2015/16

AMSI Summer School

RMIT University
4–29 January 2016

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Summer School

RMIT University, 4 – 29 January 2016

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01

Introduction

The AMSI Summer School is one of the key events in the calendar of the Australian mathematical sciences community, because of its focus on mentoring and engaging with the new cohort of emerging mathematical talent in Australia and its role in public engagement and outreach. It provides a platform to further the education of the most talented young mathematicians in the country, and an opportunity for talented lecturers to pass on their specialised knowledge to a new audience. Increasingly, the AMSI Summer School is attracting interest from both domestic and international markets, with over 120 Australian enrolments, and 4 international students attending the Summer School in 2016 event.

Ms Leonie Walsh, the Lead Scientist of the Victorian State Government officially opened the 14th annual event. Ms Walsh and Geoff Prince (AMSI Director) both spoke of the importance of STEM and the need for students to seek a wide skill set in order to fully engage in employment. Each lecturer was then invited to give a brief 3 minute, one slide summary of their subject offering, which was favourably received by students, and also gave Ms Walsh and other members of the public an engaging overview of modern mathematical areas.

This year's Public Lecture was very successful, with over 200 members of the general public attending Margaret Wertheim's talk on "Corals, Carbon and the Cosmos: The Story of Hyperbolic Space", which also attracted some focused media attention.

Students gain valuable knowledge from the specialised subjects offered, and they are exposed to some of the best young lecturing talent we have in Australia. They also made friendships and started to build professional networks, which will aid them in future careers during the four weeks at Summer School. The careers afternoon was well attended and it remains an important mentoring activity for students seeking input into future career paths. The school ended with the Conference Dinner, where the students proved that they had talents in dance above and beyond their mathematical abilities.

The foundation of a successful Summer School begins with an appealing program which the 2016 Summer School had. Ultimately the success of the AMSI Summer School was the result of the hard work, commitment, enthusiasm of talented lectures, committee members, AMSI and RMIT.

Professor Andrew Eberhard
AMSI Summer School 2016 Director

Subjects

02

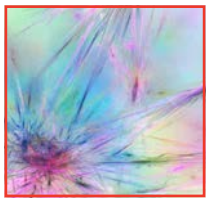
The AMSI Summer School program was organised with events spread evenly across the four week residential school, allowing students to study specialist areas of interest, socialise with their peers, network with industry and/or gain further knowledge into a different area of mathematics.

Students had the opportunity to take one or two honours level subjects for credit towards their Honours or Masters degree. This year, eight subjects were offered in both pure and applied mathematics:

CALCULUS OF VARIATIONS

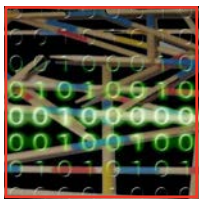
Julie Clutterbuck,
Monash University

Anja Slim,
Monash University



LINEAR CONTROL THEORY

Yoni Nazarathy,
The University of Queensland



COMPLEX NETWORKS

Stephen Davis,
RMIT University

MODERN NUMERICAL METHODS

Jérôme Droniou,
Monash University

CONIC PROGRAMMING

Vera Roshchina,
RMIT University

PROJECTIVE GEOMETRY

John Bamberg,
The University of Western Australia

DESIGN AND ANALYSIS OF EXPERIMENTS

Stelios Georgiou,
RMIT University

STOCHASTIC MODELLING

Giang Nguyen,
The University of Adelaide

Subjects - *Calculus of Variations*

Julie Clutterbuck,
Monash University

Anja Slim,
Monash University

In many physical problems, the solutions we seek minimise an energy, and as a consequence, these solutions will also satisfy a partial differential equation. This subject showed students how to find the partial differential equation associated with an energy; how to ensure that minimisers exist; how to deal with constraints; how to model these problems numerically; and the techniques of stability analysis.

Throughout the subject, the introduction and examination of applications were applied to capillary surfaces, geodesics, hair curling, elastica, optimal control, and the brachistochrone, as well as Hamilton's principle.

Course Content

- Energy functionals
- First variation
- Euler-Lagrange equation
- Existence
- Weak solutions
- Constraints

