by Ben Andrews and Julie Clutterbuck; Ben Andrews also solved the Pinkall-Sterling conjecture for embedded torus in the sphere with his collaborator. These successes have joined other recent advances overseas to drive the development of the field.

This conference was a joint event of the Australian National University, Beijing International Centre for Mathematical Research, Pacific Institute for the Mathematical Sciences and the University of Sydney. It covered a number of active research topics in current international mathematical research, such as curvature flow, complex geometry, Monge-Ampere equations and applications in optimal transportation.

Invited speakers included leading mathematicians such as Panagiota Daskalopoulos, Nicola Fusco, Slawomir Kolodziej, Robert McCann, and Leon Simon, among others. Of the 32 presentations, more than 20 of them were from international participants, providing the Australian attendees with plenty of opportunities to exchange ideas and research outcomes with their international peers.

Program highlights included:

- Professor Daskalopoulos's presentation on the resolution of a long-standing open problem in the Gauss curvature flow, namely the flow of a closed convex hypersurface by its Gauss curvature converges to a round point—the core problem for the Gauss curvature flow since it was introduced by Firey in 1970s and resolved by Ben Andrews in dimension two.
- Professor Leon Simon's cutting-edge research introducing a new class of nonlinear elliptic equations admitting solutions with isolated singularities; a phenomenon that arises in a number of geometric settings.
- A new model in optimal transportation reported by Professor Robert McCann, coming out of the principal-agent problem in economic theory; optimal transportation was also applied to John Nash's bargaining problem in the talk of Assistant Professor Micah Warren (University of Oregon).
- A discussion on the dual Minkowski problem introduced by Professor Gaoyong Zhang (Courant Institute of Mathematical Sciences, New York University) and collaborators. This currently under extensive investigation.

The event was also a powerful experience for Australian early career researchers and postgraduate students, exposing them to new developments and avenues for investigation.

The conference was well attended by researchers of all levels, including postgraduate students and early career researchers. Plenty of breaks in the schedule provided ample time for discussions and socialising between delegates.

"This is one of the most successful conferences I have ever attended."

Minchun Hong, The University of Queensland

Organisers

Prof. Ben Andrews, The Australian National University
Dr Julie Clutterbuck, Monash University
Dr Serena Dipierro, The University of Melbourne
Dr Jiakun Liu, University of Wollongong
Prof. Xu-Jia Wang, The Australian National University
Assoc. Prof. Zhou Zhang, The University of Sydney

Special Presenters

Prof. Leon Simon, Stanford University, USA
Research Interests: differential geometry, geometric analysis, PDEs
Prof. Nicola Fusco, University of Naples Federico II, Italy
Research Interests: calculus of variations and PDEs, isoperimetric inequalities
Prof. Panagiota Daskalopoulos, Columbia University, USA
Research Interests: differential geometry, geometric analysis, PDEs
Prof. Robert McCann, University of Toronto, Canada
Research Interests: mathematical physics and mathematical economics, convex analysis, geometry and optimisation, PDEs
Prof. Slawomir Kolodziej, Jagiellonian University, Poland
Research Interests: analysis, geometry, topology

MathSciNet Classification

35 Partial Differential Equations, 53 Differential Geometry

Web Links

maths.anu.edu.au/news-events/events/conference-geometric-and-nonlinear-partial-differential-equations

Other Sponsors

The Australian National University, The University of Sydney, AustMS

Key Contact

Prof. Xu-Jia Wang, The Australian National University, xu-jia.wang@anu.edu.au

WORKSHOP PARTICIPATION

52 Attendees
7 Postgraduate students
7 Early career researchers
11 Women
24 International participants

1.16 WORKSHOP ON LOGIC, ALGEBRA AND CATEGORY THEORY 2018

La Trobe University, 12–16 February 2018

Focusing on computer science and its ties with the interconnecting areas of logic, category theory and algebraic structures, discussion at this conference resulted in the proposition of new mathematical structures to support the design of reliable software and hardware systems.

The strong ties between logic, category theory and algebraic structures are particularly apparent when viewed in the context of complex modelling and systems verification across various fields of computer science. This workshop explored application of proposed mathematical structures to support design of reliable software and hardware systems and build high-confidence systems.

Other areas of expertise covered by the participants included formal methods, software engineering, ontology and error-correcting codes. This provided a good opportunity for participants to be exposed to different points of view, new ideas and trends.

Over five days attendees participated in three interactive morning tutorials, each covering emerging topics: the distributed ontology language (DOL), coalgebraic logic and institution theory. As well as additional presentations, afternoons provided opportunity for further analysis of presented content and brainstorming of ideas.

Highlights included Professor Yde Venema's introduction to the dualities in algebraic logic, and Professor Hiroakira Ono's talk on cut elimination and semi-completeness in the context of developing well-behaved proof systems. Professor Andrzej Tarlecki's tutorials introduced institution theory and his demonstrations of the use of category theory to provide a better understanding of standard classical results from the theory of specifications and mathematical logic. Professor Jose Fiadeiro's presentation was devoted to a suite of hybrid logics that support the specification and verification of cyberphysical system protocols.

A number of participants engaged in collaborative discussions, both during and after the workshop. Professor Jose Fiadeiro and his student Ionut Tutu started a collaboration with Assistant Professor Daniel Gaina on developing reliable reconfigurable systems that can automatically adapt—in real time, and without the need for software engineers to intervene—to the changing environment and conditions in which they operate. This project will develop the necessary mathematical framework and software-tool support for the study of reconfigurable systems. A joint paper resulting from this collaboration, authored by D. Gaina, I. Tutu, and A. Riesco, was submitted to the 25th Asia-Pacific Software Engineering Conference (APSEC 2018).

In addition, Professor Hiroakira Ono and Associate Professor Tomasz Kowalski continued their ongoing collaboration on universal algebra and proof theory with a joint paper in preparation, and Dr Maria Keet and Assistant Professor Oliver Kutz extended their stay to start working on a paper related to the formal methods and tools available for DOL.

Participants expressed their interest in a future edition of the workshop to be organised in collaboration with other Australian universities.

WORKSHOP PARTICIPATION

- **32** Attendees
- **6** Postgraduate students
- **6** Early career researchers
- **4** Women
- **9** International participants

Organisers

Dr Mihai Codescu, Institute of Mathematics of the Romanian Academy, Romania
Asst. Prof. Daniel Gaina, Kyushu University, Japan
Assoc. Prof. Tomasz Kowalski, La Trobe University
Prof. Wenny Rahayu, La Trobe University
Prof. Asha Rao, RMIT University

Special Presenters

Prof. José Luiz Fiadeiro, Royal Holloway University of London, UK
Research Interests: formal aspects of software system modelling and analysis in ubiquitous computing
Dr Richard Garner, Macquarie University
Research Interests: category theory and its applications to logic, topology, geometry and computer science
Assoc. Prof. Marcel Jackson, La Trobe University
Research Interests: semigroups, universal algebra and their application
Dr Maria Keet, University of Cape Town, South Africa
Research Interests: knowledge engineering, aspects of ontology engineering, natural language generation, logic-based knowledge representation
Asst. Prof. Oliver Kutz, Free University of Bozen-Bolzano, Italy
Research Interests: computational logic, knowledge representation, logic in AI, computational creativity, formal ontology, cognitive modelling
Prof. Yoshihiro Mizoguchi, Kyushu University, Japan
Research Interests: theoretical aspects in computer science, cellular automata, computer graphics, category theories, network securities
Prof. Hiroakira Ono, Japan Advanced Institute of Science and Technology, Japan
Research Interests: mathematical logic, logic in computer science
Dr Dirk Pattinson, The Australian National University
Research Interests: modal logics, domain theory, logic and category theory
Asst. Prof. Adrián Riesco Rodríguez, Universidad Complutense de Madrid, Spain
Research Interests: declarative debugging, test case generation, distributed applications, rewriting logic, unification, narrowing
Prof. Jennifer Seberry, University of Wollongong
Research Interests: cryptology, Hadamard matrices, orthogonal designs, wireless security
Prof. Andrzej Tarlecki, University of Warsaw, Poland
Research Interests: algebraic specification, program development, logic and abstract model theory
Dr Ionut Tutu, Royal Holloway University of London, UK
Research Interests: logic programming, service-oriented logic programming, algebraic specification
Prof. Yde Venema, Universiteit van Amsterdam, The Netherlands
Research Interests: modal logic, game theory, automata and process theory

MathSciNet Classification

03C95, 18C10, 08A70

Web Links

www2.math.kyushu-u.ac.jp/~lac2018/

Other Sponsors

Institute of Mathematics for Industry, Kyushu University; Department of Mathematics and Statistics, La Trobe University; La Trobe Asia, La Trobe University

Key Contact

Asst. Prof. Daniel Gaina, La Trobe University, D.Gaina@latrobe.edu.au

1.17 HARMONIC ANALYSIS CONFERENCE CELEBRATING THE MATHEMATICAL LEGACY OF ALAN MCINTOSH

The Australian National University, 12–16 February 2018

Honouring the legacy of the late Australian mathematician Alan McIntosh, this workshop brought together many of his former students and collaborators together to discuss new developments in harmonic analysis.

In August 2016, the world lost a greatly original and highly influential mathematical analyst, Alan McIntosh. For almost fifty years, Alan McIntosh had been a symbol of the strength of Australian mathematics, and a key figure in the fields of harmonic analysis and operator theory worldwide. Harmonic analysis in general, and the work of McIntosh in particular, has been, over the past two decades at least, an important component of the strong reputation of Australian mathematics internationally.

Focusing on new directions in harmonic analysis, this five-day workshop launched the Mathematical Sciences Institute's 2018 Special Year in Analysis. Featuring a comprehensive program of 18 talks and videos, the conference proved an effective platform to foster collaboration between participants.

Professor Steve Hofmann's presentation describing his latest results in the growing field of geometric measure theory proved a highlight. Closing the conference, Professor Tuomas Hytönen presented exciting new research on L^p approximations of both martingales and solutions of PDE, connecting both to classical probability and the geometric measure theory described by Hofmann.

Professor Cristina Peyeyra's undergraduate Colloquium session was popular with ANU students. The workshop also included a Women in Mathematics lunch, hosted by Professor Lesley Ward (University of South Australia), and attended by the conference's female participants and ANU staff.

The high level of discussion at the conference led to many collaborative discussions including:

- A continuance of work by Professor Hofmann and Professor Xuan Duong on their collaborative project.
- Professor Jan Van Neerven (Delft University of Technology) and Dr Pierre Portal (The Australian National University) almost completed a paper on rough pseudo-differential calculus.
- Dr Andrew Morris (University of Birmingham), Dr Portal and PhD student Julian Bailey (also at the Australian National University under Dr Portal) discussed the fact that Bailey and Dr Morris' student are currently finishing competing papers on the Kato problem with potentials. The conclusion was that the two approaches were complementary and gave different results. Future collaborations combining the approaches were planned.
- Assistant Professor Sylvie Monniaux (Universite Aix-Marseille) and Professor Tom ter Elst (University of Auckland) almost completed their paper on compactness of trace operators.

"We had excellent talks from a diverse pull of speakers on a diverse set of topics all close to Alan's heart. [There was] a conference dinner and also a women's lunch very well attended. There was plenty of opportunity for interacting with the more junior participants in between talks, at lunch time, in the evening. I specifically was given the chance to deliver a talk for the undergraduates and I was pleasantly surprised when a good number showed up despite the fact the semester had yet to start."

Prof. Cristina Peyeyra, University of New Mexico, USA

Organisers

Dr Pierre Portal, The Australian National University
Prof. Neil Trudinger, The Australian National University
Prof. Xuan Duong, Macquarie University

Special Presenters

Prof. Steve Hofmann, University of Missouri, USA
Research Interests: geometric measure theory, harmonic analysis, PDE
Prof. Tuomas Hytönen, University of Helsinki, Finland
Research Interests: harmonic analysis
Prof. Cristina Peyeyra, University of New Mexico, USA
Research Interests: harmonic analysis

MathSciNet Classification

42 Fourier Analysis, 47 Operator Theory, 35 Partial Differential Equations

Web Links

maths.anu.edu.au/news-events/events/harmonic-analysis-conference-celebrating-mathematical-legacy-alan-mcintosh

Other Sponsors

The Australian National University

Key Contact

Dr Pierre Portal, The Australian National University, pierre.portal@anu.edu.au

WORKSHOP PARTICIPATION

34	Attendees
5	Postgraduate students
3	Early career researchers
6	Women
15	International participants

1.18 VARIATIONAL ANALYSIS DOWN UNDER 2018

Federation University Australia, 19–21 February 2018

This workshop nurtured discussion and collaboration between key field leaders, and bolstered Australia's high regard as a centre for optimisation and variational analysis research.

A new, rapidly growing branch of modern mathematics, variational analysis, is motivated by and strongly connected with optimisation, optimal control, equilibrium, and stability of linear and nonlinear systems. Its name comes from the title of the famous book by Terry Rockafellar and Roger Wets, published in 1998 and widely accepted as the birth date of this new mathematical discipline.

Keynotes by stellar researchers Professor Terry Rockafellar and Professor Asen Dontchev were highlights, with the conference dedicated to Professor Dontchev's 70th birthday. Both have been involved in variational analysis since its inception, and have collaborated together on a number of papers and a book.

Professor Dontchev delivered a comprehensive survey on what is now recognised as a basic paradigm, the *radius of good behaviour*. This provides quantitative estimates by linking measurements of the effect of perturbations and approximations of a problem on its solutions as well as with estimation of convergence rate of algorithms. Broadly reaching, this includes the concept of conditioning in numerical linear algebra.

Professor Rockafellar spoke about progressive decoupling of linkages. Many problems can be formulated in terms of finding a pair (x,y) in the graph of a set-valued mapping between Hilbert spaces such that x belongs to a given subspace S and y is orthogonal to S. Progressive decoupling is an algorithm for solving that iteratively while the subspace S is suppressed. It relates to Spingarn's partial inverse method but doesn't need global or even local maximal monotonicity. It enables optimisation problems to be decomposed even without convexity.

The other two keynote presentations were given by Associate Professor Regina Burachik, who talked about Bregman-type distances for convex functions and maximally monotone operators, an idea likely to have significant applications, and by Professor Lyudmila Polyakova who spoke on smooth approximation of DC functions.

Contributed talks provided a platform for other participants, particularly early career researchers, to widely publicise their work. Local PhD students greatly benefited from the chance to interact with senior mathematicians in a relaxed and informal atmosphere.

The open problem session was voted unanimously as a highlight, creating much discussion. The session was jointly chaired by PhD students Hoa Bui (Federation University Australia) and Scott Lindstrom (University of Newcastle). It was informal but dynamic, and was followed by extensive email exchanges on the problems discussed. It seems likely to result in further research and collaboration between participants. The description of open problems discussed at the meeting has been published online in the *Journal of Optimisation Theory and Applications* (doi.org/10.1007/s10957-018-1399-x) and will appear in the Special Issue *Recent Advances in Variational Calculus: Principles, Tools and Applications*.

The workshop boosted existing research collaborations—for instance, in the framework of the current ARC Discovery project *Stability of Generalised Equations and Variational Systems*, on which Alexander Kruger and Asen Dontchev are the Chief Investigator and a Partner Investigator, respectively. Asen stayed in Ballarat after the end of the workshop to work on the project. Some progress has been achieved; a joint paper has recently been submitted.

New collaborations are anticipated on the back of conference discussions, in particular, addressing the interaction between semi-algebraic or tame optimisation and variational analysis.

The success of this workshop has upheld Australia's long-held international reputation as a centre for optimisation and variational analysis research.

Organisers

Assoc. Prof. Alexander Kruger, Federation University Australia
Assoc. Prof. Adil Bagirov, Federation University Australia
Evan Dekker, Federation University Australia
Prof. Andrew Eberhard, RMIT University
Prof. Terry Rockafellar, University of Washington, USA
Dr Vera Roshchina, RMIT University
Dr James Saunderson, Monash University
Assoc. Prof. David Yost, Federation University Australia

Special Presenters

Prof. Asen Dontchev, Mathematical Reviews and University of Michigan, USA
Research Interests: variational problems, optimisation, optimal control, differential equations, calculus of variations and approximation theory

Assoc. Prof. Regina Burachik, University of South Australia
Research Interests: optimisation theory, variational inequalities, functional analysis, maximal monotone operator theory, duality for nonsmooth and non-convex optimisation

Prof. Lyudmila Polyakova, Saint-Petersburg State University, Russia
Research Interests: nonsmooth analysis, optimisation theory, quasidifferential calculus

Prof. Terry Rockafellar, University of Washington, USA
Research Interests: convex and variational analysis, with emphasis on applications to stochastic programming, optimal control, economics, finance, and engineering

MathSciNet Classification

90C26, 90C46, 90K40

Web Links

vadu2018.org

Other Sponsors

Federation University Australia, AustMS, Mathematics of Computation and Optimisation (Special Interest Group of AustMS)

Key Contact

Assoc. Prof. Alexander Kruger, Federation University Australia, a.kruger@federation.edu.au

WORKSHOP PARTICIPATION

30 Attendees
5 Postgraduate students
4 Early career researchers
9 Women
6 International participants

PHOTO: SUPPLIED

Participants at the Microlocal Analysis and its Applications in Spectral Theory, Dynamical Systems, Inverse Problems, and PDE workshop held at the Murramarang Resort

PHOTOS: JAYNE ION

Future Directions in Representation Theory held at the The University of Sydney

1.19 MICROLOCAL ANALYSIS AND ITS APPLICATIONS IN SPECTRAL THEORY, DYNAMICAL SYSTEMS, INVERSE PROBLEMS AND PDE

Murramarang Resort, NSW, 18–23 March 2018

A fixture in the Mathematical Sciences Institute's Special Year of Analysis, Australia's first workshop on microlocal analysis generated robust discussion and new avenues for investigation.

