AMSI VACATION RESEARCH SCHOLARSHIPS 2017-2018

STEP INTO RESEARCH THIS SUMMER

EVENT REPORT

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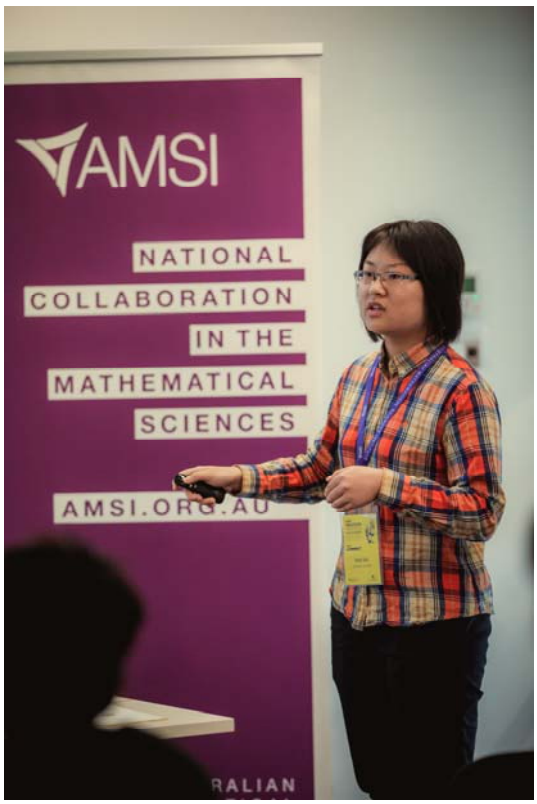
AMSI Vacation Research Scholarships 2017/18

Undertaken at AMSI Member Universities

December 2017 to February 2018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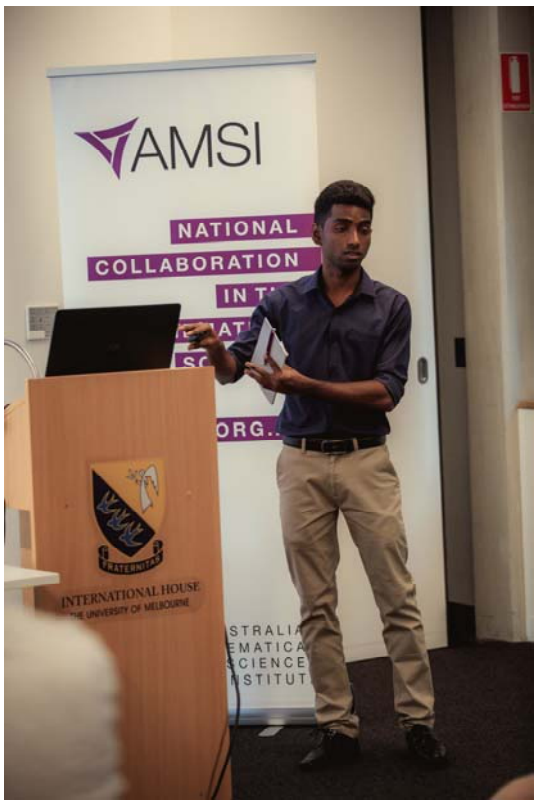
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FOREWORD

AMSI Vacation Scholars experience life as researchers, completing a six-week research project in the mathematical sciences of their choice, and presenting their findings to their peers at AMSI's two-day residential student conference AMSIConnect. Aiming to inspire students to continue with further research, the AMSI Vacation Research Scholarship has led some students to their first academic publication.

This annual scholarship program is open to intending honours and masters students studying at an AMSI Member University, and is an exciting opportunity to advance mathematical skills, develop an interest in research and expand the academic experience. Applicants are required to outline a core research component to their proposed project and identify clear outcomes, as well as meet high academic standards and be supported by their AMSI Member University. These scholarships are awarded on a competitive basis for projects in the mathematical sciences.

After receiving 65 applications for 2017/18, the program funded 39 Scholars to spend their summer holidays working on academic research in the mathematical sciences with a supervisor at their home university. Each Scholar was required to prepare an academic research report, as well as a blog post accessible to a non-specialist audience. The VRS experience culminated in the Scholars presenting their research and findings at AMSIConnect.

AMSIConnect was hosted by AMSI on 8-9 February 2018 at The University of Melbourne's International House. Scholars are funded to travel to and stay in Melbourne to participate in this event, which is an invaluable professional-development experience in communication and networking skills.