Lecturers' Comments

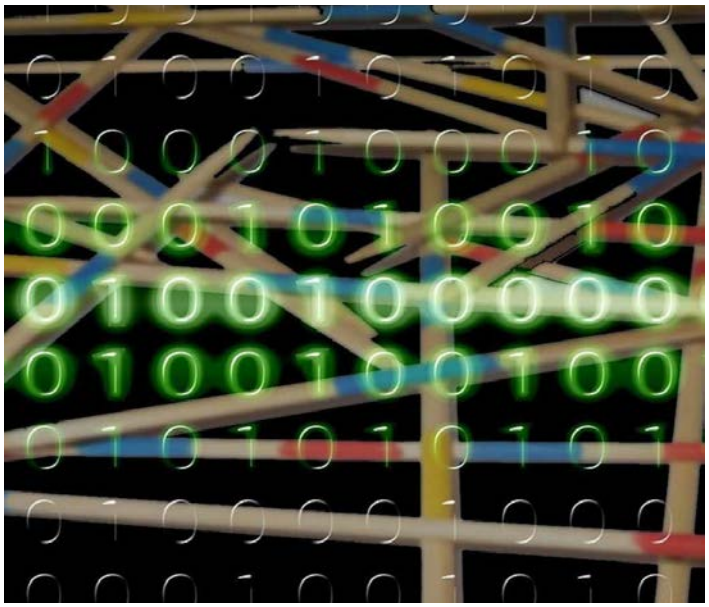
It was very enjoyable to teach a high level subject with such a large and enthusiastic group of students. The students came into the summer school with a range of backgrounds, however, we found the opening quiz very useful as a diagnostic tool.

Our intention was also to develop 'soft skills' such as team work, cross-disciplinary research, modeling, and the presentation of results to a general audience.

"A wonderful combination of theory and practice. Julie Clutterbuck and Anja Slim were great lecturers."

Summer School 2016 Participant

Stephen Davis,
RMIT University



This subject presented the mathematical and statistical techniques used to classify and characterise complex networks, which allowed students to work with real data sets to visualise and study the kinds of networks that arise in ecology and epidemiology.

Course Content

- Graph definitions; paths and circuits; connectedness and components; diameter, radius, centrality; adjacency matrix; path matrix and Laplacian matrix
- Clustering coefficient; cyclic coefficient; spectral properties of graphs; types of graphs; types of networks and detecting core-periphery structure
- Topological structure of networks; degree sequence; degree distribution; the Gini coefficient; k-regular networks; binary tree network; proximity graphs and bipartite graphs
- Small-world networks; the Watts-Strogatz procedure; properties of small-world networks; scale-free networks; network growth models; the rich get richer; the good get richer and properties of scale-free networks
- Measures of centrality; betweenness and closeness; page-rank algorithms; dependency and reliance
- Subgraphs and motifs
- Random networks; Erdos-Renyi (ER) algorithm; Gilbert, ER and anchored random networks; the configuration model; appropriate randomization
- Community detection
- Spatial networks; bond percolation; site percolation; long-range percolation; properties of spatial networks
- Using the statistical programming environment known as Rand working with real network data: food webs and contact data

Lecturer's Comments

The Summer School was a very enjoyable experience, with the engagement and enthusiasm of the students creating a lively lecturing environment and excellent discussions. The students appreciated the mix of lectures, working together in class on problems, the assignment work in the computer labs, and the discussion of journal papers.

"It was perfectly paced with a good mix of information delivery, discussion, problems, and time to digest the material."

Summer School 2016 Participant

Subjects - *Conic Programming*

Vera Roshchina,
RMIT University

Conic programming is one of the core areas in modern optimisation. Conic models such as semidefinite programming have broad applications in real life, but at the same time present nontrivial computational challenges that result in rich underlying theory and interesting research problems. This subject was designed to review the fundamentals of conic optimisation and provide an overview of the research field.

Course Content

- Convex sets: convex and conic hulls, relative interior, recession directions, extreme points and facial structure, polyhedral convex sets
- Duality and separation: projection operator, separation theorem, polars, dual cone, ill-posed problems and distance to infeasibility
- Semidefinite programming (SDP) and generalisations: the cone of positive semidefinite matrices, spectrahedra, strong duality and facial reduction, hyperbolicity cones
- Algorithms and complexity: optimisation problems and feasibility problems, condition numbers and complexity of classic algorithms

Lecturer's Comments

Summer schools are valuable for students, lecturers and organisers alike. The students were motivated and friendly, but also demanding. I thoroughly enjoyed teaching in the AMSI Summer School.

"The lectures provided very good Conic Programming content and were all well prepared."

Summer School 2016 Participant

Stelios Georgiou,
RMIT University

Design and Analysis of Experiments is an important tool that helps researchers to design and perform experiments related to any field of applied science. The methods described in this subject provided an introduction to basic statistical techniques and illustrated the power of statistical experimentation for inference. Emphasis was given to principles and guidelines of fundamental statistical techniques and experiments. Applications and examples were conducted using the Minitab statistical package.