Microlocal analysis grew out of the development of pseudo-differential and Fourier integral operators by Hörmander and others in the 1960s and 70s. An active and fast-developing area of research, it has since expanded with advances in multiple directions. Baladi, Faure, Tsujii, Dyatlov and Zworski's work in dynamical systems has notably resulted in new methods applied to hyperbolic dynamics. A signature achievement in PDE and general relativity, Vasy and Hintz's contribution to global nonlinear stability of the Kerr-de Sitter family of spacetimes has showed the efficacy of microlocal analysis in the study of nonlinear evolution equations. In addition, Uhlmann, Guillarmou, Vasy, Tzou and many others have made great strides in geometric inverse problems using microlocal techniques. Additionally, microlocal analysis continues to bear much fruit in the study of spectral and scattering theory, as it has for several decades.

Until recently the field has remained relatively small in Australia, but the emergence of researchers such as Jesse Gell-Redman (Melbourne), Leo Tzou (Sydney) and Melissa Tacy (now Otago NZ) has seen the area expand. This workshop provided a compelling platform for these researchers to engage with leaders in closely related fields, while also engaging potential talent through graduate students and postdocs. Showcasing Australian microlocal analysis to the international community, it was an ideal opportunity to strengthen new and their international partnerships.

With an emphasis on collaboration and open problems during the workshop, many speakers posed open problems in their talks and many new potential research collaborations formed during the workshop. In one example, Professor Andrew Hassell (The Australian National University) commenced a collaboration with Professor Frédéric Faure and Xiaolong Han (California State University, Northridge).

Among the highlights were the talks Professor Andras Vasy and his former student Dr Peter Hintz gave on their groundbreaking work on general relativity, particularly their proof of the global nonlinear stability of the Kerr-de Sitter family of black hole spacetimes. Dr Frédéric Faure talked about his recent seminal work with Tsujii on microlocal analysis applied to hyperbolic dynamical systems.

A two-day mini-course comprising both lectures and problem sessions was held directly before the workshop to introduce students and postdocs to microlocal analysis, attracting 23 participants, mostly from Australia.

"Many thanks for the invitation and the meeting. It was really very interesting and the atmosphere was so friendly! I really appreciated the desire of everybody to explain and share what were his or her mathematics and questions. That was definitely great and it was a success for the organisers!"

Prof. Clotilde Fermanian, Université Paris Est, France

Organisers

Prof. Andrew Hassell, The Australian National University
Dr Jesse Gell-Redman, The University of Melbourne
Asst. Prof. Yaiza Canzani, University of North Carolina, USA
Dr Gabriel Rivière, University of Lille, France

Special Presenters

Prof. Andras Vasy, Stanford University, USA
Research Interests: PDEs, microlocal analysis, geometric scattering theory
Dr Peter Hintz, University of California, Berkeley, USA
Research Interests: mathematical physics, PDEs, microlocal analysis
Dr Frédéric Faure, Université de Grenoble, France
Research Interests: dynamic systems, semiclassical analysis, quantum chaos, mathematical physics
Dr Colin Guillarmou, Université Paris-Sud, France
Research Interests: PDE, differential geometry, spectral theory
Prof. Clotilde Fermanian, Université Paris Est, France
Research Interests: PDE, spectral theory, mathematical physics
Assoc. Prof. Katya Krupchyk, University of California, Irvine, USA
Research Interests: inverse problems, spectral theory and harmonic analysis

MathSciNet Classification

35 Partial Differential Equations 58

Web Links

maths.anu.edu.au/events/workshop-microlocal-analysis

Other Sponsors

Mathematical Sciences Institute, ANU, AustMS

Key Contact

Prof. Andrew Hassell, The Australian National University, andrew.hassell@anu.edu.au

WORKSHOP PARTICIPATION

39 Attendees
5 Postgraduate students
4 Early career researchers
11 Women
30 International participants

1.20 TOPOLOGY IN AUSTRALIA AND SOUTH KOREA 2018

Institute for Basic Science, Pohang, South Korea, 23–27 April 2018

The second of this now-annual lecture series, this meeting showcased recent and emerging areas of algebraic topology while providing a critical springboard for deeper collaboration between Australian and South Korean research leaders.

A central topic within mathematics—algebraic topology has played a major role in solving some of the most compelling problems within mathematics, physics and related areas. Fields medallists who have expanded understanding of the field include Atiyah, Grothendieck, Milnor, Quillen, Serre and Veovodesky. While considered pure research, combinatorial algebraic topology has notable applications within data science (persistent homology) and in neuroscience (neurotopology) a speciality of invited speaker Kathryn Hess.

Rapidly growing in Australia and the Asia-Pacific region, the field has benefited from a spate of recent appointments in Canberra, Melbourne and Sydney and the attraction of young algebraic topologists to Australia. Recruitments in closely related areas have also been made in Korea and Japan. This event provided an ideal opportunity to leverage its current popularity and bolster Australian-Korean research efforts.

The program featured two components or "mini-courses", each given as a series of three lectures on topics of current interest. The first series featured Professor Kathryn Hess, a leading figure in algebraic topology and applied topology. Professor Hess works with the Blue Brain Project studying the shape of the brain, has been profiled in many high-level publications and has given a TedX talk on her work.

The second invited lecturer was Professor Dominic Verity, a well-regarded category theorist and computer scientist. Professor Verity is an expert in the synthetic approach to homotopy theory, building model-independent formalism for modern topologists.

The mini-course lectures were interspersed with 14 contributed talks from conference participants. Each Australia speaker was paired with a mathematical "twin" from the Asia-Pacific region, in hopes of fostering collaboration.

Two aspects of topology were featured in talks during the workshop. The first was foundational algebraic topology and category theory—a well-known strength of Australian mathematics. The second was low dimensional topology, specifically knot theory as represented by speakers Associate Professor Jessica Purcell (Monash University), Dr Benjamin Burton (The University of Queensland) and Dr Joan Licata (The Australian National University).

WORKSHOP PARTICIPATION

46	Attendees
4	Postgraduate students
6	Early career researchers
15	Women
36	International participants

Organisers

Dr Gabriel C. Drummond-Cole, IBS Center for Geometry and Physics, Korea
Dr Philip Hackney, Macquarie University
Dr Marcy Robertson, The University of Melbourne

Special Presenters

Prof. Kathryn Hess, École Polytechnique Fédérale de Lausanne, Switzerland
Research Interests: homotopy theory, category theory, algebraic topology, neurotopology
Prof. Dominic Verity, Macquarie University
Research Interests: higher category theory, homotopy theory, algebraic topology, bicategories and 2-categories, quasi-categories and complicial sets, applications to mathematical physics and computer science

MathSciNet Classification

55 Algebraic Topology, 18 Category Theory; Homological Algebra

Web Links

cgp.ibs.re.kr/conferences/Topology_in_Australia_and_South_Korea/

Other Sponsors

IBS Korea (Institute of Basic Science)

Key Contact

Dr Marcy Robertson, The University of Melbourne, marcy.robertson@unimelb.edu.au

1.21 INDEX THEORY AND APPLICATIONS TO POSITIVE SCALAR CURVATURE AND RELATED AREAS

The University of Adelaide, 4–8 June 2018

Setting the agenda for future research directions in index theory, this conference brought together current field leaders to discuss recent developments and inspire the next generation of mathematicians.

Bridging topology, geometry and analysis, index theory is a highly active area of research. There is particular interest in its application to determining obstructions to, and existence of, positive scalar curvature metrics on Riemannian manifolds. A subject of broad geometric interest among mathematicians, the topic has significant links to cutting-edge physics via the notion of positive mass.

WORKSHOP PARTICIPATION

37	Attendees
11	Postgraduate students
6	Early career researchers
7	Women
14	International participants

Among those in attendance were a number of very distinguished Australian and international research leaders, all of whom have made fundamental contributions to the field over the course of their careers. Their presence at the workshop led to powerful discussion, stimulating new collaborations and aiding the development of new directions in the field. Talks focused on front-line approaches to index theory and its applications to questions of current interest in geometry, including determining obstructions to and existence of positive scalar metrics on Riemannian manifolds, with key tools from topology, operator algebras, K-theory, end-periodic theory, microlocal analysis and higher spectral flow. Some of the highlights among the invited talks included:

- Professor Jonathan Rosenberg, who co-enunciated the famous Gromov-Lawson-Rosenberg Conjecture, which has been a guiding principle in the subject for over thirty years. He spoke on a novel approach to the concordance conjecture for positive scalar curvature, involving the study of stratified manifolds.
- Professor Nigel Higson, another pioneer in the field who has made ubiquitous contributions to index theory and related areas, notably through the use of operator algebras and K-theory. He discussed the equivariant index theory of Dirac operators from the point of view of representation theory. Set against the backdrop of long-established links between Harish-Chandra's parametrisation of the discrete series representations and the Dirac operator, he discussed a new point of view of the theory, more closely aligned with Harish-Chandra's original work on orbital integrals.
- Professor Weiping Zhang shared his ground-breaking results on positive scalar curvature along the leaves of a foliation, extending the classical result of Gromov and Lawson on enlargeable closed spin manifolds to the setting of foliated manifolds, and in particular giving a new proof that there is no foliation of positive leafwise scalar curvature on any torus.

Other key presenters included Professor Jozef Dodziuk, who spoke about improved estimates on the important construction of positive scalar curvature metrics by Gromov and Lawson, and independently Schoen and Yau; Professor Stanley Chang who discussed the parallels between positive scalar curvature and the rigidity of manifolds; and Professor Nikolai Saveliev who presented recent work on invariants of 4-manifolds with certain homology groups, in particular expressing the Seiberg-Witten invariant of such manifolds in terms of monopole Floer homology.

The workshop was a great opportunity to showcase the work of leading Australian mathematicians and to stimulate continued national progress interest in this area. It was also a valuable chance for early career Australian researchers to interact with current leaders in the field, discuss and share their research, and be inspired to further excellence. Many new international connections and collaborations were formed between the participants, benefitting the field over the longer term.

The opportunity to present their research proved a highlight for students at the workshop with best talk taking home the Elsevier Young Researcher Award. Beating out a strong field, this year's US$750 award was won by Michael Hallam, a Master of Philosophy student at the University of Adelaide.

"Great talks, excellent line up of high level speakers and talented younger ones."

Dr Peter Hochs, The University of Adelaide

Organisers

Elder Prof. Mathai Varghese, The University of Adelaide
Hao Guo, The University of Adelaide
Dr Jesse Gell-Redman, The University of Melbourne
Assoc. Prof. Diarmuid Crowley, The University of Melbourne

Special Presenters

Prof. Stanley Chang, Wellesley College, USA
Research Interests: positive scalar curvature and rigidity of manifolds, noncommutative geometry, tools of surgery theory
Prof. Xianzhe Dai, University of California, Santa Barbara, USA
Research Interests: differential geometry, geometric analysis
Prof. Jozef Dodziuk, City University of New York, USA
Research Interests: relations between analysis, topology, and geometry for manifolds, cell complexes, and graphs
Assoc. Prof. Fei Han, National University of Singapore
Research Interests: differential geometry, topology, mathematical physics
Dr Pedram Hekmati, University of Auckland, NZ
Research Interests: Gerbes and twisted K-theory, gauge theoretic moduli spaces and character varieties, vertex operator algebras, generalised geometry, geometric correspondences
Prof. Nigel Higson, Pennsylvania State University, USA
Research Interests: noncommutative geometry, operator algebra, K-theory
Dr Heather Macbeth, Massachusetts Institute of Technology, USA
Research Interests: Kähler geometry, geometric analysis
Prof. Jonathan Rosenberg, University of Maryland, USA
Research Interests: geometry, topology, mathematical physics
Prof. Nikolei Saveliev, University of Miami, USA
Research Interests: geometry, topology
Dr Melissa Tacy, University of Otago, NZ
Research Interests: microlocal analysis, semiclassical analysis, harmonic analysis, quantum chaos
Dr Huijun Yang, Henan University, China
Research Interests: geometry, topology
Prof. Weiping Zhang, Chern Institute of Mathematics, Nankai University, China
Research Interests: Atiyah-Singer index theory and its applications

MathSciNet Classification

53C27, 19K56, 19K35

Web Links

iga.adelaide.edu.au/workshops/IndexTheory2018/

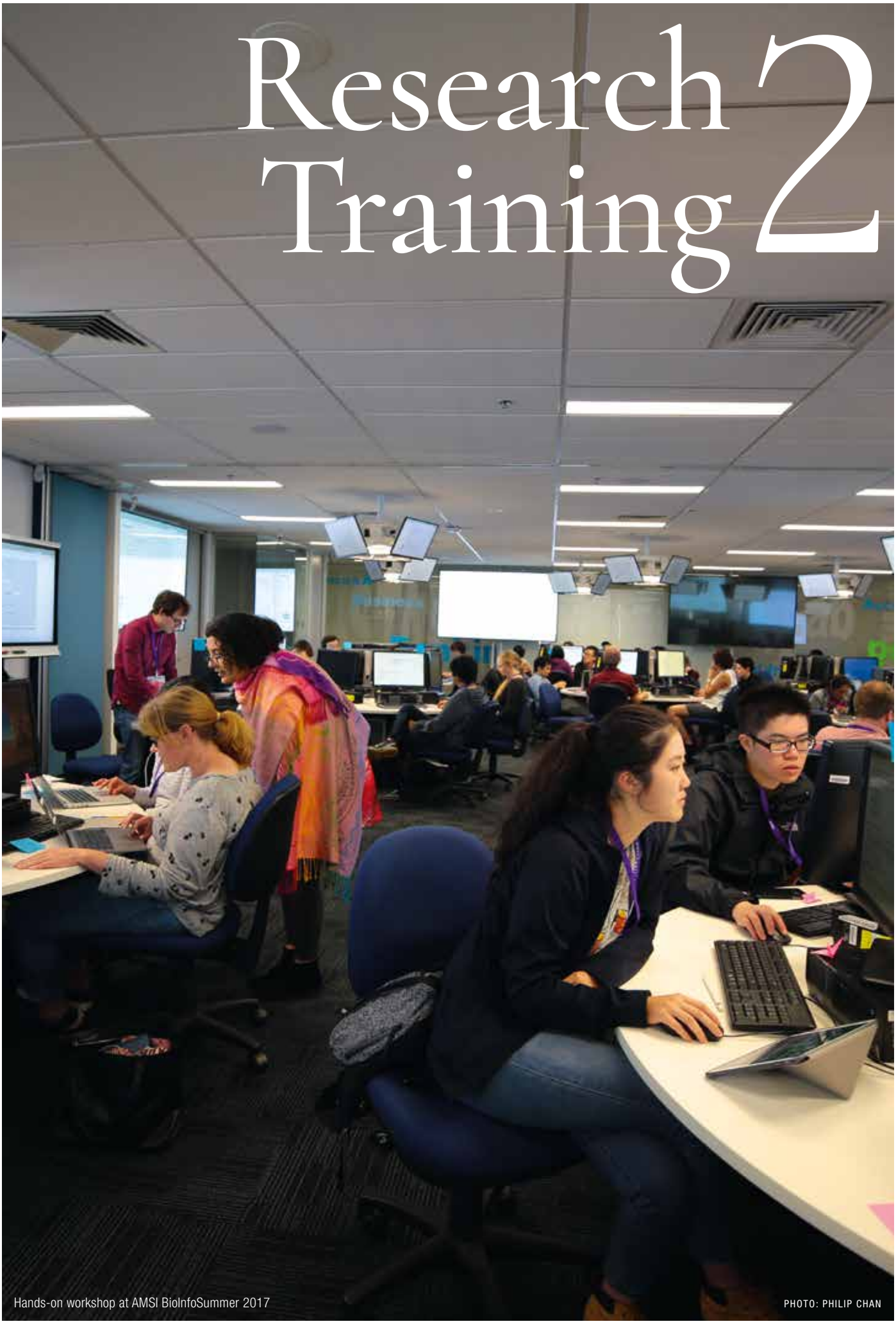
Other Sponsors

Institute for Geometry and its Applications, AustMS, Australian Research Council

Key Contact

Elder Prof. Mathai Varghese, The University of Adelaide, mathai.varghese@adelaide.edu.au

Research Training 2



Hands-on workshop at AMSI BioInfoSummer 2017

PHOTO: PHILIP CHAN

2 RESEARCH TRAINING

Since 2003, AMSI's Higher Education program has enhanced 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 550 students and researchers, more than 40 per cent of them women.

551 attendees at AMSI flagship programs
- **41%** female participants
- **24%** undergraduate students
- **49%** postgraduate students
- **6%** early career researchers

98 lecturers and speakers at flagship events
- **35%** women
- **9%** international

83 students received AMSI Travel Grants

40 female students received Choose Maths Grants

2.1 AMSI WINTER SCHOOL 2017 ON COMPUTATIONAL FOUNDATIONS OF DATA SCIENCE

Queensland University of Technology, 26 June – 7 July 2017

Aimed at developing the next generation of mathematical scientists, AMSI's popular Winter School is a two-week residential training program for graduate students, postdoctoral fellows and early career researchers. Prominent international and Australian mathematicians present a program featuring a range of short courses exploring an overarching theme. Rounding out the program are guest public lectures and sessions on women in maths, as well as social and networking events.

Held for the first time at Queensland University of Technology, the 12th annual AMSI Winter School explored the computational foundations of data science. Aimed primarily at postgraduate students and postdoctoral fellows in the mathematical sciences and related disciplines, the courses expanded on traditional academic program content to expose participants to new skillsets and areas of research. The 2017 program attracted considerable attention as a result of the topical and popular theme of data science.