The AMSI Vacation Research Scholarships 2017/18 program was jointly funded by the Australian Mathematical Sciences Institute and the Australian Government's Department of Education & Training. The program is part of the Institute's Securing Australia's Mathematical Workforce project.

"The student talks were terrific, such high-quality slides delivered with confidence and often panache. The atmosphere is friendly and the audience well engaged.

Thanks to AMSI's Research and Higher Education team for their flawless organisation. And thanks to all the supervisors for their mentorship."

Professor Geoff Prince
Director
Australian Mathematical Sciences Institute

"It was a privilege to run this program over the summer for such a passionate group of undergraduates. The national appreciation for mathematics and science-communication skills was evident from Day One of AMSIConnect. This program defines the start of their research careers."

Chloe Pearse
Program Manager, Research & Higher Education
Australian Mathematical Sciences Institute

PROGRAM MANAGER'S REPORT

CHLOE PEARSE

Australian Mathematical Sciences Institute

AMSI's Vacation Research Scholarship program has been a highly sought-after scholarship since 2003/04. The program funds undergraduate students from across Australia to complete a six-week research project over their summer break. The scholarships are awarded on a competitive basis for projects in the mathematical sciences.

In 2017/18, 39 students completed the program having been selected from 65 applicants to become AMSI VRS Scholars and complete their research project. Applicants were required to outline a clear research component to their project and to identify outcomes. Special thanks to our academic panel — Professor Brian Davey from Latrobe University and Professor Geoff Prince from AMSI for their assistance.

VRS Scholars experienced life as a researcher — completing actual research projects under the supervision of academics at their home university — giving them a taste of what it's like. The program inspires students to continue with further research in the future. For some students, a Vacation Research Scholarship project leads to their first academic publication.

At the end of summer, VRS Scholars came together in Melbourne to present their findings to their peers and supervisors at AMSIConnect. This provided the VRS Scholars with a valuable professional-development experience in communication and networking skills, and a unique opportunity to meet like-minded students in a mathematical conference setting.

A major highlight of AMSIConnect program was the opportunity for Scholars and Supervisors (academics) to network. The conference commenced on 7 February, with an ice-breaker dodgeball tournament and welcome dinner. Scholars were allocated to random teams and following a series of games, the two best-performing teams played off in a high-standard final. The tournament was well-received with Scholars showing their competitive streak and exhibiting excellent team-working skills.

AMSI Director Professor Geoff Prince opened the formal program with a warm welcome to students and supervisors from all across Australia. Nigel Clay took the students on a fascinating journey as he talked about life as a PhD student at RMIT University. 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 mathematic sciences.

AMSIConnect 2018 was hosted by AMSI at The University of Melbourne's International House and was a wonderful experience for all those attending. Over the two days, Scholars delivered high quality presentations about their research projects, prompting questions and debate amongst the audience. As well as formally finding out about each other's research, the Scholars had plenty of time for networking during dinner and break times. The final session given by AMSI Director gave Scholars a unique opportunity to discuss future study and career opportunities in a small group setting.

RESEARCH PROJECTS

Forty-one Scholars from 13 AMSI Member Universities were awarded an AMSI Vacation Research Scholarship in 2017/18. Thirty-nine Scholars completed research with a supervisor for their chosen project (two Scholars were forced to withdraw from the program due to external circumstances). Each student prepared a research report and a blog post, presenting their research and findings at AMSIConnect in February 2018. Research reports and blog posts can be viewed on the AMSI Vacation Research Scholarship website at www.vrs.amsi.org.au.

AMSI would like to express its appreciation to all Vacation Research Scholarship supervisors who gave their time and expertise to the Scholars and their projects. Their contribution is integral to the success of the program.