Course Content

- Simple Comparative Experiments
- Experiments with a Single Factor: The Analysis of Variance
- Randomize Blocks, Latin Squares and Related Designs
- Introduction to Factorial Designs
- Two Level Factorial Designs
- Fitting Regression Models

Lecturer's Comments

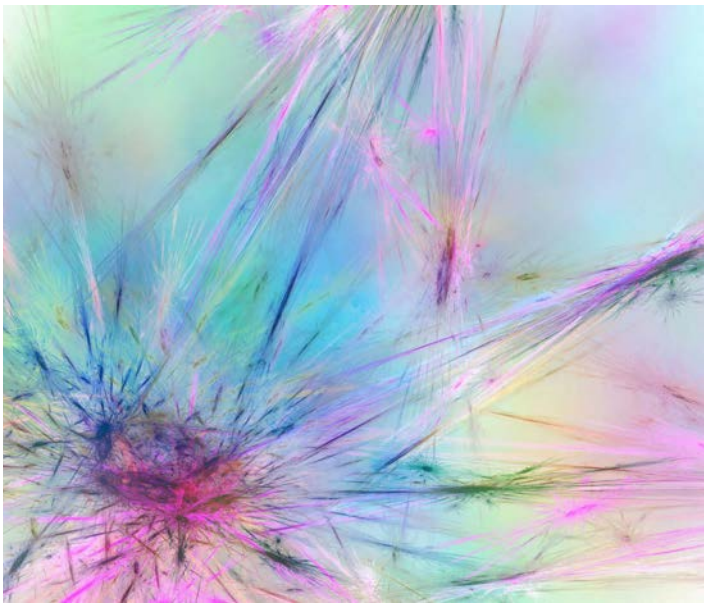
It was my pleasure to teach this subject to the summer school in 2016. The diverse backgrounds of the students required reviewing preliminary results that was necessary to ensure all students had the same preliminary knowledge.

"I enjoyed the time we had in the computer lab using Minitab. Dr Stelios Georgiou was an excellent lecturer, he was clear and concise in his explanations and was approachable for clarification."

Summer School 2016 Participant

Subjects - *Linear Control Theory*

Yoni Nazarathy,
The University of Queensland



This subject covered the core elements of linear dynamical systems, control theory and Markov chains simultaneously, where relationships between these objects also exist. The students explored these related fields together with applications, computation and theory.

Course Content

- Motivating examples from science and engineering
- Linear Time Invariant Systems and Probability Distributions
- Linear Dynamical Systems and Markov Chains
- Selected Markov Models
- State feedback, observers and separation in their design
- Lyapounov Stability for both deterministic and stochastic systems
- Bellman style optimal control for both deterministic and stochastic systems

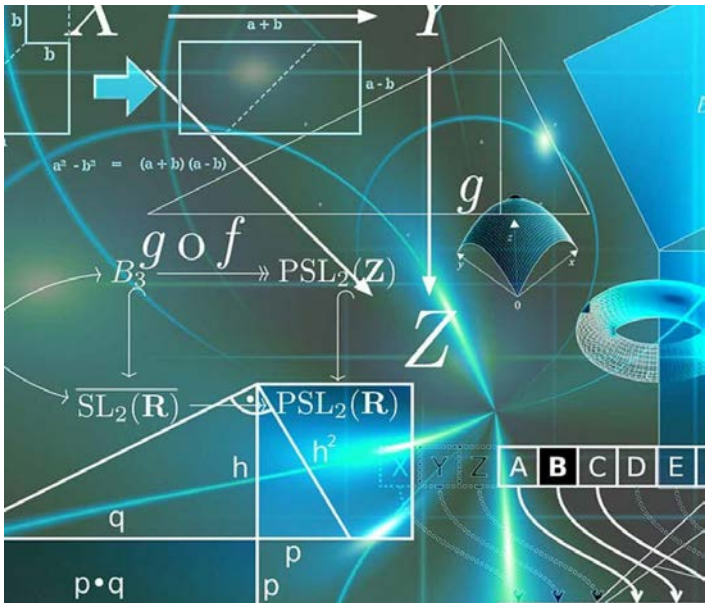
Lecturer's Comments

The seven in-class quizzes allowed the students to be continuously connected to the material and the students got quite a generous view of Linear Control theory. It was a fun (and very intense) four weeks, and I believe both the students and myself learned a lot.

"I most enjoyed the challenge of learning something new and the perspective it brings."

Summer School 2016 Participant

Jérôme Droniou,
Monash University



The content of this subject reviewed numerical methods — mostly finite volume schemes — developed in the past 15 years to tackle the numerical approximation of diffusion models under these engineering constraints. The construction of these schemes hinges on the analytical properties of the equations. These properties were detailed first, before considering the numerical schemes.