Over the two weeks of the Winter School program, 70 students and early career researchers from 17 Australian universities, as well as government agencies and departments, and industry, participated in a series of mini-courses, introductory and specialist lectures and workshop sessions.

A lively program of extracurricular activities accompanied the academic program, ranging from participation in the QUT Vice Chancellor's Forum, presented by Fields Medallist Sir Timothy Gowers (University of Cambridge) to both formal and informal social evenings promoting networking between students and lecturers.

In a program highlight, Dr Peter May (Head of Research at the Bureau of Meteorology) led a highly engaging public lecture on the quiet revolution in weather forecasting over the past few decades driven by big computers, big data and lots of maths. The popular event was attended by 120 people, and received national and international media coverage.

The ever-popular Women in Maths networking event hosted by AMSI and WIMSIG attracted more than 70 guests including both Winter School attendees and invited academic guests. Panellists included Amy Hawke from Brisbane State High School and Olivia Hutchinson from Boeing Defence Australia (both QUT alumnae), Professor Kerrie Mengersen from QUT and ACEMS, and Dr Linda Stals (AMSI Winter School 2017 Lecturer from ANU). The event stimulated a lively discussion on current issues facing women in mathematics and their contributions to the field. Another event focused on women in maths was the Choose Maths networking dinner, which highlighted the work of AMSI's Choose Maths project.

WS.AMSI.ORG.AU

Director: **Professor Ian Turner**, Queensland University of Technology

EVENT PARTICIPATION

70 Attendees
33% Female participants
2% Undergraduate students
83% Postgraduate students
7% Early career researchers

PROGRAMS

6 Themes
8 Lecturers
2 Female speakers
3 International speakers

PARTICIPATION SUPPORT

21 Students from **12** member universities received AMSI Travel Grants
6 female attendees from **5** member universities received Choose Maths Grants

"The lecturers at the 2017 AMSI Winter School were world-class. The data science focus was rigorous and the methods were well explored, especially the sampling and optimisation algorithms. Lecturers were accommodating, patient and interested."

Laurence Davies, Geoscience Australia

Hon Karen Andrews MP speaking at the opening of the AMSI Winter School

PHOTO: PATRICK HAMILTON

"The Winter School was an experience I shall cherish forever. The course content highlighted the importance of mathematics and statistics in data science and also broke down abstract concepts into simpler ones. Networking with participants from diverse academic backgrounds and industry experience gave me a valuable insight."

Indraneel Yeole, student, The University of Queensland

Professor Ian Turner PHOTO: PATRICK HAMILTON

Student Presentations

A highlight of the program was the Participant Talks, with all 70 students presenting their research. Participants were broken up into groups of six with one participant in each group selected as the group captain to collate information and keep time. Each student gave a 15-minute talk on the area of their research and was allowed five minutes for questions. After participants had voted on the talks and a robust discussion had been held on the best method to determine the finalists, eight participants presented to the whole cohort for a chance to win the prize.

The winner was **Elizabeth Qian**, one of two students attending from Massachusetts Institute of Technology (USA), who gave an outstanding presentation on *Multifidelity Global Sensitivity Analysis*.

Other Sponsors

Department of Education and Training; Queensland University of Technology; Queensland Cyber Infrastructure Foundation (QCIF); the Australian Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS); The Simulation Group; Silicon Graphics International Corp (SGI); Department of Defence – Australian Signals Directorate (ASD), Data Science and Engineering; BHP Foundation (part of the Choose Maths project)

WINTER SCHOOL CONFIRMS INDUSTRY AMBITION

La Trobe University student and AMSI Winter School 2017 participant Marzieh Moghadam is well aware of the commercial value of mathematics, particularly within the biomedical sector.

Currently completing a PhD, she is focusing her research on machine learning and deep learning approaches to optimise cell recognition accuracy. In an area of increasing focus to researchers grappling with large volumes of data, this work is maximising capacity to apply this critical information.

Rapidly identifying and accurately tracking cancer cell types to improve diagnostics and test treatment effectiveness, Marzieh's work also plays a role in managing immune diseases.

"My work has a range of applications including cancer and immune disease. The ability to track the immune system, for example, means we can check the trend of immune cells in patients with conditions such as HIV," she says.

With her specialist expertise of significant value to commercial laboratories, Marzieh plans to pursue an industry career and mentor others.

"In 10 years I see myself as a high-level industry researcher mentoring new employees at all levels," she says.

AMSI Winter School 2017, one of Australia's leading residential postgraduate training schools, gave her a taste of why such role models matter for those laying the foundations for a research career, in particular women.

"This is a male-dominated field, it was great to have interactions with other women and build additional networks," she said.

Not just about networking, the annual training school also proved the ideal platform for Marzieh to immerse herself in new areas of her field and to exchange ideas.

"Exposure to so many relevant subjects in a timely, super-efficient way was so beneficial. I also enjoyed exchanging ideas during the machine learning sessions. I was able to give advice and share approaches from my own research"

Marzieh, whose interest in maths started when she was a child and grew in high school, believes that Australia has work to do on its mathematical pipeline.

"It is essential that Australia strengthen mathematics, particularly research linkages to industry," she says.

For now, Marzieh has her sights on an APR.Intern placement, something she sees as essential to her entry into commercial research.

"Next year I hope to complete an APR internship as part of the final year of my PhD. I am really keen to do this, as I think it is an essential way to better understand industry careers and how to achieve [them]," she says.

Marzieh Moghadam received a Choose Maths Grant to attend AMSI's 2017 Winter School

Amy Hawke speaking at the AMSI Winter School's Women in Maths networking event PHOTO: PATRICK HAMILTON

COURSE DETAILS

Theme 1: Inverse Problems

Bayesian Approaches for Inverse Problems and Optimal Experimental Design

***Assoc. Prof. Youssef Marzouk**, Massachusetts Institute of Technology, USA*

Inverse problems formalise the process of learning about a system through indirect, noisy and often incomplete observations. Casting inverse problems in the Bayesian statistical framework provides a natural framework for quantifying uncertainty in parameter values and model predictions, for fusing heterogeneous sources of information, and for optimally selecting experiments or observations.

This course presented fundamentals of the Bayesian approach to inverse problems, covering both modelling issues—e.g. prior distributions, likelihoods, hierarchical models—and computational challenges—e.g. computing posterior expectations via Markov chain Monte Carlo sampling or principled approximations. Participants discussed methods that expose low-dimensional structure in inverse problems, that attempt to mitigate the computational cost of repeated forward model evaluations, and that exhibit discretisation-invariant performance in large-scale problems.

Also presented were Bayesian approaches to optimal experimental design, which attempted to answer ubiquitous questions of what or where to measure, which experimental conditions to employ, etc. Here they introduced a decision theoretic Bayesian design formulation and linked it to more classical alphabetic optimality criteria, then focused on computational issues, e.g. how to estimate and maximise expected information gain in various quantities of interest.

Theme 2: Bayesian Inference & Data Assimilation

Computational Algorithms for Bayesian Statistics

***Dr Chris Drovandi**, School of Mathematics, Queensland University of Technology*

Statistical inferences in a Bayesian framework are obtained through the posterior distribution, which quantifies the uncertainty in model parameters based on information from observed data and prior knowledge. To make these inferences it is often necessary to generate samples from the posterior distribution, but this can generally not be done perfectly. AMSI Winter School 2017 participants had already been introduced to one of the foundational methods, Markov chain Monte Carlo (MCMC), for approximate sampling from the posterior. This part of the Winter School described some more advanced MCMC methods that are more efficient when the posterior distribution has a complex landscape to traverse. An alternative and complementary method to MCMC called sequential Monte Carlo (SMC) was also covered. SMC methods are easier to adapt than MCMC, are more suitable to implementation on parallel computing devices and can straightforwardly estimate quantities required to compare models in a Bayesian framework. The methods were illustrated with MATLAB code.

Data Assimilation: A Mathematical Introduction

***Dr Kody Law**, Oak Ridge National Laboratory, USA*

These lectures provided a systematic treatment of the mathematical underpinnings of work in data assimilation, covering both theoretical and computational approaches. Specifically, participants developed a unified mathematical framework in which a Bayesian formulation of the problem provides the bedrock for the derivation, development and analysis of algorithms. Explicit calculations, numerical examples, exercises and MATLAB code were provided in order to illustrate the theory. The lectures also included an introduction to some state-of-the-art algorithms.

Theme 3: Numerical Linear Algebra

Large-Scale Matrix Problems

***Dr Linda Stals**, Mathematical Sciences Institute, Australian National University*

What do data compression and image recognition have in common? How does different soil composition affect the flow of a liquid? How much water can the dam hold before it bursts? The common tool needed to address these problems and countless more arising in industry and academia is the solution of large-scale matrix problems. Some estimates say that 70 per cent of supercomputer time is spent on the solution of such large problems.

The techniques that we are most familiar with cannot be applied to these large systems. For example, suppose it takes 1 second to solve

Dr Linda Stals' course on Large Scale Matrix Problems PHOTO: PATRICK HAMILTON

a 100 x 100 sized matrix using Gaussian Elimination, then a quick analysis based on the number of operations implies that it would take about 11.5 days to solve a 10,000 x 10,000 sized matrix.

In this course, participants were introduced to new solution techniques to deal with these large-scale problems. They focused on the solution of linear systems of equations using iterative methods. They were introduced to the nomenclature used to measure the efficiency and accuracy of these methods. They also defined and developed the theoretical properties of the algorithms and then determined their practical use by studying their stability.

Theme 4: Machine Learning

A Decision-Making View of Machine Learning

***Dr Hanna Kurniawati**, School of Information Technology and Electrical Engineering, The University of Queensland*

This course covered recent advances in decision-making under uncertainty and its application to machine learning, in particular reinforcement learning. Participants were provided with an overview of current work on Markov decision processes (MDPs), partially observable Markov decision processes (POMDPs) and Bayesian reinforcement learning. They focused on both basic concepts and state-of-the-art algorithms and computational techniques that made these approaches become practical. This course also included a hands-on demo using available software tools.

Martingales, Mcdiarmid and Machine Learning: How to Validate Models like a Pro!

***Dr Brendan van Rooyen**, ACEMS, Queensland University of Technology*

In this course, participants explored the underlying mathematics of model validation, where they laid bare the underlying assumptions underpinning learning. They were provided with an introduction to concentration inequalities, martingales and found out what Colin Mcdiarmid has to do with machine learning.

Not limited to machine learning model validation, concentration inequalities have broader application across computer science and mathematics, where they facilitate a powerful set of tools for creating efficient algorithms.

Theme 5: Nonlinear Optimisation

Optimisation Techniques for Data Analysis

***Professor Stephen Wright**, University of Wisconsin-Madison, USA*

Optimisation techniques have become a mainstay of data analysis and machine learning. Many problems in these domains can be formulated and solved naturally as optimisation problems. The explosion of interest in data applications has led to renewed focus on optimisation techniques that are relevant to this area, and thus to re-examination and enhancement of many techniques that were in some cases previously thought to be of limited interest. Many important discoveries have been made over the past five to eight years about the properties of such fundamental approaches as first-order methods, accelerated gradient, stochastic gradient, coordinate descent and augmented Lagrangian techniques. Advances have been made too in the sophisticated implementation of these techniques to key problems in data analysis, and in their parallel implementation. This course reviewed basic optimisation techniques, their application in data analysis problems, and their fundamental theoretical properties.

Theme 6: High-Dimensional Statistics

Model Selection and Inference for High-Dimensional Data

***Dr Davide Ferrari**, School of Mathematics and Statistics, The University of Melbourne*

Modern data sets are increasingly large and complex due to the rapid development of data acquisition and storage capabilities. This course focused on developing a rigorous understanding of modern statistical learning methods needed to model large data sets, assess the reliability of the selected models, and obtain accurate predictions. This course covered recent methodological developments in this area such as inference for high-dimensional regression, model-selection and model-combining methods, and post-selection inference methods.

2.2 AMSI BIOINFOSUMMER 2017

Monash University, 4–8 December 2017

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 field utilising mathematical and computational methods to analyse and simulate the structures and processes of biological systems. It is a constantly evolving field that offers researchers and students a wide breadth of opportunities.

Almost 180 researchers and students from diverse scientific backgrounds gathered for the five-day BioInfoSummer program to increase their knowledge and skills in this truly interdisciplinary field. The 2017 program commenced with an introduction to bioinformatics on Day One followed by four days of specialised content focused on visualisation, modelling and analysis, RNA-seq, proteomics and metabolomics and single-cell genomics.

Once again, the hands-on workshops proved popular, with sessions on Python programming, visualisation in Python, RNA-seq analysis, and metabolomics analysis at capacity before the week even began. Feedback from participants emphasised the value of these sessions.

Highlights included the public lecture by Professor John Mattick (Garvan Institute of Medical Research) on *Genomics, big data and the future of medical research and healthcare*, which attracted a wide audience and generated much interesting discussion. The COMBINE Careers Panel showcased career opportunities in bioinformatics and provided advice on skills development, while the Diversity in STEM lunch encouraged participants to think about the importance of diversity in bioinformatics and the wider mathematical sciences community.

"The speaker line-up was sensational"

Nick Wong, Monash University

BIS.AMSI.ORG.AU

Director: **Assoc. Prof. David Powell**, Monash University

EVENT PARTICIPATION

178 Attendees
51% Female participants
14% Undergraduate students
47% Postgraduate students
7% Early career researchers

PROGRAMS

32 Lecturers and workshop presenters
15 Female speakers
3 International speakers

PARTICIPATION SUPPORT

9 Students and ECRs from **6** member universities received AMSI Travel Grants
12 Female attendees from **10** member universities received Choose Maths Grants

THE MATHEMATICS OF ECHIDNAS

University of Adelaide PhD student and BioInfoSummer (BIS) 2017 attendee Tahlia Perry is on a mission to help save Australia's beloved echidnas. Analysing and manipulating large datasets and using complex mathematical models, she hopes to identify and compare reproductive genes being turned off and on in both adult and juvenile echidnas.

"By identifying these genes, I can piece together the pathways that become active and control their reproduction and development," she says.

With some echidna populations now endangered, these insights into their reproductive biology are essential, and can lead to aiding the success of Australian breeding programs.

Eager to expand her knowledge and share her PhD research, Tahlia was excited when she found out about the opportunities at leading Australian postgraduate bioinformatics training school, BIS. With this year's event at Monash University in Melbourne, travel and accommodation costs threatened to put the brakes on her attendance. Thanks to the assistance of a Choose Maths Grant, she was able to make her BIS dream a reality.

Providing a rare glimpse into the breadth of her field that reframed approaches to her own research, the event was a rare opportunity for Tahlia to network and build her research profile.

"BIS was immensely helpful in giving direction to my research and confirming I am on the right track with my analyses. It also gave me a new-found perspective of how varied the field is and an appreciation of how maths really is everywhere in various forms," she says.

"Coming from interstate, this grant was incredibly important to assist with both travel and accommodation so I could fully attend BioInfoSummer 2017"

Having come close to not being able to attend, Tahlia was determined to get the most from the event and her grant. This included sharing her work in a poster submission that took out top honours.

"Having this opportunity to share my research and winning Best Poster was a confidence boost and confirmation I am heading in the right direction with both my research and communication skills," says Tahlia.

As she applies her new knowledge and confidence to her research, all signs point to a big win for some seriously cute and precious Australians.

Tahlia Perry received a Choose Maths Grant to attend AMSI's BioInfoSummer in 2017

Best Poster

This year's poster competition attracted 13 entries from event participants. The winners were:

Edward Kerr, The University of Queensland, *A proteomic approach to understand protein abundance and modifications in beer brewing*

Tahlia Perry, The University of Adelaide, *First Differential Gene Expression Analysis between Juvenile and Adult Echidnas*

Other Sponsors

Department of Education and Training, Monash University, BHP Foundation (part of the Choose Maths project), ABACBS, Maxima

"I enjoyed the hands-on workshops and introductions to modern techniques, like the single-cell talks… The workshop content will be immediately useful at my work and in my studies."