UNIVERSITY	STUDENT	SUPERVISOR	PROJECT TITLE
Australian National University	Dominique Douglas-Smith	Barry Croke	Nonlinear unit hydrograph models of rainfall-streamflow events for water quality analysis
	Edric Wang (The University of Sydney)	Scott Morrison	Tensor Networks and Categories
	Jane Tan	Vigleik Angeltviet	Spectral sequences in algebraic topology
Federation University	Tanya Pedersen* **withdrawn*	Dean Webb, Diederik Roijers, Peter Vamplew	Determining and Evaluating Bounded Algorithms for MOMAB
La Trobe University	Patrick Adams	Grant Cairns, Yuri Nikolayevsky	Planar Graphic Sequences
	Yao Tang	Grant Cairns, Yuri Nikolayevsky	Algebra and geometry of quandles
Monash University	Asama Qureshi	Yann Bernard, Ting-Ying Chang	Estimating constants in generalised Wente-type estimates
	Drew Mitchell	Hans De Sterck	Numerical Optimisation Methods for Big Data Analytics
	Liam Hernon	Josh Howie, Norman Do	Knots, polynomials and triangulations
	Marcus Pensa	Mark Flagg	An inverse modified Helmholtz problem for identifying morphogen sources from sliced biomedical image data

	Michael Fotopoulos	Yann Bernard	Functionals of higher-order derivatives of curvature for surfaces
	Phillip Luong	Hans De Sterck, Grégoire Loeper	Numerical Optimisation Applied to Monte Carlo Algorithms for Finance
	Robert Hickingbotham	Andreas Ernst	Splitting integer linear programs with a Lagrangian axe
	Sean Malcolm	Norman Do	Parallelogram polyominoes, partitions and polynomials
	Tim Banova	Michael Payne	Colouring intersection graphs of complete geometric graphs
Queensland University of Technology	Jacob Ryan	Scott McCue	Reaction diffusion models for cell motion
	Joel Rutten	Pascal Buenzli, Matthew Simpson	Patterns in Turing patterns: sequential growth and the inhibitory cascade
	Steven Kedda	Fawang Liu	Parameter Estimation for the Fractional Order Nonlinear Dengue and Epidemic Models
	Tamara Tambyah	Matthew Simpson	Incorporating FUCCI technology in discrete random walk models of collective cell spreading
University of Newcastle	Riley Cooper	Hamish Waterer	Lot Sizing on a Cycle
Swinburne University of Technology	Chrishan Christesious Aloysious	Tonghua Zhang	Time delays in modelling the bubble chain system
The University of Adelaide	James Beck	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	Patty Solomon, John Moran	Using Meta-Analysis and Statistical Learning to Identify Sepsis Biomarkers
	Miriam Slattery	Giang Nguyen	Optimal Animal Foraging in a Two-Dimensional World
	Rose Crocker	Sanjeeva Balasuriya	Extracting coherently moving flow structures from fluid flows

	Tobin South	Lewis Mitchell, Matthew Roughan	Network Analysis of the Spotify Artist Collaboration Graph
University of Western Australia	Vishnu Mangalath	Lyle Noakes	Simplicial homology and computation from nerves
University of Wollongong	Angus Alexander	Adam Rennie, Alan Carey	Dirac operators on manifolds and applications to physics
	Lachlann O'Donnell	Glen Wheeler	Fully nonlinear curvature flow
	Quinn Patterson	Adam Rennie, Alan Carey	Differential operators on manifolds and positive scalar curvature
The University of Melbourne	Benjamin Metha	Jennifer Flegg	Modelling the spread of malaria and antimalarial drug resistance
	Bing Liu	Laleh Tafakori	Forecasting of Realised Variance Measure
	Finn McGlade	Yaping Yang, Arun Ram	Notes on alcove path models and affine Springer fibres
	Jiangrong Ouyang	Sophie Hautphenne	Stochastic models for populations with a carrying capacity
	Tianhe Xie	David Balding, Jennifer Flegg	The population history of indigenous Australians: what can the available genetic data tell us?
The University of Sydney	Leo Jiang	Zsuzsanna Dancso	Niemeier Lattices and Homological Algebra
	Ruebena Dawes	Michelle Dunbar	Mathematics in Medicine: Using Optimisation to Improve Cancer Treatment
	Syamand Hasam	Uri Keich	The Effects of Dependency in False Discovery Estimation using Target-Decoy Competition
	Yilun He	Uri Keich, Kristen Emery	Confidence control for false discovery proportion
	Yueyi Sun	Beniamin Goldys	Can we make money using the game theory?

"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

AMSIConnect

AMSIConnect 2018 gave students the experience of presenting their research in a conference setting. It provided an opportunity to network, engage in debate and conversation, and explore future career pathways. Outside of academic pursuits, everyone enjoyed ice-breakers and social events including dodgeball, dinners and drinks.