Course Content

- Weak formulation of linear diffusion equations, properties of solutions
- Conforming Galerkin methods
- Non-conforming Finite Element methods
- Elements of convergence analysis: gradient scheme framework
- Hybrid Mimetic Mixed methods
- Finite volume methods on orthogonal grids

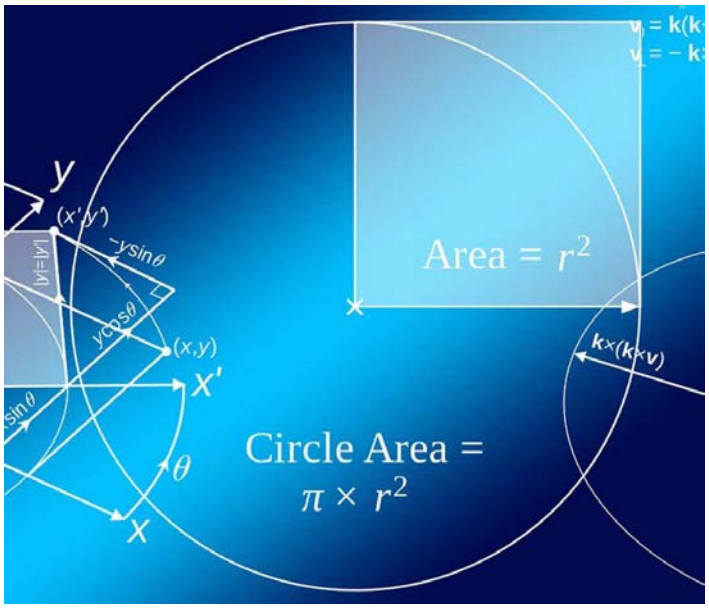
Lecturer's Comments

The AMSI Summer School was a very enriching experience. Giving the course and interacting with the students was a pleasure. Most students acknowledged that the content was challenging and interesting, and I think that they really took something out of the subject. A clear benefit of the program is for students to be exposed to visiting lecturers, and vice versa.

"Jerome Droniou is very well versed in this topic, and was very helpful."

Summer School 2016 Participant

John Bamberg,
The University of Western Australia



There are essentially four schools of practice in geometry: axiomatic, synthetic, analytic and transformational. In most modern day secondary and tertiary education, the analytic perspective holds sway. This course redressed this situation by emphasising the synthetic and transformational approach to projective geometry. The synthetic approach recaptures what geometry is all about, whilst bringing in the modern transformational perspective initiated by Hjelmslev, Hessenberg, Thomsen and Bachmann.

Course Content

- Transformation geometry
- Classification of isometries
- Group actions, permutational isomorphism
- Thomsens calculus of half-turns and reflections
- Geometric invariants
- Doing affine and Euclidean geometry from a projective perspective

Lecturer's Comments

I delivered interactive lectures with exercises, which worked very well, and used the GeoGebra software. The AMSI Summer School was a fantastic thing; the students could extend their knowledge of mathematics, they could meet other students from other institutions and can trade their experiences, and the lecturers could see the landscape of tertiary mathematics education from a different perspective.

"I enjoyed seeing the maths behind a synthetic view of geometry with minimal use of coordinate."

Summer School 2016 Participant

Giang Nguyen,
The University of Adelaide

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

Course Content

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

Lecturer's Comments

In general, I posed a lot of questions throughout the lectures, in order to get the students to actively get involved in class. This interaction between the students and myself worked well.

"A good introduction to measure theory and stochastic processes from a social analytical viewpoint. Giang Nguyen was an excellent lecturer – passionate and highly knowledgeable about Stochastic Modelling."

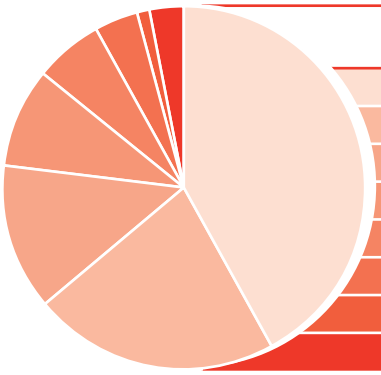
Summer School 2016 Participant

03 Participation Statistics

Enrolments by Institution

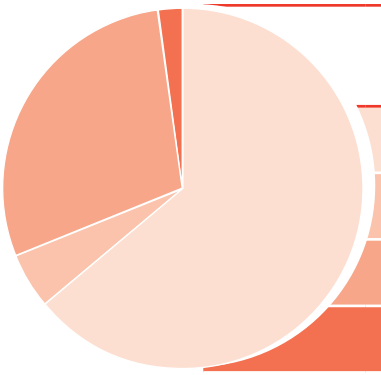
Chung-Ang University	1
Curtin University of Technology	2
Deakin University	1
Federation University Australia	1
Flinders University	4
James Cook University	1
La Trobe University	3
Macquarie University	2
Monash University	13
Queensland University of Technology	2
RMIT University	17
Simula Research Laboratory	2
The Australian National University	8
The University of Adelaide	6
The University of Melbourne	17
The University of New England	3
The University of New South Wales	6
The University of Newcastle	2
The University of Notre Dame Australia	1
The University of Queensland	13
The University of Sydney	1
The University of Western Australia	3
University of South Australia	3
University of Tasmania	1
University of Technology Sydney	6
University of Wollongong	7
Other	1
TOTAL	**127**