Samuel Gardiner, Macquarie University

Conference Speakers

Speaker	Talk Title	Organisation
Dr Mirana Ramialison	I've got my list of differentially expressed genes, now what?	Australian Regenerative Medicine Institute, Monash University
Assoc. Prof. Jose Polo	Exploring the boundaries of transcription factor-mediated reprogramming	Australian Regenerative Medicine Institute, Monash University
Prof. Christine Wells	The molecular atlas—transcriptomes from tissues to single cells.	Centre for Stem Cell Systems, The University of Melbourne
Prof. Steve Rozen	Computational analysis of mutations in tumours reveals unexpected carcinogenic exposures	Duke-NUS Medical School, Singapore
Beth Signal	Machine learning in genetics	Garvan Institute of Medical Research
Dr Mark Cowley	Translating genomics to the clinic for rare and advanced cancers	Garvan Institute of Medical Research
Dr Michael Lawrence	An introduction to bioconductor	Genentech, USA
Dr Joseph Powell	Using ultra high-throughput single cell sequencing to understanding cellular heterogeneity	Institute for Molecular Bioscience, The University of Queensland
Dr Saravanan Dayalan	Metabolomics bioinformatics—current state and future challenges	Metabolomics Australia, The University of Melbourne
Dr Mark Flegg	The people that paved the way for biological insight through mathematics	Monash University
Prof. Dianne Cook	"How do you see if you don't see": using randomisation with plots to explore 'omics data	Monash University
Prof. John Bowman	Lessons from the Marchantia genome	Monash University
Dr Lan Nguyen	Identification of effective combinatorial therapies for cancer using integrated pathway modelling	Monash University
Assoc. Prof. Alicia Oshlack	Designing and analysing single-cell RNA sequencing experiments	Murdoch Children's Research Institute
Dr Nicola Armstrong	Statistics in biology	Murdoch University
Dr Ralf Schittenhelm	Mass spectrometry, proteomics and more	Proteomics Platform, Monash University
Dr Ann-Marie Patch	Detecting somatic variants in cancers using whole genome sequencing	QIMR Berghofer Medical Research Institute
Dr Jeff Christiansen	Data driven science in biology: a brief view into the many resources available to help you	Queensland Cyber Infrastructure Foundation and The University of Queensland
Dr Sriganesh Srihari	An introduction of molecular network analysis	South Australian Health and Medical Research Institute
Assoc. Prof. Andrew Lonie	Developing national bioinformatics infrastructure	The University of Melbourne, Melbourne Bioinformatics & EMBL- Australia Bioinformatics Resource
Dr Tallulah Andrews	From cell-type to function using single-cell RNA sequencing	The Wellcome Trust Sanger Institute, UK
Dr Tamara Heck	Open Science—one goal, many perspectives	University of Southern Queensland
Dr Sebastian Lunke	Translating research: how is it done, why is it important, and what are the impacts?	Victorian Clinical Genetics Services
Dr Melissa Davis	Introduction to pathway and network analysis	Walter & Eliza Hall Institute of Medical Research
Dr Saskia Freytag	Bioinformatics, the honest trailer	Walter & Eliza Hall Institute of Medical Research
Prof. Gordon Smyth	Statistical analysis of RNA-seq data: from reads to genes to pathways	Walter & Eliza Hall Institute of Medical Research
Prof. Melanie Bahlo	Bioinformatics: just pipelines, isn't it?	Walter & Eliza Hall Institute of Medical Research

Workshops

Workshop leader	Workshop Title	Organisation
Dr Claire Sloggett	Data visualisation with Python and the Jupyter Notebook	Melbourne Bioinformatics
Dr Stuart Archer	RNAseq via GVL+ degust demo	Monash University
Dr Andrew Perry	Introduction to Python programming	Monash University
Dr Alysha De Livera & Dr Kaushala Jayawardana	Introduction to statistical analysis of metabolomics data	The University of Melbourne, Baker Heart & Diabetes Institute

2.3 AMSI SUMMER SCHOOL 2018

Monash University, 8 January – 2 February 2018

Hosted over four weeks, 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, providing 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 with their research career.

The 16th Annual AMSI Summer School brought together 168 honours and postgraduate students from around the country for an intensive four-week residential program. Students had the opportunity to tackle one or two of the eight honours-level pure and applied mathematics, statistics and cognate subjects on offer, with the option to take one course for credit, completing assessment tasks including a final examination. Students also benefited from enrichment lectures, social events, a careers afternoon and other special events.

Drawing an audience of 120, Professor Nick Trefethen FRS (University of Oxford, UK) delivered a public lecture on *Discrete or Continuous*? This exploration of the mathematical and scientific world was followed by a wide-ranging discussion with the speaker. Professor Trefethen also gave a seminar to the Monash School of Mathematical Sciences, which was attended by about 20 of the summer school participants.

The 16th annual Summer School Careers Afternoon was also extremely popular, providing the rare chance to network with specialists from industry leaders including the Centre for Quantitative Finance (Monash), Australian Signals Directorate, Commonwealth Bank of Australia, AustMS, the Bureau of Meteorology, the Statistical Society of Australia, Australian Bioinformatics and Computational Biology Society (ABACBS), CSIRO's Data61 and GELI, as well as AMSI's APR.Intern program. As well as networking, the session provided insights into career opportunities across the mathematical sciences.

This year's Diversity in STEM panel discussion and lunch also proved popular with both summer school students and external guests, with a lively discussion on barriers hindering diversity in academia. In addition, AMSI's Choose Maths project hosted a networking dinner for female participants and academics.

The four-week program also contained many other opportunities for students and lecturers to socialise and network.

SS.AMSI.ORG.AU

Director: **Dr Simon Clarke,** Monash University

EVENT PARTICIPATION

168 Attendees
82 Attendees taking course for credit
29% Female participants
39% Undergraduate students
53% Postgraduate students
5% Early career researchers

PROGRAM

8 Honours level courses
14 Lecturers
5 Female lecturers

PARTICIPATION SUPPORT

46 Students from **12** member universities received AMSI Travel Grants
16 Female attendees from **10** member universities received Choose Maths Grants

Other Sponsors

Department of Education and Training, Monash University, BHP Foundation (part of the Choose Maths project), AustMS, ANZIAM, SSA, Department of Defence – Australian Signals Directorate, Monash Centre for Quantitative Finance and Investment Strategies, Commonwealth Bank

PHOTO: MATHS AT MONASH

DISCOVERING NEW HORIZONS AT AMSI SUMMER SCHOOL

Perfect preparation for his honours research, AMSI Summer School 2018 gave the University of Adelaide's Michael Sandford an exciting introduction to the emerging field of statistical machine learning.

"The knowledge I gained has served as an excellent basis for my honours project, in which I will be learning and applying complex machine learning techniques such as random forests and boosting to mass spectrometry data," he explains.

One of the big takeaways for Sandford, who hopes to work in industry, is the broad commercial application of statistics. As the data age sets in, career opportunities are only set to grow.

"With an interesting array of speakers from various companies, the careers afternoon solidified my interest in this area, and potentially widened the scope of job opportunities available to me."

Juggling a student income, it was only thanks to the support of an AMSI Travel Grant that Sandford was able to attend the Melbourne-based event.

"Without a Travel Grant I likely wouldn't have attended the AMSI Summer school despite being interested in the event. It was crucial in supporting me financially," he said.

Financial barriers are a common issue, with such funding key to increasing student attendance at such events. Opportunities, Michael says, are critical to provide students with in-depth field knowledge and networking.

"Travel Grants are an important initiative, since they increase the number of students able to attend useful events like Summer School. Training events particularly useful for students whose home universities aren't equipped to provide training or networking"

Now focused on his honours research and eyeing future opportunities, Sandford is thankful for his recent experience at Monash University's Clayton campus.

"I thoroughly enjoyed AMSI Summer School 2018. It was well organised and executed, and provided me with valuable knowledge, networking and careers information. I'm thankful for the Travel Grant that allowed me to attend."

Michael Sandford received an AMSI Travel Grant to attend AMSI's 2018 Summer School

Course Details

Iterative Methods for Sparse Matrices

***Assoc. Prof. Timothy Moroney**, Queensland University of Technology*

Sparse matrices arise in many applications across science, engineering, statistics, business and beyond. Exploiting the sparsity of these matrices is essential for overcoming the scaling on storage and floating-point calculations that otherwise renders even problems with dimensions in the thousands utterly impractical to solve.

A remarkably versatile family of numerical methods called Krylov subspace methods can be applied to sparse matrix operations, and in doing so requires only having minimal requirements on the means by which a matrix is utilised, paving the way for many of today's high-performance codes. This course covered Krylov subspace methods for three common problems: linear systems, eigenvalue problems and matrix functions, from their derivation through to efficient numerical implementation.

- Arnoldi iteration
- Theory of Arnoldi iteration
- GMRES
- Preconditioning
- Restarting and deflation
- Jacobian free Newton-Krylov methods
- Matrix functions

Low-Dimensional Topology *(Sponsored by AustMS)*

***Dr Daniel Mathews** and **Assoc. Prof. Jessica Purcell**, Monash University*

The study of spaces of dimensions 2, 3, and 4, including the study of surfaces and their symmetries, knots and links, and structures on 3-and 4-manifolds, is an area of active research with deep connections to mathematical fields such as geometry and dynamics and modern applications to microbiology, chemistry and quantum physics. It requires a different set of tools to higher-dimensional topology. This course covered some foundational results of low-dimensional topology, studying surfaces in two dimensions, knots in three dimensions, and some applications in four dimensions.

- Surfaces and their homeomorphisms
- The mapping class group and Dehn twists
- 3-manifolds: Heegaard splittings and Dehn filling
- Decompositions of 3-manifolds
- Knots and knot invariants

Mathematical Relativity and Lorentzian Geometry

***Dr Andy Hammerlindl** and **Assoc. Prof. Todd Oliynyk**, Monash University*

General relativity is currently our most accurate theory of gravity. It applies across a huge range of physical scales describing the motion of small bodies such as satellites orbiting Earth to the dynamics of supermassive black holes and even our universe. General relativity is formulated in the language of differential geometry. This course introduced the differential geometry needed to understand the fundamental concepts and field equations of general relativity.

Continued on page 54

Prof. Kate Smith-Miles at the 16th annual Summer School Careers Afternoon PHOTO: SHARON MCDOWALL

Course Details - *continued*

Applications of the theory to static black holes, the perihelion precession of Mercury's orbit and gravitational waves were discussed.

- Manifolds, manifolds with boundary, smooth maps, submanifolds, partitions of unity
- Tangent vectors and spaces, tangent bundles, tangent maps, vector bundles, vector fields
- Multilinear algebra, tensors, tensor bundle, tensor fields
- Contractions, index manipulation, tensor derivations, Lie derivative
- Metrics, covariant derivatives, Curvature
- Fundamental concepts of mathematical relativity
- Einstein Field equations
- Schwarzschild solution
- Applications: perihelion precession of Mercury's orbit, linearised Einstein equations and gravitational waves

Mathematics of Extensional Flows

(Sponsored by ANZIAM)

***Prof. Yvonne Stokes**, The University of Adelaide*

This course focused on extensional flows having a small geometric parameter or aspect ratio. These are ubiquitous in nature and industry and include honey dripping from a spoon, ink-jet printing, the float-glass process used for making sheet glass, and a spider spinning a web. We considered the work on the so-called 'Trouton viscosity' modelling of the spinning of polymer threads in the late 60s and early 70s, through to modern research particularly relating to the fabrication of optical fibres.

- Trouton models and the Trouton viscosity
- Scaling and asymptotic methods
- The Reynolds transport theorem and the equations of Newtonian fluid flow
- 1D model derivation, neglecting inertia and surface tension
- Lagrangian coordinate systems
- Finite-time 'blowup'
- Drop 'pinch-off'
- Draw stability
- Inclusion of surface tension and the cross-plane problem
- The 'reduced-time' transformation
- Extension of a solid rod
- Extension of an axisymmetric tube

Probability, Complex Analysis and Lattice Models

***Dr Laurie Field**, The Australian National University*

***Dr Gregory Markowsky**, Monash University*

Physicists have long conjectured that many of their discrete models in the plane have conformally invariant scaling limits at criticality. Recent work by mathematicians has shown this to be correct, as well as identifying the natural limiting process of interfaces in many of these models as the Schramm–Loewner evolution (SLE). This theory has led to the rigorous determination of critical exponents such as the Brownian intersection exponents and the Hausdorff dimensions of many random planar fractals.

In the first half of this course, we studied the most important discrete models that exhibit conformal invariance in the scaling limit, and discussed which forms of discrete complex analysis can be used to illuminate these models.

In the second half of the course, we passed to the continuum, where Brownian motion becomes a key tool. By applying Loewner's differential equation to a Brownian motion on the boundary, we obtained the definition of SLE, derived its first important properties, and heuristically explained why it is the scaling limit of interfaces in the models studied in the first half. In addition, a fair amount of necessary complex analysis was developed along the way, with planar Brownian motion being employed as a key tool.

- Simple random walk and its convergence to Brownian motion
- Loop-erased random walk and the uniform spanning tree
- Critical percolation and Smirnov's proof of conformal invariance
- The Ising model and its discrete holomorphic fermions
- Self-avoiding walk and the connective constant on the hexagonal lattice
- Lévy's theorem on the conformal invariance of Brownian motion
- Analytic functions and conformal maps
- The Poisson integral formula and its relation to Brownian motion
- (Non-random) Loewner evolution
- The basics of the Schramm–Loewner evolution and its relation to the discrete physical processes

PHOTO: MATHS AT MONASH

Course Details - *continued*

Probabilistic Methods and Random Graphs

Prof. Nick Wormald *and* ***Dr Jane Gao****, Monash University*

The probabilistic method proves the existence of a mathematical structure by showing a random element in an appropriate probability space has the desired properties with positive probability. This course introduced some basic techniques of the probabilistic method and applications in graph theory and combinatorics. In particular, the probabilistic method gives easy proofs of the existence of some graphs (and other objects) that are very hard to construct explicitly, or not known to exist by other methods. The course also studied random graphs: graphs selected at random from some given probability space, proving some appealing properties of these graphs and demonstrating how they can be incorporated into the probabilistic method.

- Linearity of expectation and alterations
- The second moment method
- Random graph models and properties
- The local lemma
- Martingales and concentration inequalities
- Janson's inequality
- Randomised algorithms and de-randomisation

Statistical Machine Learning *(Sponsored by SSA)*

Dr Ivan Guo *and* ***Dr Tiangang Cui****, Monash University*

Statistical machine learning merges statistics with the computational sciences—computer science, systems science and optimisation. Much of the work in statistical machine learning is driven by applied problems in science and technology, where data streams are increasingly large-scale, dynamic and heterogeneous, and where mathematical and algorithmic creativity is required to bring statistical methodology to bear. The applications include financial modelling, pattern recognition and remote sensing. In this course we studied how to use probability models to analyse data, focusing on the mathematical details of the models and the algorithms for computing them.

- Bayesian inference and parameter estimation
- Regression and classification
- Sampling methods
- Time series filtering

Topological Data Analysis

Dr Vanessa Robins *and* ***Dr Katharine Turner****, The Australian National University*

Topological data analysis (TDA) is an interdisciplinary field combining methods from algebraic topology, statistics and computational algorithms. It quantifies the shape of data over a full range of length scales and, most importantly, captures how that shape changes as the length scale parameter is varied. Its diverse applications include the quantification of bone morphology and porous materials, the connectivity structure of the brain, and time series analysis.

This course covered the relevant background from algebraic topology, to provide a detailed overview of persistent homology (the main tool in TDA) and various approaches to summarising the information provided by persistent homology. Since any data analysis must consider the effect of randomness and of noise we also studied statistical aspects in TDA including stability, correlation and statistical significance tests.

- Introduction to homology
- Filtrations and persistent homology
- Essential algorithms in TDA
- Summaries of persistent homology information
- Statistical aspects of TDA
- Further techniques: Discrete Morse theory, the Reeb graph and Mapper
- Example applications

2.4 AMSI OPTIMISE 2018: DECISION MAKING UNDER UNCERTAINTY & HUMANITARIAN APPLICATIONS

The University of Melbourne, 18–22 June 2018

Now in its second year, AMSI Optimise aims to strengthen mathematical research engagement and its applications across industry. The event exposes industry practitioners, academics and postgraduate students to the current state of the art in optimisation research, and the opportunity to network and develop collaborations.

With an opening address by Biarri co-founder Joe Forbes, Optimise 2018 launched with a business breakfast encouraging networking between the academic, industry and agency participants. This year, Optimise comprised a three-day industry-focused conference followed by a two-day research workshop on the themes of Decision Making Under Uncertainty, as well as Humanitarian Applications of optimisation research.

A mixture of lectures, case studies and panel discussions as well as hands-on sessions ensured that the participants got a wide exposure to a variety of topics in optimisation research, with both academic and industry perspectives.

A highlight was the Women in Optimisation panel, which looked at gender diversity in the optimisation field, and was featured in the media. Chaired by the University of Melbourne's Professor Kate Smith-Miles, the panel included plenary speakers Associate Professor Maria Antónia Carravilla and Associate Professor Marie-Ève Rancourt, as well as optimisation pioneer Alison Harcourt (The University of Melbourne).

A networking session over drinks closed the conference portion of the week and welcomed the workshop participants.

"I think the conference did a good job finding relevant representatives of the OR community, capable of offering a wide variety of topics in a compelling way."

Alvaro Flores, CSIRO/Data61

OPTIMISE.AMSI.ORG.AU

Director: **Dr Alysson Machado Costa**, The University of Melbourne

EVENT PARTICIPATION

- **95** Registered attendees
- **34%** Female participants
- **44%** Undergraduate and postgraduate students
- **6%** Early career researchers
- **14%** Industry/agency participants
- **3%** International participants

PROGRAM

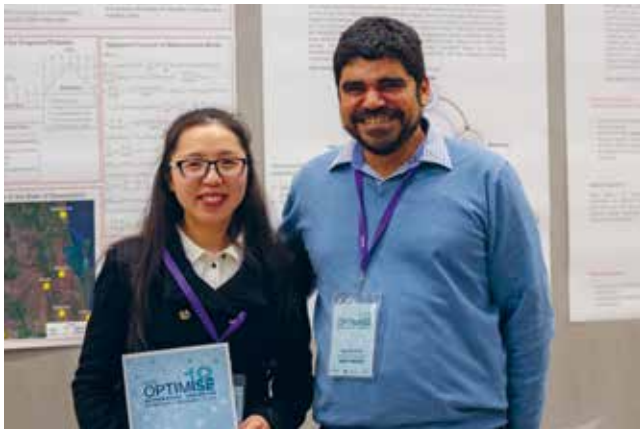
- **38** Speakers/workshop presenters
- **12** Female speakers/workshop presenters
- **3** International speakers/workshop presenters

PARTICIPATION SUPPORT

- **7** Students and ECRs from **5** member universities received AMSI Travel Grants
- **6** Female attendees from **6** member universities received Choose Maths grants

"[Meeting] people from different backgrounds using optimisation for different applications increased my knowledge of the field and gave me many new ideas."