Dodgeball Icebreaker

Scholars were welcomed to AMSIConnect in Melbourne at International House by the AMSI Research and Higher Education team, and got the ball rolling with the annual VRS Dodgeball tournament. Everyone participated in friendly round-robin matches that brought out their team-working skills and competitive energy.

Networking & Social Events

As well as exploring unfamiliar areas of research, Scholars were encouraged to network, collaborate and socialise with other like-minded individuals during AMSIConnect. To facilitate this, the program included a number of formal and informal networking opportunities such as a welcome pizza dinner, second-night BBQ and catered break times.

Guest Speakers

Life as a PhD Student

Nigel Clay (RMIT)

Nigel Clay kicked off Day One of the AMSIConnect program by describing the ups and downs of a research journey linking the mathematical sciences to real-world outcomes. Nigel is completing a PhD, modelling an optimal supply chain of blood for transfusions in partnership with the Australian Red Cross Blood Service.

Life as a Researcher

Associate Professor Andrew Robinson (Centre of Excellence for Biosecurity Risk Analysis, The University of Melbourne)

Andrew Robinson spoke to the AMSIConnect VRS Scholars about his life as Director of the Centre of Excellence for Biosecurity Risk Analysis (CEBRA). Drawing on his background in biosecurity, Andrew discussed the importance of flexibility or "pivoting" in shaping an interesting research career in the mathematical sciences.

Careers in Maths

Professor Geoff Prince (Australian Mathematical Sciences Institute)

AMSI Director Geoff Prince closed this year's AMSIConnect event with information and careers advice on where mathematics and statistics could take the scholars. Geoff shared 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 post-graduate study including applying for and undertaking a PhD.

Research Presentations

Over the two days, Scholars delivered high-quality twenty-minute presentations. They provided an overview of their project and findings and conveyed their research in a professional and engaging manner. Presentations were held in parallel sessions and Scholars were encouraged to carefully select and attend other presentations, to learn from others and improve their own skills and knowledge in the mathematical sciences.

Best Presentations

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. 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”.

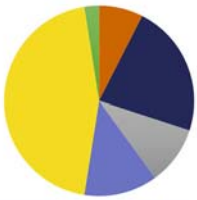
Left to right: Michael Ucci, AMSI Director Professor Geoff Prince, Tobin South.

PARTICIPATION BREAKDOWN

UNIVERSITY

The Australian National University	3
Federation University Australia	1
La Trobe University	2
Monash University	9
Queensland University of Technology	4
Swinburne University of Technology	1
The University of Adelaide	5
The University of Melbourne	5
The University of Newcastle	1
The University of Sydney	5
The University of Western Australia	1
University of Wollongong	3
TOTAL	**40***

*One student participated in four out of six weeks of the VRS program but withdrew in the early 2018 due to external circumstances.



STATE/TERRITORY

ACT	3	7%
NSW	9	22%
QLD	4	10%
SA	5	13%
VIC	18	45%
WA	1	3%

GENDER

Male	29	72%
Female	11	28%

RESIDENCY STATUS

Australian Citizen	34	85%
Permanent Resident	1	2%
Student Visa	5	13%

ATSI STATUS

Yes	0	0%
No	40	100%

"[I found VRS highly valuable for] seeing what other people my age are doing, learning about areas of maths I rarely encounter at my own university, and the pleasant surprise of being able to follow and ask meaningful questions about most presentations."

Quinn Patterson

University of Wollongong

FEEDBACK ANALYSIS

Seventy-four per cent of VRS Scholars completed the online survey to provide their feedback and comments on the scholarship program and AMSIConnect event.

There was unanimous support for the satisfaction with the quality of the scholarship program with 100 per cent of responses agreeing or strongly agreeing that VRS experience was positive and rewarding.

In rating their overall VRS program and AMSIConnect event experience on a scale of 1 to 10, where 1 is poor and 10 is excellent, the respondents' average rating was 8.3.