Breakdown by State



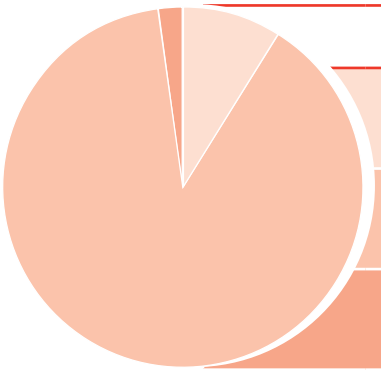
42%	VIC
22%	NSW
13%	QLD
9%	SA
6%	ACT
4%	WA
1%	TAS
3%	International

Breakdown by Residency Status



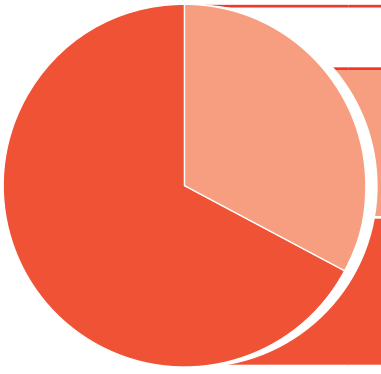
64%	Australian Citizen
5%	Permanent Resident
29%	Student Visa
2%	Other

Breakdown by ATSI



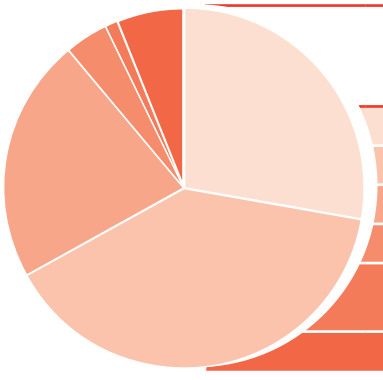
9%	Yes
89%	No
2%	Undisclosed

Breakdown by Gender



33%	Female
67%	Male

Breakdown by Academic Status



28%	PhD
39%	Honours
22%	Masters
4%	Academic
1%	Early Career Researcher
6%	Other

Women in Maths Networking Event

This event, open to all students who identify as any gender, highlighted mathematical career pathways through panel discussions, centred on gender inequality in Science, Technology, Engineering and Mathematics (STEM) subjects and careers.

Panel Members included:

- **Trish Campbell** – Mathematician involved with the Mathematicians in Schools Program with CSIRO
- **Rachael Lanigan** – Industry representative from the National Australia Bank (NAB)
- **Giang Nguyen** – Treasurer of the Women in Mathematics Special Interest Group (WIMSIG)
- **Peter Taylor** – Former Head of the School of Mathematics and Statistics at the University of Melbourne
- **Margaret Wertheim** – Vice Chancellor Fellow in Science Communication at the University of Melbourne

"The classes were interesting, the networking opportunities were great, and I learned some new career paths at the careers afternoon."

Ruvindha Lecamwasam, **The Australian National University**

Careers Afternoon

The careers afternoon gave students the opportunity to:

- Hear employers talk about mathematics and statistics opportunities in the workplace
- Find out about exciting new career opportunities
- Network with different employers
- Ask questions

Companies attended included:

Australian Bureau of Statistics; Australian Government Bureau of Meteorology; Australian Government Department of Defence; CSIRO; DST Group; optiver; pwc; Reserve Bank of Australia

"I enjoyed learning and having the opportunity to study mathematics topics that I wouldn't be able to learn at my own institution."

Adrian Van Etten, **Monash University**

Lunchtime Lectures

Each Wednesday, one-hour lunchtime lectures were organised to introduce students to different aspects of mathematical research completed by academics and their collaborators. Below is a listing of the speakers and the title of their talks:

- Professor Bill Moran, **RMIT University**
  Pas de Deux: Mathematics and Engineering
- Professor J. Hyam Rubinstein, **The University of Melbourne**
  2, 3 and 4 dimensional worlds
- Professor Jerzy Filar, **Flinders University**
  Musings about a career in mathematics
- Professor Peter Taylor, **The University of Melbourne**
  The Paradox of Parrondo's Games

Videos of the lectures can be viewed here:
http://ss16.amsi.org.au/lunchtime-lectures/

Open Day Workshop

Associate Professor Marc Demange, RMIT University, ran the Open Day Workshop. The workshop presented some mathematical models and techniques arising in bushfire emergency management.