Sofia Chaudry, Murdoch University



Best Poster

A poster session was held on Day 3 of the conference to give participants an opportunity to showcase their research to the audience and build their networks. Each presenter was given a few minutes to provide an overview of their poster to the audience followed by a Q&A session. Nine abstracts were submitted for the poster competition from which attendees voted by an online poll to determine two Best Poster winners:

Dr Minh Dao, The University of Newcastle, *Optimisation Design for Energy-Efficient Downlink Cloud Radio Access Networks*

Cheng Cheng, The University of Melbourne, *Optimisation of Disaster Waste Management Systems*

Other Sponsors

Department of Education and Training, The University of Melbourne, ACEMS, Biarri, APR.Intern, BHP Foundation (as part of the Choose Maths project)

AMSI OPTIMISE: A HAPPY, DYNAMICAL ACCIDENT

University of Newcastle PhD student and AMSI Optimise 2018 attendee Scott Lindstrom fittingly describes his mathematical journey as a "long, hopping sequence of happy, dynamical accidents".

This seems a fitting analogy for a researcher fascinated by dynamical systems that arise from "hopping" methods for solving optimisation problems.

Asked to explain his work, Lindstrom uses the example of a grasshopper only able to see one plate at a time while trying to find the point where two plates overlap.

"A natural strategy is to hop first to the closest point in the first plate and from there to the nearest point of the second plate. This sequence of hops forms what mathematicians call a dynamical system," he explains.

Such dynamical systems (swap plates for restrictions on the solution) are used to solve a wide range of optimisation problems.

Keen to explore these applications, he was drawn to AMSI Optimise. Despite a student income, he was able to attend thanks to an AMSI Travel Grant.

> *"Financial assistance from AMSI enabled me to participate in this event. I think it's very important we continue to keep these types of resources available to future students"*

Events such as AMSI Optimise offer students rare access to industry, established researchers and importantly field leaders.

"I found it very helpful to meet with my collaborators from around Australia and to ask some of my pressing questions to Terry Rockafellar, a leading expert in my field," he says.

With the aim of strengthening ties between academia and industry, the event gives attendees a glimpse of how the pieces of the optimisation puzzle fit together. This opens exciting opportunities for new investigation and collaboration.

"AMSI Optimise brings together a diverse collection of students and [field] experts. I appreciate the opportunity to meet and collaborate with researchers in my own area, and also look for connections to other research areas," says Lindstrom.

While yet to work with industry, Lindstrom hasn't rule out anything for when he returns from a postgraduate position with Hong Kong's Polytechnic University.

"I feel greatly blessed to be part of the Australian optimisation community. In future, I see myself returning to Australia and giving back, in a continuing academic capacity".

Scott Lindstrom received an AMSI Travel Grant to attend AMSI Optimise 2018

Plenary Talks

Speaker	Organisation	Talk Title
Assoc. Prof. Maria Antónia Carravilla	Universidade do Porto, Portugal	OR inside-influence charts (Hands-on session) Women in optimisation (Panel)
Assoc. Prof. Marie-Ève Rancourt	HEC Montréal, Canada	Applied network design problems to support humanitarian operations Tactical network planning for food aid distribution in kenya Women in optimisation (Panel)
Prof. Emeritus R. Tyrrell Rockafellar	University of Washington, USA	Risk and reliability in optimisation under uncertainty-progressive hedging in nonconvex stochastic optimisation

Conference Talks

Speaker	Organisation	Talk Title
Paul Barnard	The University of Melbourne	Disaster management and public safety (Panel)
Craig Brownlie	Country Fire Authority	Burning down stereotypes
Pedro B. Castellucci and Dr Alysson M. Costa	The University of Melbourne	Solving a logistics distribution problem using mixed-integer programming and matheuristics (Hands-on session)
Alan Dormer	Opturion	Plan, react, repeat (Industry challenge)
Dr Simon Dunstall	CSIRO Data61	Optimisation and quantitative risk opportunities in preparedness, mitigation and emergency management
Prof. Greg Foliente	Centre for Disaster Management and Public Safety (CDMPS)	Black swans and perfect storms: challenges in disaster management and resilience research disaster management and public safety (Panel)
Ged Griffin	Victoria Police Force	Critical incidents and next generation public safety Disaster management and public safety (Panel)
Alison Harcourt	The University of Melbourne	Women in optimisation (Panel)
Prof. Gregoire Loeper	Monash University, Centre for Quantitative Finance and Investment Strategies	Reconstruction of missing data by optimal transport: applications in finance
Dr Vicky Mak-Hau	Deakin University	Redesigning medical wards by optimally allocating specialties to minimise outliers (case study)
Dr Gabriela Nodari	Reserve Bank of Australia	Uncertainty and monetary policy in good and bad times
Dr Darryn Reid	Defence Science & Technology Group	Predictability, and its discontents
Prof. Kate Smith-Miles	The University of Melbourne	Optimisation in the darkness of uncertainty: when you don't know what you don't know, and what you do know isn't much! Women in optimisation (Panel)
Steve Tsikaris	Department of Treasury and Finance	Disaster management and public safety (Panel)
David Williams	CDMPS	Disaster management and public safety (Panel)

Workshop Talks

Speaker	Organisation	Workshop Title
Mesias Alfeus	University of Technology Sydney	On numerical methods for spread options
Dr Gleb Belov	Monash University	Process plant layout optimisation: equipment allocation
Dr Geoffrey Brent	Australian Bureau of Statistics	Quantifying expert judgement in an objective function for table-balancing
Assoc. Prof. Regina Burachik	University of South Australia	Sparsity optimisation for a network of coupled oscillators
Pamela Cortez	Universidade Estadual de Feira de Santana, The University of Melbourne	Post-disaster humanitarian logistics
Dr Michelle Dunbar	The University of Sydney	Mathematics in medicine: optimising image acquisition and cancer treatment in radiotherapy
Prof. Andrew Eberhard	RMIT University	A fixed-point operator in discrete optimisation duality
Chaojie (Jasmine) Guo	The University of Melbourne	An algorithm for the network flow problem with multi-transport modes and time window constraints
David Hemmi	Monash University, CSIRO Data61	Recursive evaluate and cut
Arash Kaviani	The University of Melbourne	Optimising the resilience of road networks under uncertainty
Dr Yalçın Kaya	University of South Australia	Optimal control of a UAV in search and rescue operations
Prof. Christopher Kellett	The University of Newcastle	Workshop plenary: optimal control for computing carbon prices
Dr Philip Kilby	CSIRO Data61	Efficient computation of cost allocations for the vehicle routing problem
David Kirszenblat	The University of Melbourne	Using column generation to solve an aircrew training timetabling problem
Assoc. Prof. Alexander Kruger	Federation University Australia	About stability of error bounds
Scott Lindstrom	CARMA, The University of Newcastle	Douglas-Rachford method: a view from strongly quasi-nonexpansive operators
Jose Nicolas Melchor Gutierrez	São Paulo State University and University of Melbourne	A comparison of nonlinear, second order cone and linear programming formulations for the optimal power flow problem
Andrew Perryman	Monash University	Augmented benders' decomposition for synchromodal logistics
Dr Moshe Sniedovich	The University of Melbourne	Decision-making under severe uncertainty: from worst-case analysis to robust optimisation
Dr Belinda Spratt	Queensland University of Technology	Reducing post-surgery recovery occupancy under uncertainty
Dr Nadia Sukhorukova	Swinburne University of Technology and Federation University Australia	Curve clustering using Chebyshev and least squares approximation

PHOTOS: KRYSTLE WESTCOTT

2.5 AMSI VACATION RESEARCH SCHOLARSHIPS

December 2017 – February 2018

AMSI Vacation Research Scholarships provide undergraduate students with the opportunity to spend six weeks at the frontline of their chosen area of the mathematical sciences, developing essential research and communications skills. Rounding out the research experience, the two-day AMSIConnect conference challenges each student to present their research to their peers, while fostering networking and providing information on mathematical career pathways. An inspiring and empowering experience, AMSI Vacation Research Scholarships give students valuable insight into a research future.

More than 40 undergraduate students took part in this year's AMSI Vacation Research Scholarship (VRS) program. Mentored by established researchers at their home university, students took on six-week research projects, submitting a research report at the end of the project.

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

VRS.AMSI.ORG.AU

PROGRAM PARTICIPATION

39* participants completed research projects
*(*2 withdrawals due to external circumstances)*
28% female students
12 member universities participating
3 guest speakers at AMSIConnect

"It was great getting to meet so many like-minded and talented mathematics students. The guest speakers were also really enlightening and the careers talk especially was very useful."

Ruebena Dawes, The University of Sydney

PHOTO: KRYSTLE WESTCOTT

AMSIConnect

8–9 February 2018, The University of Melbourne

Concluding the summer of research, AMSI hosted two-day residential student conference AMSIConnect at the University of Melbourne's International House. Scholars were funded to travel to and stay in Melbourne to participate in this event, viewed as an invaluable professional development experience in 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 project and findings.

Invited speakers included AMSI Director Professor Geoff Prince, who welcomed all of the students and their supervisors to the conference, and gave a closing address sharing his views on the current employment landscape for mathematical sciences graduates and the skillset they would need to grow. He also gave them advice on postgraduate study including applying for and undertaking a PhD.

Nigel Clay took the students on a fascinating journey as he talked about life as a PhD student at RMIT University, while Associate Professor Andrew Robinson of the University of Melbourne's Centre of Excellence for Biosecurity Risk Analysis spoke of the importance of flexibility in creating a successful and fulfilling career in the mathematical sciences.


PHOTO: AMSI

Best Presentation

Tobin South (The University of Adelaide) won the Best Presentation award for his research talk, *Collaborative Network Based Categorisation Models*, in the peer voted competition.
An honourable mention was awarded to **Michael Ucci** (The University of Adelaide) for his presentation, *A Statistical Machine Learning Approach to Identifying Procalcitonin as a Biomarker for Sepsis*.

Web Links

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

Other sponsor

Department of Education and Training

2017 Students and Projects

Student	Supervisor/s	Project Title
THE AUSTRALIAN NATIONAL UNIVERSITY		
Dominique Douglas-Smith	Assoc. Prof. Barry Croke	Nonlinear unit hydrograph models of rainfall-streamflow events for water quality analysis
Edric Wang	Assoc. Prof. Scott Morrison (USYD)	Tensor categories
Jane Tan	Dr Vigleik Angeltviet	Spectral sequences in algebraic topology
LA TROBE UNIVERSITY		
Patrick Adams	Dr Grant Cairns, Dr Yuri Nikolayevsky	Planar graphic sequences
Yao Tang	Dr Grant Cairns, Dr Yuri Nikolayevsky	Algebra and geometry of quandles
MONASH UNIVERSITY		
Asama Qureshi	Dr Yann Bernard, Dr Ting-Ying Chang	Estimating constants in generalised Wente-type estimates
Drew Mitchell	Prof. Hans De Sterck	Numerical optimisation methods for big data analytics
Liam Hernon	Dr Josh Howie, Dr Norman Do	Knots, polynomials and triangulations
Marcus Pensa	Dr Mark Flegg	An inverse modified Helmholtz problem for identifying morphogen sources from sliced biomedical image data
Michael Fotopoulos	Dr Yann Bernard	Functionals of higher-order derivatives of curvature for surfaces
Phillip Luong	Prof. Hans De Sterck, Prof. Grégoire Loeper	Numerical optimisation applied to Monte Carlo algorithms for finance
Robert Hickingbotham	Prof. Andreas Ernst	Splitting integer linear programs with a Lagrangian axe
Sean Malcolm	Dr Norman Do	Parallelogram polyominoes, partitions and polynomials
Tim Banova	Dr Michael Payne	Colouring intersection graphs of complete geometric graphs
QUEENSLAND UNIVERSITY OF TECHNOLOGY		
Jacob Ryan	Prof. Scott McCue	Reaction diffusion models for cell motion
Joel Rutten	Dr Pascal Buenzli, Prof. Matthew Simpson	Patterns in turing patterns: sequential growth and the inhibitory cascade
Steven Kedda	Prof. Fawang Liu	Parameter estimation for the fractional order nonlinear dengue and epidemic models
Tamara Tambyah	Prof. Matthew Simpson	Incorporating Fucci technology in discrete random walk models of collective cell spreading
THE UNIVERSITY OF NEWCASTLE		
Riley Cooper	Dr Hamish Waterer	Lot sizing on a cycle
SWINBURNE UNIVERSITY OF TECHNOLOGY		
Chrishan Christesious Aloysious	Dr Tonghua Zhang	Time delays in modelling the bubble chain system
THE UNIVERSITY OF ADELAIDE		
James Beck	Prof. Patty Solomon	A statistical study to validate the icon-s staging system for a south australian cohort of patients with HPV-positive oropharyngeal squamous cell carcinoma
Michael Ucci	Prof. Patty Solomon, Assoc. Prof. John Moran	Using meta-analysis and statistical learning to identify sepsis biomarkers
Miriam Slattery	Dr Giang Nguyen	Optimal animal foraging in a two-dimensional world
Rose Crocker	Assoc. Prof. Sanjeeva Balasuriya	Extracting coherently moving flow structures from fluid flows
Tobin South	Dr Lewis Mitchell, Prof. Matthew Roughan	Network analysis of the spotify artist collaboration graph
UNIVERSITY OF WESTERN AUSTRALIA		
Vishnu Mangalath	Prof. Lyle Noakes	Simplicial homology and computation from nerves
UNIVERSITY OF WOLLONGONG		
Angus Alexander	Assoc. Prof. Adam Rennie, Prof. Alan Carey	Dirac operators on manifolds and applications to physics
Lachlann O'Donnell	Dr Glen Wheeler	Fully nonlinear curvature flow
Quinn Patterson	Assoc. Prof. Adam Rennie, Prof. Alan Carey	Differential operators on manifolds and positive scalar curvature
THE UNIVERSITY OF MELBOURNE		
Benjamin Metha	Dr Jennifer Flegg	Modelling the spread of malaria and antimalarial drug resistance
Bing Liu	Dr Laleh Tafakori	Forecasting of realised variance measure
Finn McGlade	Dr Yaping Yang, Prof. Arun Ram	Notes on alcove path models and affine springer fibres
Jiangrong Ouyang	Dr Sophie Hautphenne	Stochastic models for populations with a carrying capacity
Tianhe Xie	Prof. David Balding, Dr Jennifer Flegg	The population history of indigenous australians: what can the available genetic data tell us?
THE UNIVERSITY OF SYDNEY		
Leo Jiang	Dr Zsuzsanna Dancso	Niemeier lattices and homological algebra
Ruebena Dawes	Dr Michelle Dunbar	Mathematics in medicine: using optimisation to improve cancer treatment
Syamand Hasam	Assoc. Prof. Uri Keich	The effects of dependency in false discovery estimation using target-decoy competition
Yilun He	Assoc. Prof. Uri Keich, Kristen Emery	Confidence control for false discovery proportion
Yueyi Sun	Prof. Beniamin Goldys	Can we make money using the game theory?

VRS STORIES

For two of this year's VRS students, whose reports and blog posts are featured below, the research project led to a collaboration, and their first published research paper:

Simpson, M.J., Jin, W., Vittadello, S.T., Tambyah, T.A., Ryan, J.M., Gunasingh, G., Haass, N.K., and McCue. S.W. (2018). Stochastic models of cell invasion with fluorescent cell cycle indicators, *Physica A: Statistical Mechanics and its Applications*, 510, 375-386. doi:10.1016/j.physa.2018.06.128

Research report

Each student writes up their research at the end of their project. Links to all reports can be found at vrs.amsi.org.au/projects/

INCORPORATING FUCCI TECHNOLOGY IN DISCRETE RANDOM WALK MODELS OF COLLECTIVE CELL SPREADING

Student: **Tamara Tambyah**, Queensland University of Technology
Supervisor: **Prof. Matthew Simpson**

1. Abstract

Scratch assay experiments are conducted to observe the behaviour of cancerous cells in wound healing and tumour growth scenarios. FUCCI is a new technology which allows the age of melanoma cells to be observed on a scratch assay as different colours. We developed a lattice-based random walk model that incorporates cell migration, cell-to-cell crowding, and we represented various ages of cells within the cell cycle as a series of interacting sub-populations. Numerical simulations were used to explore how the population-level behaviour depends on the individual-level mechanisms. The Gillespie Stochastic Simulation Algorithm was used to incorporate stochasticity into the random walk model by randomly determining the time between events. To provide more formal insight, we applied averaging arguments to produce a series of new continuum reaction diffusion models that can be used to describe experiments performed with FUCCI. An accurate and easily adaptable model was developed that experimentalists can use to model melanoma cell behaviour.

2. Introduction

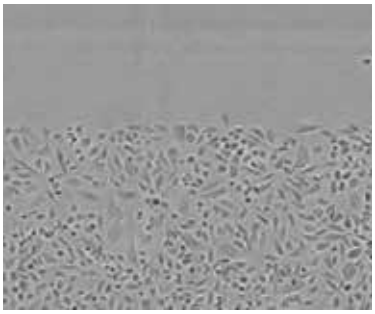
The behaviour of cancerous cells is a widely studied area of biology and has been thoroughly modelled in mathematical biology. Experimentalists observe cell migration and proliferation by conducting a typical scratch assay experiment. Melanoma cells are placed on a petri dish and a scratch is made through the dish to remove some of the cells (Figure 1(a)). Experimentalists then observe over a 5-day period how the cells move to fill the gap and how the number of cells increases due to proliferation. These experiments have the potential to be useful in predicting wound healing and tumour growth.

There exists several discrete and continuous mathematical models which model melanoma cell migration and proliferation. Discrete models take the form of lattice-based or lattice-free random walks. Baker & Simpson investigate a discrete birth-death-movement process for an initially uniformly seeded lattice [4]. The Fisher-Kolmogorov model is a continuous model which considers cell migration and proliferation in terms of a partial differential equation (PDE). Jin et al studies the diffusion and proliferation parameters required for the Fisher-Kolmogorov model [1].