THE EXPERIENCE OF UNDERTAKING A RESEARCH PROJECT WAS POSITIVE AND REWARDING

Strongly Agree	86.2%
Agree	13.8%
Neutral	0%
Disagree	0%
Strongly Disagree	0%

THE EXPERIENCE OF PRESENTING MY RESEARCH AT AMSIConnect WAS POSITIVE AND REWARDING

Strongly Agree	72.4%
Agree	27.6%
Neutral	0%
Disagree	0%
Strongly Disagree	0%

I FOUND THIS RESEARCH PROJECT A GOOD OPPORTUNITY TO EXPLORE MY CHOSEN AREA OF MATHEMATICS

Strongly Agree	82.8%
Agree	17.2%
Neutral	0%
Disagree	0%
Strongly Disagree	0%

I MADE USEFUL CONTACTS AND NETWORKS AT AMSIConnect

Strongly Agree	69%
Agree	24.1%
Neutral	6.9%
Disagree	0%
Strongly Disagree	0%

VRS HAS STRENGTHENED MY RESOLVE TO CONTINUE ONTO A MASTERS/HONOURS COURSE

Strongly Agree	65.5%
Agree	20.7%
Neutral	13.8%
Disagree	0%
Strongly Disagree	0%

OVERALL, THE AMSIConnect EVENT WAS WELL-ORGANISED BY AMSI

Strongly Agree	86.2%
Agree	13.9%
Neutral	0%
Disagree	0%
Strongly Disagree	0%

FEATURED PROJECT

OPTIMAL ANIMAL FORAGING IN A TWO-DIMENSIONAL WORLD

Miriam Slattery, The University of Adelaide

1 ABSTRACT

This paper aims to maximise the efficiency of a foraging animal locating unknown food targets, under the assumption that the animal moves in a Lévy walk. Both destructive and non-destructive forms of foraging are considered. We use simulations to verify the known optimal results —

$\mu_{opt} \to 1$ *for destructive foraging* $\mu_{opt} = 2 - \left(\ln \frac{\lambda}{r_v}\right)^{-2}$ *for non-destructive foraging*

— for the simple one-dimensional space, and also explore the analytic optimisation for this case. We then extend the model into a two-dimensional foraging space, in which simulations are again employed to seek the optimal solution:

$\mu_{opt} \to 1$ *for destructive foraging* $\mu_{opt} \to 3$ *for non-destructive foraging.*

2 INTRODUCTION

Search processes, in which a searcher seeks targets in unknown locations are important in many physical, chemical and biological problems; for example, reactants diffusing in solvent until they are close enough to react, a protein finding its specific target on DNA or coast guards seeking wreak victims. In this paper, the motivating example is an animal in search of food targets in unknown positions. Note that this is a stochastic process rather than deterministic since the location of food targets is unknown. We seek to optimise the way in which the animal moves such that it will find the food targets most efficiently. Since the location of these targets is unknown to the searcher, it is not simply a shortest path problem. This scenario is of interest because it is assumed that animals have evolved to walk in such a way as to find food most efficiently, so if we seek to model and learn about animal behaviour, we should solve this optimisation problem.

To begin with, we explore the simpler one-dimensional case, in which the animal is restricted to moving only along a line. The results for maximum efficiency proposed by Viswanathan et al. will be confirmed through both simulations and an analytic approach.
Then the stochastic optimal foraging problem is extended to a two-dimensional space. Similarly [in] the one- dimensional case, we use simulations to find the optimal solution.

Miriam's full research report can be found at:
www.vrs.amsi.org.au/wp-content/uploads/sites/6/2018/04/slattery-researchpaper.pdf

BLOG POST

"WHAT DO I TELL MY PARENTS?"

Finn McGlade, The University of Melbourne

Here's an excerpt from a REAL conversation I had with my mum.

My Mum: "Hi Finn, what have you been doing with your summer"

Me: "Maths is great, this summer I've been working on a refined alcove path model for affine Springer fibres."

My Mum: "Oh yeah, sounds interesting, what's an affine springer fibre?" My response….

Let k be an algebraically closed field, G a connected reductive group over k, and A a maximal torus in G. Let $\mathbb{F} = k((\epsilon))$ be the field of formal Laurent series over k and write $\mathrm{Lie}(G)$ for the Lie algebra of G. We define $\mathbf{G} = G(\mathbb{F})$ to be the loop group of G and set $\mathfrak{g} = \mathrm{Lie}(G) \otimes_k \mathbb{F}$. Next we define $\mathbf{X}^*(A) = Hom(A, k^\times)$ (resp. $\mathbf{X}_*(A) = Hom(k^\times, A)$) to be the character (resp. cocharacter) of A and set $\mathfrak{a} = \mathbf{X}_*(A) \otimes_{\mathbb{Z}} \mathbb{R}$.