This particular context involves specific mathematical problems due to the lack of information and resources, a strong dynamic environment and the necessity to design quick and efficient solutions. It induces fascinating mathematical challenges, particularly in operational research.

Travel Grants

AMSI offers travel grants for students to attend higher education flagship events. This year, 64 students received travel awards to attend the AMSI Summer School 2016 in Melbourne.

Choose Maths Grants

The Choose Maths Grants are designed to offer full or partial support for Australian female mathematical sciences students and early career researchers to participate in the AMSI higher education programs to build and extend their skills and professional networks. These grants provide financial funding to attend and/or assist with caring responsibilities.

The grants are funded by BHP Billiton Foundation and are an initiative of the Choose Maths Project.

In 2015, three students were awarded a Choose Maths Grant to attend AMSI Summer School 2016:

- Azam Asanjarani, **The University of Queensland**
- Xuemei Liu, **University of South Australia**
- Meghann Spinner, **University of Wollongong**

CHOOSE MATHS

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Social Events

05

The Summer School featured a number of social events, designed to bring students together to break the ice and give overtaxed minds a chance to relax.

Open Day Campus Tour & Orientation Event

The Summer School's social event calendar opened with a Silent Disco tour around the RMIT University City Campus. Students listened to music on headphones, as they were encouraged to dance around the campus. Students also participated in getting-to-know-you games.

Food Truck Lunches

Food Truck lunches were organised for two days during the Summer School. There were many catered events at Summer School, so the Food Truck days were purposely spread out. The first day was on Open Day, with the second in Week 3. With the diverse food requirements of students in mind, the school engaged the services of Cornutopia who were able to cater to all food requirements from Halal to Vegan.

Cinema Nights

This year Summer School hosted weekly cinema nights in the newly built cinema spaces at RMIT University's Swanston Academic Building (SAB). The movies shown all had a mathematical theme:

WEEK 1: The Imitation Game (2014)

WEEK 2: The Theory of Everything (2014)

WEEK 3: 21 (2008)

Chess Night

The Chess Night was organised by RMIT University's Chess enthusiast and Mathematics PhD student, David Ellison in the fourth week of the program. The Chess Night involved friendly chess games, chess related puzzles, and lots of snacks. It provided for a social and relaxed environment for students to play chess, snack on lollies, and reflect on their Summer School experiences to date with their fellow peers. The session was such a hit with students that the duration of the session was extended by an additional 1.5 hours.

Conference Dinner

The Conference Dinner was organised as the final event for the Summer School, and was a chance for students, speakers and staff to relax at the end of a rigorous four weeks of study/teaching. The dinner was held at Rydges Bobby McGee's, one of Melbourne's most unique function venues. Guests celebrated the end of the school and talked about future plans.

Geometry, according to Jesse Lansdown, is both elegant and satisfying. A motivator for many areas of mathematics, its beauty lies in the visual aspect it brings to the abstraction of theory, and its ability to intrigue and challenge.

Based at the University of Western Australia, where he is completing a PhD, Jesse is currently exploring the existence or non-existence of ovoids, a set of points where every line is incident with exactly one point, in polar spaces.

"Summer School is a fantastic opportunity to learn from national mathematical leaders while meeting other young mathematicians from around Australia."

"I look at when ovoids occur and why or why not. This research has a range of applications including cryptography and coding theory. The advantage of applying geometry is that the nice structures are efficient and easy to implement," Jesse explains.

While he has always loved mathematics, Jesse didn't see it as a career pathway until he began university. Initially enrolled in Engineering, he decided to take on a second major in Mathematics. Realising his passion was matched with a natural aptitude he eventually left Engineering behind to study a Mathematics degree.

"AMSI does a great job at encouraging mathematics at all levels. This is really important as younger students and the public are often not aware of what maths has to offer. Many people tend to view maths as elusive or obscure when in actual fact it is useful, learnable and interesting!"

"I have always enjoyed mathematics. I had a number of great teachers at high school who not only encouraged me but also helped me see the challenge and satisfaction it could bring. However, I only took it seriously after I started university."

So seriously in fact that he recently decided to spend his summer break studying at AMSI Summer School 2016. An opportunity he relished, he built new networks and learnt from leaders in his field.

"I chose to study Projective Geometry, as well as attending some of the Conic Programming classes on offer. Projective Geometry is fundamental to the general study of geometry and many problems are easier to solve when viewed projectively. I learnt a lot and had a great time," he explains.

Quick to recommend AMSI Summer School to other students, Jesse is full of praise for the events' success in fostering engagement between mathematical science leaders and students, as well as seeding collaboration.

"Summer School is a fantastic opportunity to learn from national mathematical leaders while meeting other young mathematicians from around Australia. The high standard of the classes and its great mix of learning and fun exceeded my expectations."