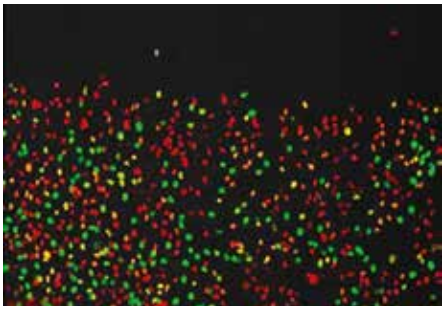
The fluorescent ubiquitination-based cell cycle indicator (FUCCI) is a new technology that allows experimentalists to monitor cell age, as well as migration and proliferation, on a scratch assay [5]. The stages of the melanoma cell cycle are observed as different colours on the scratch assay as seen in Figure 1(b). Figure 1(c) indicates how melanoma cells transition through the cell cycle. FUCCI highlights cells in the G1 phase as red, the S phase as yellow, and the S/G2/M phases as green.

In this study, we develop a lattice-based model which incorporates cell migration, cell-to-cell crowding and cell phase transitions. To incorporate each phase of the melanoma cell cycle, we consider 3 interacting sub-populations on a hexagonal lattice. We apply averaging arguments over a series of time intervals to produce a series of new continuum reaction, diffusion models that simulate experiments performed with FUCCI. In this report, we explain the development of the lattice-based model and the use of the Gillespie Stochastic Simulation Algorithm (SSA). We define the sub-population interaction rules and the assumptions made in this model. We then investigate the density of red, yellow and green cells over a 5-day period and further investigate the applications of this model.

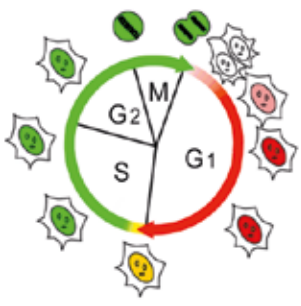
Tamara's full research report can be found at: vrs.amsi.org.au/wp-content/uploads/sites/67/2018/04/tambyah-researchpaper.pdf



(a) Typical scratch assay [1]



(b) Scratch assay with FUCCI [2]



(c) Melanoma cell cycle [3]

Fig 1. Experimental scratch assays

Blog post

During their Vacation Research Scholarship tenure, students also have to write a blog post about their experience. More blog posts can be found at vrs.amsi.org.au/projects/

HIDDEN EVERYWHERE: THE UTILITY OF MATHEMATICS

Student: **Jacob Ryan**, Queensland University of Technology
Supervisor: **Prof. Matthew Simpson**

"Wow you study maths, you can get a good job from that" is often a response myself and many maths students like me hear whenever we first introduce ourselves to strangers (well that or "do you want to be a maths teacher"). Whatever the situation, most people I meet know of the importance of mathematics, yet the conversation rarely progresses past this.

I don't expect everyone to know how to solve differential equations and there are numerous jobs I don't have the first idea about but consider that everyone studies maths at school for as many as 12 years. In my experience, I didn't really start to truly grasp the versatility of mathematics until I continued my studies at university.

For instance, my research with AMSI involved using differential equations (DEs) to model the behaviour of cells. For example, getting cut causes the cells in that area to be divided, leaving a gap that they will work to fill. Cells will also divide along the way, creating copies of themselves to continue the healing process. This system can be modelled with a DE known as Fisher's equation, describing how cells move to fill space, while bumping into other cells around them and occasionally dividing in two.

This work has applications in cancer research as mutated cells will attempt to spread around the infected patient following these basic rules. In fact, research into the spread of Melanoma cells is where much of the original data that motivated this project came from.

Learning how to solve DEs for this project was not actually necessary for me. These types of equations exist everywhere which I discovered when I had an assignment last year to model how the flow of groundwater changed when a coal-seam-gas plant was built in the region, as this would remove water from the system necessary for the agriculture in the area.

It was in this class that I began to learn how to solve these more complex models that have a very specific and important application but one of the best parts of mathematics is how so many problems can be translated into something familiar. Groundwater does not behave like cells, but the same skills can be applied to solve both problems. I think this is something mathematics has over other fields which is why teaching it at school is so heavily emphasised.

I've heard someone refer to mathematicians in the workplace as 'invisible people' since they're always working alongside professionals in engineering, IT and other industries even though they're without the same training. This is a testament to the versatility of mathematics, from scheduling and transport modelling to biology and a plethora of other areas, the results of their work are far from invisible. The challenge for mathematicians moving forward is to do a better job at showing people.

Student profile

MUSIC AND VRS PROVE PERFECT SUMMER MIX

Student: **Tobin South**, The University of Adelaide
Supervisor: **Dr Lewis Mitchell**, **Prof. Matthew Roughan**

From pop and rock to a little rap or soul, nothing beats that perfect summer Spotify play list. Using maths, Tobin South used his recent AMSI Vacation Research Scholarship (VRS) to take a different look at the world of music.

Working with University of Adelaide researchers Dr Lewis Mitchell and Professor Matt Roughan, the second-year bachelor of Mathematical and Computer Sciences student investigated the network properties of artist collaboration and the links that weave music together. Delving into human analysis and evaluation of music and how we determine what is important revealed some interesting insights.

"My research had some exciting findings which demonstrated how different genres have contributed to the underlying network of popularity within all music," he explains.

The perfect preparation for future industry engagement, the project and VRS experience proved a challenging learning experience.

As well as new skills, the University of Adelaide student added an award to his CV after taking out best presentation at AMSIConnect, the VRS highlight. While he was honoured by the recognition, it was the chance to hear from peers and attend information sessions that he enjoyed most.

> *"The VRS project pushes you out of your intellectual comfort zone and challenges you to learn new things and develop skills to solve unexpected problems"*

"I was excited to hear the other students' presentations—which were fantastic! Hearing about experiences with industry collaboration has piqued my interest in engaging in similar opportunities," he says.

When asked about the importance of the program, South is quick to answer—"the opportunity to apply the knowledge learned in a theoretical sense opens a new lens through which you can explore your abilities and develop valuable skills to take into the workplace."

2.6 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.

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

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

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)

Opening Possibilities: Removing Barriers to Maths

Growing up with a GP in the house, maths was always on the cards for Macquarie University student Aya Alwan.

"I was raised in a family that appreciated science and knowledge. My father was always my mentor and guide and helped me at every stage of my study," she says.

The hard work has paid off for the AMSI Winter School 2017 participant and Choose Maths Grant recipient, with Aya currently completing her PhD in mathematical and statistical modelling.

Used extensively across many industry sectors, these approaches allow estimation of performance variables in systems and processes. Aya points to transport as an example.

"Essential in transport planning, these models help variables such as traffic flow to simulate urban transportation systems. This helps in reducing issues such as traffic congestion," she explains.

With dreams of using her specialist skills to drive industry research, Aya found AMSI Winter School the perfect combination of networking and exposure to cutting-edge scientific techniques within her field.

"Many of the courses and presentations had a direct or indirect relationship to my work. This represents a fortune to me. There is no other way to receive this amount of knowledge within such a short time," she says.

Instrumental to this experience was a Choose Maths grant funded by BHP Foundation. With Winter School falling at school holiday time, Aya would not have been able to attend without this support and the ability to bring her family.

"I would not have been able to leave my four kids at home for four weeks. Even if I could organise care, I would struggle to concentrate being away from them," she says.

As maths grapples with a significant gender challenge, she believes that barriers such as family separation contribute to the low number of women currently in high-level maths positions.

"Maths is an interesting area to work and research in, but lack of finding support, flexibility and time and space to concentrate is contributing to women leaving the field," she says.

Events like Winter School not only provide access to learning and development but also to support and mentorship from other women within the discipline.

"I believe it is extremely important for women to have access to support. I have found other women in the field to be a tremendous support. Opportunities such as Winter School provide access to build these essential networks,"

Aya Alwan received a Choose Maths Grant to attend AMSI's 2017 Winter School

2017–2018 recipients

AMSI Winter School

Caitlin Gray, The University of Adelaide
Aya Alwan, Macquarie University
Marzhieh Rahmani Moghadam, Macquarie University
Sohelia Ghane Ezabadi, The University of Melbourne
Lin Jiang, Monash University
Mahrita Harahap, University of Technology Sydney

AMSI BioInfoSummer

Jasmine Bermas, The University of New South Wales
Bobbie Cansdale, The University of Sydney
Chi Cao, Murdoch University
Catisha Coburn, The University of Adelaide
Charmaine Enculescu, The University of Queensland
Daniela Gaio, University of Technology Sydney
Carmel Maher, Flinders University
Loan Nguyen, The University of Queensland
Tahlia Perry, The University of Adelaide
Emily Plant, University of Southern Queensland
Georgie Samaha, The University of Sydney
Brooke Whitelaw, James Cook University

AMSI Summer School

Kimberly Becker, The University of Adelaide
Laura Cartwright, University of Wollongong
Samten Choden, The Australian National University
Youstina Elzahaby, The University of New South Wales
Xiangyuanchai Guo, The University of Sydney
Elizabeth Harris, The University of Newcastle
Yuting Huang, The Australian National University
Adele Jackson, The Australian National University
Madeleine Kyng, The University of New South Wales
Cassie Marshall, The University of Queensland
Elizabeth McCarthy, University of Southern Queensland
Ellena Moskovsky, Monash University
Theresa O'Brien, University of Wollongong
Shuaige Qiao, The Australian National University
Hanyi Yang, The University of Sydney
Liya Zhao, The University of Queensland

AMSI Optimise

Mahla Babagolzadeh, University of Southern Queensland
Hoa Bui, Federation University Australia
Sofia Chaudry, Murdoch University
Michelle Dunbar, The University of Sydney
Xuemei Lui, University of South Australia
Saskia van Ryt, The University of Queensland

Choose Maths Grant recipients at AMSI BioInfoSummer PHOTO: AMSI

Choose Maths Grant recipients at AMSI Optimise PHOTO: KRYSTLE WESTCOTT

Caitlin Gray, The University of Adelaide PHOTO: PATRICK HAMILTON

Aya Alwan, Macquarie University PHOTO: PATRICK HAMILTON

Choose Maths Grant recipients at AMSI Summer School PHOTO: AMSI

2.7 ACE NETWORK

Through the Advanced Collaborative Environment (ACE) Network, 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 30 member universities—belong the ACE Network. In addition to offering honours and masters courses, the video conferencing facilities are used to bring interest groups from the mathematical sciences community together for workshops and seminars. From late 2018 Dr Judy-anne Osborn will join AMSI as the program director of the ACE Network.

HIGHERED.AMSI.ORG.AU/ACE

Overall **44** students from **12** universities accessed honours courses remotely

5 subjects offered by **3** universities in semester 2 2017

1 subject offered by **1** university in summer semester 2018

8 subjects offered by **4** universities in semester 2 2017

ACE Honours/Masters Courses 2017 Semester 2

Host University	Name of Course	Lecturer	Number of Students Enrolled
La Trobe University	Theory of statistics	Assoc. Prof. Paul Kabaila	6 remote, 2 local
La Trobe University	Model theory	Assoc. Prof. Tomasz Kowalski	6 remote, Local not supplied
The University of Sydney	PDEs in mathematical biology	Assoc. Prof. Peter Kim	6 remote, 11 local
The University of Sydney	Integrable systems	Prof. Nalini Joshi, Dr Milena Radnovic, Dr Yang Shi	1 remote, 15 local
Flinders University (delivered from RMIT University)	Differential geometry	Dr Simon Williams	1 remote, Local not supplied

2018 Summer Semester

Host University	Name of Course	Lecturer	Number of Students Enrolled
The University of Newcastle	Graph Drawing	Prof. Peter Eades	Data not available

2018 Semester 1

Host University	Name of Course	Lecturer	Number of Students Enrolled
Macquarie University	Algebra	Assoc. Prof. Steve Lack	4 remote, 2 local
Macquarie University	Analysis	Prof. Xuan Duong	10 remote, 2 local
Macquarie University	Optimisation and optimal control	Prof. Vlad Gaitsgory	Data not available
Macquarie University	Asymptotic methods for applied differential equations	Dr Justin Tzou	5 remote, 2 local
La Trobe University	Theory of statistics	Assoc. Prof. Paul Kabaila	No remote students
The University of Sydney	Asymptotic methods and perturbation theory	Assoc. Prof. Sharon Stephen	No remote students
University of Wollongong	Statistical consulting	Prof. David Steel	4 remote, 2 local
University of Wollongong	Advanced data analysis	Dr Pavel Krivitsky	2 remote, 6 local

ACE Short Courses

From time to time, AMSI member institutions offer short courses. These run over a short but intense a couple of weeks outside general teaching weeks. The specialist subject matter might be of interest to students as well as academics. There is no assessment or examination.

WINTER 2017: Chevalley Groups and Lie Algebras With Built-in Structure Constants

11–20 July 2017

The structure constants of a Lie algebra or Kac-Moody algebra g are the constants that occur in the evaluation of the Lie bracket in terms of a choice of basis for the Lie algebra. In the known methods for computing them, structure constants are determined only up to a sign due to the existence of a canonical central extension of the root lattice of the Lie algebra by a cyclic group of order two. Determining a consistent system of signs of structure constants is a persistent problem in computational Lie theory, computational number theory and their applications. In this short course, the basic structure theory of Lie algebras and Chevalley groups was covered.

Lecturer

***Assoc. Prof. Lisa Carbone**, Rutgers University, USA*

Lisa Carbone is an Associate Professor of Mathematics at Rutgers, The State University of New Jersey. She has bachelor (honours) and masters degrees in mathematics from the University of Melbourne and she obtained her PhD at Columbia University in 1997. She was a Benjamin Peirce Assistant Professor at Harvard University and a visiting Assistant Professor at Yale University before moving to Rutgers. She has held visiting positions in four continents, most recently at IHES in Paris and Universita dell'Insurbria / Politecnico di Milano. Her research interests are in group theory, infinite dimensional Lie groups and Lie algebras and algebraic symmetries of high-energy theoretical physics.

2.8 AUSTRALIAN MATHEMATICAL SCIENCES STUDENT CONFERENCE

University of Wollongong, 6–8 December 2017

The Australian Mathematical Sciences Student Conference (AMSSC) is an opportunity for postgraduate students from across the country to communicate their work, facilitate dialogue, and encourage collaboration. Students at the conference have a valuable opportunity to 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 2017, 36 students presented on key areas of applied and pure mathematics, while three plenary speakers talked about their own research and provided career advice.

All talks were very well received, with three students—Liam Morrow, Alex Casella and Becky Armstrong, awarded prizes for their presentations.

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

PHOTOS: SUPPLIED

Organisers

Tom Dyer, University of Wollongong
Alexander Mundey, University of Wollongong
Michael Mampusti, University of Wollongong
Vivian Ke, University of Wollongong
Tom Pedersen, University of Wollongong
Michael Cromer, The Australia National University

Invited Speakers

Dr Norman Do, Monash University
Dr Melanie Roberts, Griffith University
Dr Glen Wheeler, University of Wollongong

Web Links

amssc.org/2017/

Other Sponsors

AustMS, Institute for Mathematics and its Applications, University of Wollongong, Australian Signals Directorate, Department of Defence

Contact

amssc2017@gmail.com

2.9 AMSI-ANZIAM EARLY CAREER WORKSHOP

Hotel Grand Chancellor, Hobart, 3–4 February 2018

Scheduled every second year as a satellite workshop to the annual ANZIAM 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 ANZIAM conference in February, the 2018 workshop theme was communication. The two-day program focused on skills development to improve career opportunities in research and industry.

The 44 participants comprised PhD students, postdoctoral researchers and other early career mathematicians. Day one included three speakers, ranging from early career to established mathematicians, who each talked about their research against the backdrop of their own career trajectories. A highlight was Dr Alys Clark, from the University of Auckland, who talked about communication and collaboration. A Q&A-style panel discussion followed, allowing conference attendees to ask questions of the speakers.

The second day of the conference took a different approach, with participants taking part in a variety of activities aimed at enhancing communication skills. This was followed by a well-being presentation and a career-planning session.

Organisers

Dr Hayden Tronnolone, The University of Adelaide
Dr Melanie Roberts, Griffith University

Invited Speakers

Prof. Joshua Ross, The University of Adelaide
Claire Reeves, AGL
Dr Alys Clark, University of Auckland
Dr Sarah Dawkins, The University of Tasmania

Weblinks

maths.utas.edu.au/anziam2018/registration.htm#ecw

Other Sponsors

AustMS

Contact

hayden.tronnolone@adelaide.edu.au

2.10 HEIDELBERG LAUREATE FORUM

Heidelberg, Germany, 18–23 September 2017

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

The annual Heidelberg Laureate Forum 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.

2017 recipient

Saul Freedman, The University of Western Australia

HIGHLIGHTS FROM THE 5TH ANNUAL HEIDELBERG LAUREATE FORUM REPORT

The main feature of the HLF's formal program was a series of lectures delivered by some of the attending laureates. As I am a pure mathematician, currently undertaking a masters research project on group theory and representation theory, I was very interested in the introductory talk on asymptotic group theory given by Efim Zelmanov, a winner of the Fields Medal. Additionally, Sir Michael Atiyah, a winner of the Fields Medal and the Abel Prize, delivered an insightful lecture on the discrete and continuous aspects of mathematics and physics. This lecture was more philosophical and historical than many of the others, and encouraged the young researchers to pursue new research that could change the world. There were also many fascinating computer science lectures, on topics including the advent of public key cryptography; the interplanetary Internet that will be necessary for efficient data transfer during future space missions; the possibility of conscious machines; and neural networks that have learned to do amazing things, such as automatically adding colour to greyscale photographs, or transforming photographs to look like they have been painted by famous artists. These lectures were very accessible even to mathematicians, and helped to enhance my appreciation for computer science. A lecture on the future of medicine was also delivered by Aaron Ciechanover, a winner of the Nobel Prize in Chemistry, in order to highlight the affiliation between the HLF and the Lindau Nobel Laureate Meetings, the annual event that inspired the Forum. In addition to the laureate lectures, several researchers gave talks about new developments in quantum computing, which was the "Hot Topic" of the 5th HLF.