Fix a Cartan subalgebra $\mathfrak{h}$ of $\mathfrak{g}$. For each $\alpha \in \mathfrak{h}^*$ let

$$\mathfrak{g}_\alpha = \{X \in \mathfrak{g} \mid \text{if } Y \in \mathfrak{h} \text{ then } [Y, X] = \alpha(Y)X\}$$

The *root system of* $\mathfrak{g}$ is

$$R = \{\alpha \in \mathfrak{h}^* \mid \mathfrak{g}_\alpha \neq 0 \text{ and } \alpha \neq 0\}$$

For each $y \in \mathfrak{a}$ and $t \in \mathbb{R}$ define $\mathbf{G}_{y,\geqslant t}$ to be the parahoric subgroup of $\mathbf{G}$, with Lie algebra

where the direct summand above ranges through all values of $(\alpha, k) \in \mathfrak{h}^* \oplus \mathbf{Z}$ such that $\alpha(y) + k \geqslant t$. For further details concerning this definition see [9].

Let V be a finite dimensional G-module and define $\mathbf{V} = V \otimes_k \mathbb{F}$. For each $\lambda \in \mathbf{X}^*(A)$, let V_λ denote the weight space

$$V_\lambda = \{v \in V \mid \textit{if } a \in A \textit{ then } av = \lambda(a)v\}$$

For each $y \in \mathfrak{a}$ and $t \in \mathbb{R}$ define

$$\mathbf{V}_{y,\geqslant t} = \bigoplus_{\lambda(y)+k \geqslant t} \epsilon^k V_\lambda$$

where the direct summand above ranges through all values of $(\lambda, k) \in X^*(A) \oplus \mathbf{Z}$ such that $\lambda(y) + k \geqslant t$. For further details concerning this definition see [9].

Defintion 2.1.1. Let $v \in \mathbf{V}$, $t \in \mathbb{R}$ and $y \in \mathfrak{a}$. *The generalised affine Springer fibre* $\mathcal{F}_y(t, v)$ *of* v *in the affine flag space* $\mathbf{G}/\mathbf{G}_y$ is

$$\mathcal{F}_y(t, v) = \left\{g\mathbf{G}_y \in \mathbf{G}/\mathbf{G}_y \;\middle|\; g^{-1} \cdot v \in \mathbf{V}_{y,\geqslant t}\right\}$$

where we have abreviated notation by writing $\mathbf{G}_y$ in place of $\mathbf{G}_{y,\geqslant 0}$

This interaction put me a reflective mood. Was the above definition really the best way of communicating my research? I wasn't sure, judging by her reaction she seemed displeased with the definition, perhaps I needn't have stated it in such generality. Maybe she would have been content with an example?

My supervisor once told me that one-sentence answers are best when communicating your research to those outside of the know. I brainstormed this one.

My Mum: "Oh yeah, sounds interesting, what's an affine springer fibre?"

Me: "Hmmm good question mum, you could think of it as infinitely many spheres each glued to one another at a single point, like an infinitely long chain of spherical beads."

This response seemed decent although in truth affine Springer fibres constitute a far more general class of objects. Moreover, the reality is that even this response would appear to otherworldly for my mum. "Why the hell would anyone be interested in spending there summer studying infinitely long chains of spherical beads".

Such a reaction from my mum allowed me to ponder further on how we can present the world of abstract mathematics to the general public. The physicists need only evoke the wonders of black or the absurdity of the quantum world in order to captivate an audience.

However abstract mathematics often feels far removed from the realm of our physical experience, and as such the intricacy and inherent beauty of the structures involved is often hard to convey. This presents an issue for mathematics education. How are we meant to encourage people, particularly the younger generation, to become interested in the work that mathematicians do?

This, I think, is less related to the content we teach our youngins, and more to do with attitudes we foster. For instance, when I was in high school, I was more or less under the impression that mathematics was a "solved" field. That there weren't any outstanding problems and that it was just a useful tool for the other sciences. This is rather depressing, given what I now understand as the wondrous landscape of mathematics.

Finn's blog post can be found at:
www.vrs.amsi.org.au/what-do-i-tell-my-parents/

STUDENT PROFILE

MUSIC AND VRS PROVE PERFECT SUMMER MIX

Tobin South, The University of Adelaide

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.

“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,” he says.

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.

“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,” he says.

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STEP INTO RESEARCH THIS SUMMER

APPLY FOR AN AMSI RESEARCH SCHOLARSHIP

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