A supporter of the AMSI's efforts to enhance the profile of Australian mathematics, Jesse remains impressed by the institute's ability to create opportunities for people at all levels to engage with the discipline.

Corals, Carbon and the Cosmos:

THE STORY OF HYPERBOLIC SPACE

The internationally noted science writer and exhibition curator, Margaret Wertheim, was the public speaker at the Summer School. Margaret's work focuses on relations between science and the wider cultural landscape. She is the author of six books, including The Pearly Gates of Cyberspace, a ground breaking exploration of the history of Western concepts of space from Dante to the Internet, and she has written for the New York Times, Los Angeles Times, The Guardian, and many other publications. She is a contributing editor at Cabinet, the international arts and culture journal, where she often writes about mathematics.

The evening public lecture titled "Corals, Carbon and the Cosmos: The Story of Hyperbolic Space" was held on Thursday, 14 January. This multifaceted talk bridged the domains of mathematics and culture, as science writer and exhibition curator Margaret Wertheim discussed the story of hyperbolic space, followed by a Q&A session. The lecture concluded with a networking event.

Margaret Wertheim

Media Release

Throughout the natural world – in corals, cactuses, sea-slugs and lettuce leaves – we see swooping, curving and crenelated forms. All these are biological manifestations of hyperbolic geometry; an alternative to the Euclidean geometry we learn about in school. While nature has been playing with permutations of hyperbolic space for hundreds of millions of years, human mathematicians spent centuries trying to prove that such forms were impossible.

The discovery of hyperbolic geometry in the nineteenth century helped to usher in a mathematical revolution, giving rise to new ways of mapping and analysing curved surfaces. Such "non-Euclidean geometry," now underlies the general theory of relativity and thus our understanding of the universe as a whole.

If the cosmos may be a hyperbolic manifold, at the molecular level carbon atoms can assemble into hyperbolic lattices, giving rise to exotic new materials. Meanwhile, on the Great Barrier Reef, global warming and the human deluge of carbon into our oceans are threatening the corals making hyperbolic structures.

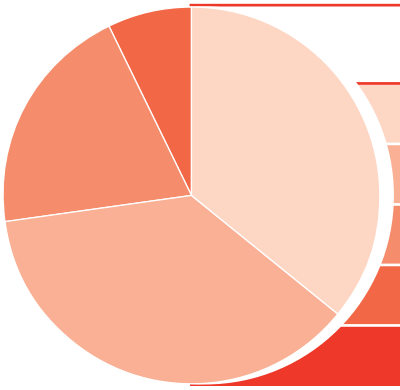
In this multifaced talk bridging the domains of mathematics and culture, science writer and exhibition curator Margaret Wertheim discusses the story of hyperbolic space. How do hyperbolic forms arise in nature, in technology, and in art? And what might we learn about alternative possibilities for being from a mathematical discovery that redefined our concept of parallel lines.

In the Media

Crochet Coral, Possible New Planet,
774ABC, 21 January, 2016

Maths Worthy of a Golden Globe,
ABC Morning Show, 14 January 2016

Corals, Crochet and the Cosmos: How Hyperbolic Geometry Pervades the Universe,
The Conversation, 28 January 2016



I made useful contacts at Summer School

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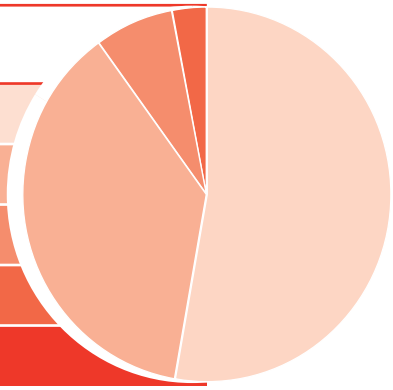
The subjects I took were of a high standard



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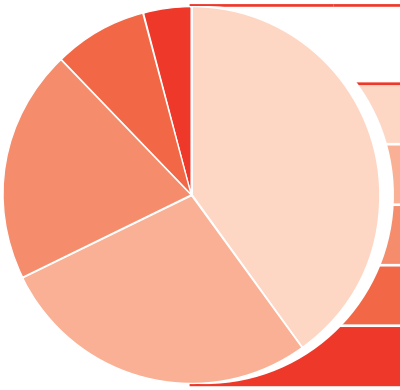

The Careers Afternoon highlighted work opportunities

STRONGLY AGREE
AGREE
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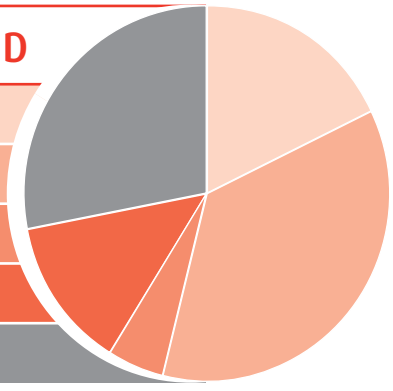
STRONGLY DISAGREE

Post Summer School attendee is looking at possible PhD



STRONGLY AGREE
AGREE
NEUTRAL
DISAGREE
NOT APPLICABLE

Committees

AMSI wishes to acknowledge the generous donation of time and scientific advice of the following committees - without their contribution this event would not be a success.