Perhaps the only disappointing aspect of the HLF's formal program was that all of the people who presented talks, and all of the laureates who attended, were men. Barbara Liskov, a winner of the ACM A.M. Turing Award, had planned to attend, but ended up being unable to make it to Germany. Although this lack of representation wasn't as extreme for the young researchers, about a third of whom were women, it is clear even from the composition of this cohort that the harmful attitudes and stereotypes related to gender in mathematics and computer science need to be addressed at all levels of education and in all sectors of society. Only then will people of all genders be able to properly pursue their interest and fulfil their potential in these areas. Many of the attendees at the HLF recognised this, and so organised an impromptu session for the women in attendance to discuss gender equity issues in mathematics and computer science. There are hopes that, in future years, the formal program of the HLF will include such a discussion session, and possibly also a session on this topic that all participants will be able to attend.

Outside of the formal program of the HLF, I attended a very fun and interesting workshop on topological quantum computing, run by Sir Michael, Julia Plavnik (a postdoctoral researcher from Texas A&M University) and Ismael Sierra, an undergraduate student from the University of Cambridge. This workshop explored topological quantum computing's relationship with mathematics, physics and computer science, and I was especially pleased to learn about its connection to representation theory. I also had the opportunity to visit the MAThematics Center Heidelberg (MATCH), Heidelberg University's mathematics research centre, where pure and applied mathematics researchers spoke about their current work. Throughout the week of the Forum, a free exhibition showcasing the works of the late artist Aldo Spizzichino was open to the Forum attendees and the public. These inspirational artworks were computer-generated using mathematical concepts from geometry and topology.

The HLF also included a substantial social program, with many opportunities for young researchers to talk to each other and to the laureates over tea, lunch and dinner. This allowed me to make many new friends, to learn about the current research being undertaken by the laureates and the other young researchers, and even to gain a better understanding of how group theory and representation theory can be applied in other areas of mathematics.

> *"My time at the HLF was thoroughly enriching, from an intellectual perspective and a social perspective."*

I was able to meet and learn from a huge number of researchers from around the world who work in areas both very close to and very far from my own, and this experience has strengthened my passion for my own research. Just as importantly, my presence at the HLF allowed other young researchers to learn from and be inspired by me.

(This is an edited extract from the report submitted by recipient Saul Freedman. The full report can be seen at research.amsi.org.au/5th-heidelberg-laureate-forum-report/)

WOMEN IN MATHEMATICS

Improving Gender Ratios in the Mathematical Sciences – AMSI's Approaches

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

70 per cent of undergraduate and postgraduate students in the Australian mathematical sciences are male with only 30 per cent of departmental staff female. Gender inequity only becomes starker at senior levels with women accounting for only 10 per cent of staff employed at the highest academic levels.

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 each of 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. This includes measures such as a mandatory presence on event organising committees, engagement of high-profile female speakers and support of female participation through the provision of information on and assistance with childcare availability. We have seen some growth in 2017-2018, with participation figures showing 21 per cent female attendance across 22 workshops. This is up from 17 per cent during the previous year.

Barriers to Participation

A number of barriers continue to impact gender equity 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

AMSI's Scientific Advisory Committee has recommended a number of strategies further address these barriers and support women attending AMSI-sponsored workshops. These include:

- Strengthened 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

WORKSHOPS STATS

Invited speakers receiving funding: **25%** female (**16%** in 2016-2017)
Workshop participants: **22%** female (**17%** in 2016-2017)
Female students/ECRs receiving travel funding from AMSI: **47%** (**4%** in 2016-2017)

FLAGSHIP PROGRAM STATS

Overall, women accounted for **41%** of attendees across the five flagship training programs in 2017-2018, up from **39%** in 2016-2017.

Winter School
33% female students, **25%** female lecturers

BioInfoSummer
51% female participants, **47%** female speakers

Summer School
29% female students, **36%** female lecturers

Optimise
34% female participants, **12%** female speakers

Vacation Research Scholarships
28% female students, **8%** female supervisors

"Receiving a Choose Maths Grant meant more than just financial support, it has proven to me that AMSI has made a conscious effort to create balance to bring awareness that we, as women, are equally valued as men in this field."

Jasmine Bermas, The University of New South Wales

Prof. Kerrie Mengersen speaking at the AMSI Winter School's Women in Maths networking event PHOTO: PATRICK HAMILTON

Choose Maths

AMSI's Schools program continues to partner with the BHP Foundation to deliver the national Choose Maths project. This 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. The project challenges community attitudes to participation in mathematics, especially for girls and young women, through a variety of programs and initiatives including:

- The Choose Maths Outreach program, which provides teacher professional development and support at 120 schools across Australia. Data is collected about student preferences and teacher self-efficacy, and analysed and reported to the wider mathematics education community by our dedicated Choose Maths research staff
- The national Choose Maths Awards program for both teachers and students celebrating mathematics achievements, creativity and excellence
- A national Careers Awareness campaign showcases inspiring Australian maths professionals, mostly women, 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, including both the Choose Maths Mentoring program for girls in Years 11 and 12, and the Choose Maths Days, which aims to engage high school students, particularly girls, with mathematics
- Choose Maths Travel Grants for students and early career researchers

Choose Maths Grants

AMSI Choose Maths grants help 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 caring responsibility costs such as childcare, support for partner and child travel.

Networking events are held for Choose Maths recipients at AMSI's major flagship events including Winter and Summer Schools and BioInfoSummer.

Mathematics, Gender and Mathematics Education Workshop

AMSI Choose Maths held its first *Mathematics, Gender and Mathematics Education* workshop in Melbourne from 19–21 June 2018. Invited speakers from Canada, New Zealand and Australia presented their research which was complemented by showcasing of the inspirational practical work of the major Choose Maths Teacher Award winners in 2016 and 2017 and the Choose Maths Outreach team. The 35 workshop participants comprised teachers, representatives of state departments of education, researchers from ACER and academics from mathematics, statistics, mathematics education, psychology, engineering and, of course, the Choose Maths team.

The participants welcomed the opportunity to meet with people from outside their normal 'boundaries' with a clear indication from all participants to continue with this new network of people

AMSI Summer School Diversity in STEM event PHOTO: MATHS AT MONASH

with similar aims. The mix of presentations and working groups—complemented by a welcome reception and dinner—led to fruitful discussions in particular on maths anxiety in students, parents and their teachers and on how to address these.

AMSI Schools/Choose Maths Gender Report

With a focus on Australian and Choose Maths data, this report provided a comprehensive analysis of Australian primary and secondary mathematics education trends in relation to gender difference and its impact on Year 12 participation, students' performance and attitudes over the last 10 years (amsi.org.au/publications/gender-report-2017-participation-performance-attitudes-towards-mathematics/)

Events in 2017–18:

- Networking events for recipients of Choose Maths Grants were held at Winter School, BioInfoSummer, and Summer School for the recipients of Choose Maths Grants and others interested in AMSI's Choose Maths initiatives.
- July 2017 – AMSI Winter School's Women in Maths networking event: more than 70 people attended this active discussion on current issues facing women in mathematics and their contributions to the field. Panel speakers included Amy Hawke from Brisbane State High School and Olivia Hutchinson from Boeing (both QUT alumnae), Professor Kerrie Mengersen from ACEMS and Dr Linda Stals (AMSI Winter School 2017 Lecturer from ANU).
- July 2017 – *Harmonic Analysis and PDE women's luncheon* at Macquarie University attended by both conference participants and local academics.
- December 2017 – *Diversity in STEM Lunch* hosted by BioInfoSummer to raise awareness about diversity issues including gender in STEM (attended by 85 delegates).
- December 2017 – Gender Diversity Dinner during the *Future Directions in Representation Theory* workshop.
- January 2018 – 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.
- February 2018 – Women in Mathematics lunch as part of *Harmonic Analysis Conference Celebrating the Mathematical Legacy of Alan McIntosh* hosted by Professor Lesley Ward from the University of South Australia. This was attended by the conference's female participants and staff from the Australian National University.
- June 2018 – *Women in Optimisation* panel during AMSI Optimise. Facilitated by AustMS head Professor Kate Smith-Miles, this included Associate Professor Maria Antónia Carravilla (Universidade do Porto, Portugal), Associate Professor Marie-Ève Rancourt (HEC Montréal, Canada) and optimisation pioneer Alison Harcourt from the University of Melbourne.
- June 2018 – *AMSI Choose Maths Mathematics, Gender and Mathematics Education* workshop on maths anxiety.

DETERMINED TO **SUCCEED**

Interview with Professor Kate Smith-Miles

Georgina Sweet Australian Laureate Fellow in Mathematics and Chair of Applied Mathematics at The University of Melbourne, President of AustMS, and Chair of AMSI Schools' Choose Maths Advisory Committee

Have you always been interested in maths? Were you encouraged in your studies growing up?

I always enjoyed maths at school but I didn't consider a career in mathematics until Year 12. Before then I was considering journalism, because I also love writing and communicating ideas. But during Year 12 I had an inspiring maths teacher who managed to show me a little glimpse of the power of mathematics and its elegance and beauty, and I decided that I needed to learn more! Interestingly, she tried to discourage me from studying maths at university, because she wasn't sure where it would lead apart from becoming a maths teacher like her, and she thought that I should be aspiring to do "more" (meaning law or medicine!). But I had no interest in law or medicine, and I considered a career as a maths teacher—inspiring the next generation to love maths as much as I did—to be a pretty fine option if a maths degree didn't lead anywhere else. Little did I realise how many doors would open with a maths degree! Fortunately, my parents were happy for me to pursue whatever interested me. My Dad was a GP with his own medical practice, working ridiculously long hours. I was lucky that they were not the kind of parents who would ever push me into a medical, or any other, career if my passions lay elsewhere.

Who were your role models and mentors? How important was this support?

Apart from the inspiring female high school maths teacher in Year 12, I am sorry to report that I didn't really have any female role models once I commenced my university studies. In my four years of undergraduate study, I never had a female lecturer, and was only aware of a couple of female academics in the maths department who I didn't get the opportunity to know at that time. There were only a handful of female students in my first-year classes, and we quickly become friends and supported each other over the years of study. Fortunately, that was pretty much all the support I felt that I needed. There was no notion back then (in the late 1980s and early 1990s) of women in maths networks or mentoring schemes, so I didn't know what I was missing! My PhD studies were similar, with a lack of female role models, but were more challenging because I also lacked female peers. It was a pretty lonely few years, but fortunately I had a healthy social life outside academia! Once I commenced my academic career as a lecturer, I found some female peer support again with other female lecturers, but I never had a female academic more senior than me to serve as a role model in my work environment. And without the internet back then, I wasn't aware of the wonderful role models that could have been available to me elsewhere in the country. In fact, the first female professor I encountered was Lynn Batten at Deakin, but by then I was already a full professor myself and was Head of her school. I have been very fortunate throughout the earlier stages of my career however to have had some wonderful male role models, my direct managers, who saw their role as to support me to achieve my potential. And of course, my incredibly supportive husband has been a constant source of advice and support over the decades.

How important is it for female mathematics leaders to take on the role of mentor and role model for girls and women entering the discipline? How have you approached this responsibility?

These days we are all much more aware of the "diversity dividend" that comes when organisations seek to achieve greater diversity of talent in the workplace, and to eliminate the barriers that prevent equity of opportunity. When I was a student, I think the attitude tended to be that women are less interested in mathematics, and if a handful of women choose to work in maths, then they will succeed if they really want to. To be honest, I probably thought that too when I was younger; I didn't expect anyone to help me to succeed. It was my choice to move into a male-dominated area, and I was determined to succeed on my own. Why should anyone else care if I succeeded? But ever since organisations started realising that having more women in the workplace is a critical goal—for the diverse views and perspectives they bring, the role modelling they offer to younger women, and because women are half the population and an untapped source of potential students and future workforce—a lone woman should no longer expect to be on her own without support. There are others now who want her to succeed, and enough senior women that a critical mass of role models and mentors can be available—especially since the world is smaller now with technology facilitating long-distance interactions.

In hindsight I can see that such support would have been wonderful at earlier stages of my career, but I just didn't have senior women around me.

So I consider it a really important part of my role now to provide as much mentoring and support as I can for young female mathematicians—whether in primary schools, high schools, undergrads, postgrads, and early career academics as well. Lending my support to the many great programs, such as AMSI Choose Maths where I chair the Advisory Committee, as well as the numerous activities of the AustMS's Women in Maths Special Interest Group (WIMSIG) is also important. And being willing to be interviewed and become one of the public faces of women in mathematics is also a responsibility that I am proud to accept.

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

Most of the time the gender bias I have experienced has come from men telling me why women can't do maths, or why it is apparently surprising to them that I can! But this has only served to make me more determined to prove them wrong, like waving a red flag at a bull! I had a high school teacher who told me that

girls' brains aren't "hard-wired" for maths like boys' brains are because we can't visualise in 3-d! Rather than feeling discouraged by this though, I just thought it sounded like nonsense, and didn't give it any credibility. At university I had a lecturer who announced on day one that 50 per cent of the class would fail, and 100 per cent of the handful of girls in the class would fail … statistically speaking based on historical data. Well, I didn't believe for a minute that I would fail his class. It was just first-year calculus and I was prepared to work hard. The result of these experiences however was an attitude that I assumed – a determination to prove people wrong and succeed despite their discouragement—and this attitude accompanied me for much of my early career, until I had a wake-up call when I returned from maternity leave in 2003. When I announced to my assigned "mentor" that I was taking maternity leave, his reaction was horrific. "Oh no, what have you done? Don't you realise this will be the end of your research career? I've seen it happen so many times!" Again, like waving a red flag to a bull, I was determined to prove him wrong. I returned from maternity leave after three months and immediately submitted three ARC grants, all of which were successful. I then found myself later that year with a ridiculous workload and a baby at home. I took stock that year and decided that burning out to prove people wrong is not the answer; that work-life balance is much more important than what an old man thinks of me! It was an important life lesson that I often share with the women I mentor.

How can we improve female participation in mathematics in Australia particularly in higher-level academic positions?

The Choose Maths project's research is showing that the low participation rate of females in mathematics begins as early as the primary years, where girls show less confidence in their mathematics ability (not to be confused with their true mathematics ability). But the good news is that, with suitable intervention and teacher training, it seems that girls are very responsive to altering their perceptions. And for the first time in many years, we are now seeing an upward trend commencing in the number of girls taking advanced mathematics in Year 12. But this is obviously a very long pipeline before the excellent work being done with this cohort will see a significant increase in the number of female students studying mathematics at university and going on to commence academic positions in universities. Meanwhile, the marketing message for the AMSI Choose Maths campaign, targeting girls as they make choices about university courses, will hopefully lead to a boost. Recruitment of women into academic positions can be done if a department has a strategic vision to make it so, as we have seen with the female-only positions at the University of Melbourne and several other institutions.

PHOTO: MICHAEL SHAW

Industry Research and Training 3

Deakin University PhD student Indivarie Ubhayaratne at The Environment Protection Authority

PHOTO: MICHAEL SHAW

3 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 Australia has the mathematical and statistical skills to remain internationally competitive and protect national security, population health and climate stability.

From July 2017 through June 2018, AMSI's industry internship program placed **82 interns** from **14 disciplines** with **45 industry partners** across **9 industry sectors** AMSI's **250th intern student** was placed in February 2018

"I really enjoy collaborative and multi-disciplinary research. Taking on the role of mentor with APR. Intern broadens your horizons beyond academic research and helps foster industry relationships"

Associate Professor Paul Kennedy, University of Technology, Sydney

3.1 APR.INTERN

APR.Intern (formerly AMSI Intern) is the only national, all sector, all discipline internship program placing PhD students into business. A not-for-profit postgraduate internship program, it is open to all Australian universities and industry sectors including small-to-medium and large enterprise, and government agencies.

In 2017 the Australian Government confirmed its commitment to invest $28.2 million to expand AMSI's Intern program on a national scale through the *National Research Internships Program: supporting more women into STEM careers*, supporting the delivery of PhD internships across all industry sectors, with access provided to all Australian universities. Renamed APR.Intern to reflect the broad national scope, AMSI's industry intern program provides PhD students with the opportunity to work with an industry partner on a research project of up to five months' duration. Operating across all disciplines and sectors, the program is open to women and men with an emphasis on gender equity and getting domestic, regional, Indigenous and disadvantaged PhD students into STEM internships

The internships give PhD students an opportunity to apply their research skills to commercial applications, in turn providing a platform for industry to engage with and attract talent into their organisation through short-term tightly focused research projects.

From July 2017 through June 2018, the program placed 82 interns from 14 disciplines with 45 industry partners across 9 industry sectors. This represents a 60 per cent increase in the number of interns over the previous year, and an 80 per cent increase in the number of industry partners, reflecting the increase in the range of the program. The program is now truly national with interns placed in every state and territory except the Northern Territory.

In October 2017, APR.Intern entered into an agreement with Defence Science and Technology Group (DST Group), the R&D arm of the Department of Defence, to place 100 interns into the group over 3 years. An agreement with the newly established ARC Centre for Personalised Therapeutics Technologies to place 24 PhD students into industry projects over the next four years was signed in May 2018. 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 280 postgraduate students from 27 universities into industry since the intern program began in 2007. More than 140 businesses and government agencies have hosted interns during this time, and significantly, 22 per cent are repeat customers.