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AMSI Summer School 2016 Director

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RMIT University

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Australian Mathematical Sciences Institute

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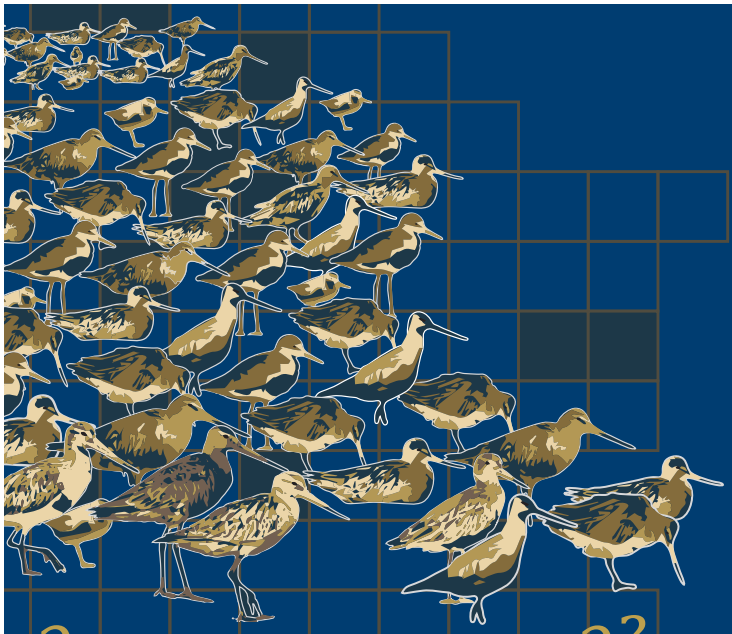
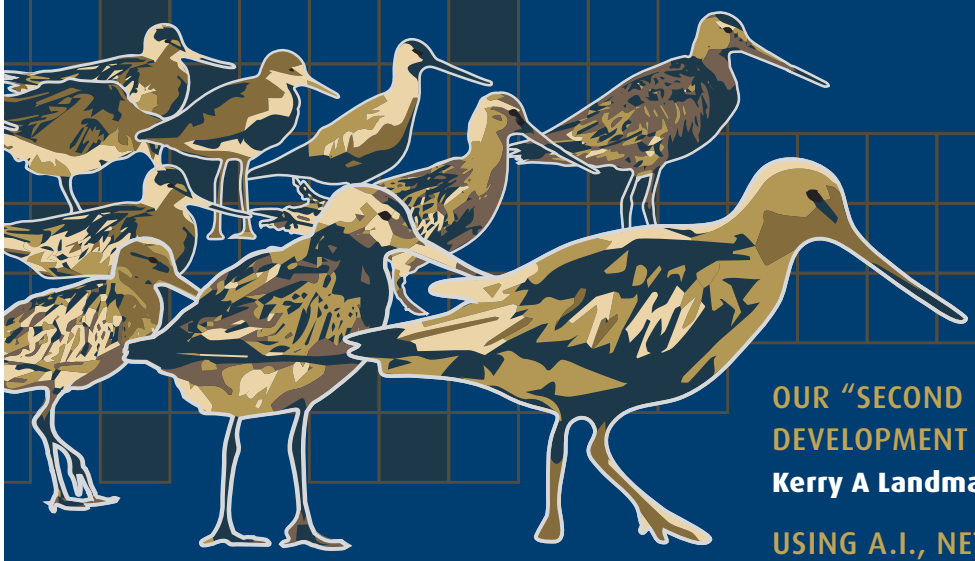


$$\frac{\partial p}{\partial t} = f(x) + \alpha \frac{\partial^2 p}{\partial x^2}$$



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USING LONG READ SEQUENCING FOR WHOLE GENOME ASSEMBLY
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IMAGE: OVERLAPS BETWEEN KNOWN BIOLOGICAL PROCESSES BY VILLE-PETTERI MÄKINEN, SAHMRI

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COMPUTATIONAL BAYESIAN STATISTICS
Scott Sisson, The University of New South Wales

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Markus Hegland, The Australian National University

GEOMETRIC GROUP THEORY
Lawrence Reeves, The University of Melbourne
& Anne Thomas, The University of Sydney

HARMONIC ANALYSIS
Pierre Portal, The Australian National University

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