APRINTERN.ORG.AU

PROGRAM PARTICIPATION

From July 2017 through June 2018, 82 interns from 14 disciplines with 45 industry partners across 9 industry sectors

STATE BY STATE:

ACT – 4	NSW – 21
QLD – 1	SA – 5
TAS – 1	VIC – 46
WA – 4	

ATLASSIAN CHAMPIONS PhD WOMEN

When information technology leader Atlassian needed a smart innovation solution to optimise their lead product, Confluence, they turned to APR.Intern.

"We wanted to access the expertise to develop a content recommendation engine to provide Confluence customers faster access to relevant content so they could get back to what they do best," said Derek Ho, Senior Data Scientist at Atlassian.

Australia's leading all-sector, all-discipline national postgraduate internship program matched Atlassian to University of Technology Sydney (UTS) PhD student Nazanin Borhan.

"Her research expertise and her full-time dedication were the qualities we needed most. Her great work led to the successful implementation of the content recommendation proof of concept"

Derek Ho, Senior Data Scientist at Atlassian

For Nazanin, it was a chance to apply her background in data mining and machine learning to a real-world industry challenge and work with a sector leader. It was also a great way to get a foot in the industry door and fast track her career.

"APR.Intern is one of the best ways to start fresh in the market and develop the skills and networks needed to pursue industry. I learned how machine research is used in industry and new techniques, as well as developing essential soft skills," said Nazanin.

One of the keys to success was the support of academic mentor UTS Associate Professor Paul Kennedy. He helped both Nazanin and the Atlassian team bridge the research-industry divide, bringing unique insights to advance the project.

"I really enjoy collaborative and multi-disciplinary research. Taking on the role of mentor with APR.Intern broadens your horizons beyond academic research and helps foster industry relationships," Associate Professor Kennedy said.

Thanks to the project, Atlassian is keen to pursue further research collaboration, and is keen to take on future APR.Intern placements.

"This project has shown us that research collaboration with academia can be a fruitful process. We definitely have plans for further engagement with the program," said Derek.

FULLY CHARGED: OPTIMISATION THE KEY TO ENERGY SAVING

In a bid to combat rising energy costs, an energy software start-up has enlisted PhD skills to optimise the management of batteries connected to solar power systems.

Founded in San Francisco, Growing Energy Labs, Inc.'s local operation—Geli Australia—partnered with APR.Intern to reduce customer energy costs by employing cutting-edge optimisation research.

Monash University IT PhD Shan (Dora) He was placed into a five-month internship project with Geli Australia, which resulted in the delivery of a proof of concept for enhancements to Geli's demand charge management optimisation.

For He, the industry experience was an opportunity to apply her expertise in mathematical optimisation and computer science skills to a real-world problem.

"Throughout my internship, I learnt that technical skills are important, but the soft skills to deliver outcomes successfully are just as crucial," said He.

"I believe the experience will support my career in both industry and academic sectors," she added.

Senior Staff Data Scientist at Geli, Zach Ernst, said Dora's expertise in optimisation was of great interest to Geli.

> *"Dora's research and analysis provided us with a strong jumping-off point to introduce new and innovative approaches to optimisation into our systems"*
>
> **Zach Ernst, Senior Staff Data Scientist at Geli**

With only two per cent of Australian businesses reporting engagement in innovation, Ernst believes the relationship between research and industry is key to future-proofing business with innovation opportunities.

"Government support for early-stage R&D is critical to the diversity of technical progress we can achieve as a global society," he added.

MENTORING APR.INTERN STUDENTS: Q&A WITH PROF. LUKE PRENDERGAST, LA TROBE UNIVERSITY

What benefits have you gained from your APR.Intern internship mentor experience?

Mentoring intern students has been a very rewarding experience. It has opened my eyes to some interesting, real-world problems that have helped me to better appreciate what we do to train our future mathematicians and statisticians. I have seen our students provide real input into challenging problems and from this I hope to develop further collaborations with industry partners for both myself and my students.

> *"The academic landscape is changing… Academics are expected to engage with industry and to progress their research towards impact outside of academia"*
>
> **Prof. Luke Prendergast, La Trobe University**

What are your thoughts about the important role research plays in accelerating innovation in industry?

I think research plays a crucial role in competitive industries. The interns I have mentored have been given new problems that they have solved, and in doing so have provided their industry partner with something new that can improve efficiency in how they operate, or provide a better understanding of their customers to get an edge. Examples include automated records matching and anomaly detection replacing extremely time-consuming by-hand processes, and models that predict customer behaviour based on their specific traits. These were real research projects, based on very large and complicated data sets that had no obvious best method of solution prior to the start of the project. The interns researched various methods to solve their problems. As an academic, barriers may include time and the need to change a little from what we are currently doing. I was like this, but since mentoring my first student a few years ago I am now a believer and hoping to mentor my third intern soon!

What changes are needed to increase gender equity, and the engagement of women, in STEM PhDs and research careers?

We need to encourage young women at school to consider careers in STEM. One way to do this will be to show their teachers that there are exciting career paths across a diverse range of disciplines including the medical and health sciences, climate science, finance, sports analytics to name just a few. Many career paths simply do not have enough graduates to fulfil demand, and many of these paths will be of a great interest to women. As an example, I have seen some of my past female students get jobs in cancer research and they love what they do! I wonder if their school teachers know?

How does industry experience and exposure to research in this context benefit academic researchers?

The academic landscape is changing. Academics are expected to engage with industry and to progress their research towards impact outside of academia. This is not simply pipe-dreaming, but something real and which is now being measured by government initiatives. An academic who has previously been exposed to industry (either as an intern or a mentor) will be much better placed to achieve these goals.

3.2 MATHEMATICS IN INDUSTRY STUDY GROUP (MISG)

The University of South Australia, 29 January – 2 February 2018

AMSI partners with ANZIAM to support the annual Mathematics in Industry Study Group. 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 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, manufacturing (including car manufacturing), railways and freight, metal processing, food and beverages, oil and gas, utilities, biomedical science, and technology.

MISG 2018 tackled four industry problems, delivering a range of challenges for the 75 attending researchers in mathematical statistics, operational mathematics, applied and computational mathematics. The workshop was opened by Professor Emily Hilder, from the Future Industries Institute, who spoke about collaborating with industry and South Australian State Government incentives for encouraging collaboration between industry and universities.

Every participating industry partner received a brief summary report immediately following the MISG workshop, capturing the essence of what was achieved during the workshop and summarising the ongoing work to be discussed in full technical detail in a final report.

MATHSININDUSTRY.COM

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

EVENT PARTICIPATION

75	Attendees
29	Students
20	Female participants
15	International participants

The program is acclaimed by industry partners as a low-cost, high-yield investment in problem-solving. Some partners have implemented MISG practices directly following the workshops, while others have expanded their investment into collaborative research partnerships to solve even larger business challenges.

Web Links

mathsinindustry.com/about/misg-2018/

Other Sponsors

ANZIAM, University of South Australia

Contact

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

Projects

Planning Electricity Transmission Networks

ElectraNet is responsible for the long-distance, high-voltage transmission of electricity throughout South Australia, connecting traditional and renewable power generators and large industrial customers to the transmission network, and connecting South Australia to the eastern states.

Stochastic generation technologies, including distributed rooftop solar along with emerging grid-scale, distributed and even mobile (electric vehicles) battery technologies are changing the way that the transmission network is used. Emission reduction goals will ultimately see the fleet of conventional coal and gas fleet retired. To plan future transmission infrastructure, ElectraNet must predict, up to 20 years in advance, when and where power will be generated and used.

To make this problem tractable, the current planning approach has two stages. First, a long-term plan is developed. The long-term plan takes into account existing generation, renewable resources that might be used for future generation, and load predictions. Load is modelled as a sequence of monthly load distributions for the next 20 years. Each monthly load distribution indicates the proportion of time that the load will exceed a given level during the month, but does not specify when. The long-term planning process uses a large linear program to optimise the fleet of generators that will be used to meet the monthly load distributions.

Next, the long-term plan is tested by simulating the operation of the proposed transmission network and generator fleet for the next 20 years, using hourly time steps. At each time step, the optimal mix of generators is selected from the proposed fleet.

This second stage often shows that the first stage—the long-term plan—undervalues interconnectors, because it does not model the hourly variability of generation and the resultant power flows in the transmission network. Furthermore, the impact of storage, which is likely to cycle daily, may not be effectively taken into account in the long-term model.

The aim for MISG is to suggest modelling and optimisation approaches that will more accurately reflect the increasingly stochastic nature of future generation in the long-term modelling of the system.

Partner: ElectraNet

Summary report: mathsinindustry.com/about/misg-2018/2018-projects/electranet-planning-summary-report/

Inertia in Electricity Networks

In electricity generation systems, large thermal or hydro power plants use rotating synchronous machines to generate three sinusoidal voltage phases with a frequency near 50 Hz. The electrical flux and mechanical dynamics of a synchronous generator can be modelled by well-known differential equations that depend on terms including the mechanical power being applied to the generator, the electrical load on the generator, and the moment of inertia of the rotor.

When synchronous generators are connected together, they synchronise to form a stable equilibrium. If the load on the grid increases then the increased load will be shared automatically among the synchronous generators in a way that maintains synchronisation. Generators with higher inertia will take a higher proportion of the additional load, and all generators will slow at about the same rate until the mechanical power applied to the generators can be increased or load can be reduced. This slowing of the generators causes a drop in the frequency of the grid power. Similarly, if the load on the grid decreases then the frequency will rise. The rate of change of frequency (RoCoF) is a key indicator of system stability; if frequency changes too quickly then the system will become unstable and may be at risk of losing synchronism.

New renewable generation systems, such as wind turbines and photovoltaic power systems, use power electronics to control their output to ensure that they are synchronised to the traditional generators. They have zero or low physical inertia, but can potentially emulate inertia. The growth of these loosely-coupled generators is reducing the total inertia in the system, which can impact on the stability of the system and system strength. Furthermore, the new generators are scattered across the power system, and can be far from big load centres and from synchronous generators.

The aim for MISG was to help ElectraNet understand the impact of low-inertia generation, far from loads and synchronous generation, on the stability of the South Australian power system. How should the equivalent inertia of a wind farm be calculated, and how does it impact the rate of change of frequency in the system? Ultimately, the aim is to understand how energy storage and devices such as synchronous condensers (large rotating synchronous machines that provide mechanical inertia without generating) can be used to stabilise power systems.

Partner: ElectraNet

Summary report: mathsinindustry.com/about/misg-2018/2018-projects/electranet-inertia-summary-report/

Optimising Carcase Cuts in the Red Meat Industry

The red meat industry is moving into a new era of objective carcase measurement. Until now, meat processors have sorted carcases based on weight. New measurement technologies give detailed, accurate information on the amount of lean meat, fat and bone tissue in each carcase before it is processed. The lean meat and fat tissue present on a carcase influence the profitability; generally, carcases containing more fat have a lower profitability. Profitability of a carcase is also influenced by the market prices being paid and the types of meat cuts being used. If a meat processor is able to leave more fat on a given set of meat cuts then they are able to reduce wastage and increase profitability, due to the vastly higher wholesale price of lean meat versus fat trim.

The red meat industry has started to develop an optimisation tool to determine the most profitable options for each carcase, given the cut orders received from each market. However, this optimisation tool is very specific, allocating individual cuts from individual carcases for a fixed set of carcases and orders. The tool needs to be more flexible, because new carcases arrive and orders change during processing. Our problem is to determine what types of approaches may be taken to increase the flexibility of the optimisation, and how we can re-work the tool to make it more useful in the ever-changing environment of a meat processor.

Partner: Australian Lamb Company

Summary report: mathsinindustry.com/about/misg-2018/2018-projects/australian-lamb-company-summary-report/

Combining ABS Publicly Available Data With Other Publicly Available Data

There is a wealth of publicly available data produced by Commonwealth and State and Territory Government agencies. The Australian Bureau of Statistics (ABS) produces official economic, social and population statistics and data. Other agencies publish data that, if combined with ABS data, can help provide more information about policy or issues of interest. For example, the ATO publishes personal income tax data by postcode. State and Territory government agencies publish data sets covering education, health, social conditions, employment, income and wealth. All of these data sets are available at different geographic levels and so are therefore difficult to combine. For example, the ATO publishes aggregated incomes by suburb, whereas the ABS uses the Australian Geographic Statistical Standard.

The ABS is seeking to develop techniques to analyse these geographically different data sets to identify patterns and correlations that will support enhanced decision-making. The key questions include:

- What can we learn about sub-populations or sub-state areas by combining publicly available ABS data with other publicly available data?
- Can unstructured searches of data trained on high-quality census and survey data be used to discover characteristics of sub-populations, provide estimates of future characteristics, and identify leading indicators?

Partner: Australian Bureau of Statistics

Summary report: not available at the time of publication

3.3 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 million hectares (about 17 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.

Through this agreement, AMSI statistician Kally Yuen became a research partner in Parks Victoria and has been actively involved in research activities including evaluation of data capture options for remote camera wildlife monitoring projects and assessing the effectiveness of invasive plant control programs. Due to its continuing success, the partnership was extended at the end of the original agreement in 2014. The current partnership will continue until 2020.

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 Centre for Youth Mental Health at the University of Melbourne.

Accredited by the Statistical Society of Australia in 2004, Kally's qualifications include a master of Science degree in Statistics, 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

An experimental monitoring program was set up in November 2015 to investigate the effectiveness of five techniques to control the spread of sallow wattle in the Grampians National Park. Sallow Wattle (*Acacia longifolia* subsp. *longifolia*) is not native to the area. Invasion by this species will result in a change of species composition in the Grampians if it is not managed.

The techniques included two mechanical treatments (brushcutting and mulching), two herbicide treatments and one manual treatment (removal of weeds by hand pulling and hoeing). All five treatments were also examined for their possible damage to neighbouring species (off-target effects) and costs. Kally worked in conjunction with Dr Marie Keatley, Parks Victoria Environmental Scientist-Flora, and park managers to design the program and set up a project-specific database for data storage.

The results from analyses of the data conducted in 2017 suggested that all treatments were effective to some degree after one year. However, no conclusion could be made about their off-target effects as longer-term follow up of the experimental plots is required. The results also indicated that the costs incurred by the treatments varied considerably. Kally presented these results to the study team in a meeting in October and received very positive feedback. Based on these results it was decided to seek funding to maintain the program and Kally will continue to provide statistical support to the team.

Brushcutting, one of the techniques investigated in the sallow wattle control monitoring program in the Grampians National Park.

Investigation of Suitable Software for Remote Camera Data Management

At Parks Victoria, remote cameras are frequently used to monitor animal species in the parks. A typical remote camera survey can easily produce thousands of camera images. Traditionally, the process of sorting the images after each survey and the entry of data for statistical analysis have been extremely tedious and time consuming. In recent years, several software programs have been made available to the public for remote camera data management. Kally identified the essential requirements for the management of remote camera data at Parks Victoria and conducted a review of each software program. The goal was to identify the most suitable program for data management across all remote camera projects in Parks Victoria. Following the review, Kally put forward recommendations which are currently considered by the Science and Management Effectiveness team. Once a suitable software program has been adopted, Kally will streamline the entire process so that it can be easily implemented by managers in the parks.

A Red Fox captured by remote cameras in the Great Otway National Park

Science and Management Effectiveness Team Workshop

As a team member of the Science and Management Effectiveness branch at Parks Victoria, Kally attended a special branch workshop held in Inverloch on 27-29 November 2017. The workshop included update from all team members on their current key projects, trials of special software designed for specific case studies, and meeting with park managers in the region to gain insight into their current monitoring and conservation activities. Kally contributed to the discussions of different projects and there is scope in the future to utilise her specialised skills in the design and analysis of some of the projects that were discussed.

Trial use of special software designed for a monitoring project on marine species at Inverloch beach during the Science and Management Effectiveness Team workshop.

ACRONYMS

ABACBS	Australian Bioinformatics and Computational Biology Society
ABS	Australian Bureau of Statistics
ACE	Advanced Collaborative Network
ACEMS	ARC Centre of Excellence for Mathematical and Statistical Frontiers
ACOLA	Australian Council of Learned Academies
AMSI	Australian Mathematical Sciences Institute
AMSSC	Australian Mathematical Sciences Student Conference
ANU	The Australian National University
ANZAMP	Australian and New Zealand Association of Mathematical Physics
ANZIAM	Australian and New Zealand Industrial and Applied Mathematics
APR.Intern	Australian Postgraduate Research Intern program
ARC	Australian Research Council
AustMS	Australian Mathematical Society
BIS	BioInfoSummer
CARMA	The Priority Research Centre in Computer Assisted Mathematics and Applications, The University of Newcastle
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DST Group	Defence Science Technology Group
ECR	Early Career Researchers
EMBL Australia	European Molecular Biology Laboratory Australia
ERA	Excellence in Research for Australia (Australian Research Council)
FAA	Fellow of the Australian Academy of Science
FAAAS	Fellow of the American Association for the Advancement of Science
FAMS	Fellow of the American Mathematical Society
FAustMS	Fellow of the Australian Mathematical Society
FRSC	Fellow of the Royal Society of Canada
HDR	Higher Degrees by Research
ISI	The Institute for Scientific Information
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)
MCMC	Markov chain Monte Carlo
MISG	Mathematics in Industry Study Group
MSI	Mathematical Sciences Institute, Australian National University
NSF	National Science Foundation (USA)
OECD	Organisation for Economic Co-operation and Development
PDE	Partial Differential Equation
QCIF	The Queensland Cyber Infrastructure Foundation
QUT	Queensland University of Technology
RHE	Research and Higher Education
RHEC	Research and Higher Education Committee
SPCM	South Pacific Conferences in Mathematics
SAC	Scientific Advisory Committee
SSA	Statistical Society of 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
WEHI	The Walter and Eliza Hall Institute of Medical Research
WIMSIG	Women in Mathematics Special Interest Group

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