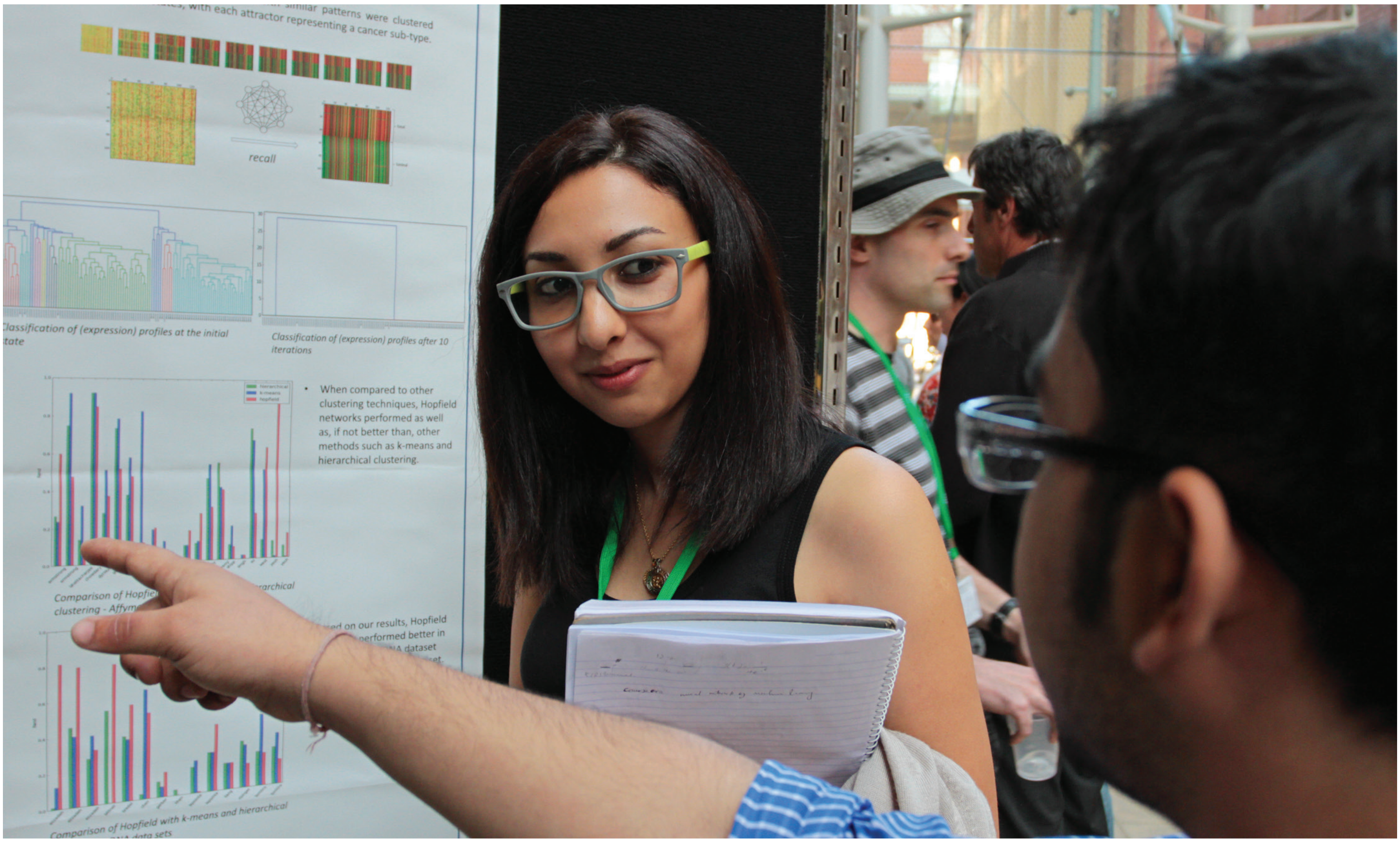


2013/14

AMSI Vacation Research Scholarships

AMSI
AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

CSIRO

Australian Government
Department of Education

Mathematics of Planet Earth 2013
AUSTRALIA

INTRODUCTION

Inspiring the next generation of researchers

Each year undergraduate students are funded under the AMSI Vacation Research Scholarship program to complete six-week research projects over the summer holidays. The scholarships are awarded on a competitive basis for projects in the mathematical sciences.

Students complete their research project under the supervision of academics at their home university. At the end of summer, students come together with CSIRO Vacation Scholars to present their findings at the Big Day In Conference.

The projects give students a taste of mathematical sciences research and aim to inspire students to take up research careers. The opportunity to meet their peers and present their findings at Big Day In gives students invaluable professional development in communication and networking skills.

For some students the Vacation Research Scholarship project leads to their first academic publication.

AMSI thanks CSIRO for their continued support of the Vacation Research Scholarship program.

"AMSI programs provide the next generation of mathematicians the opportunity to pursue their interests and be inspired by world leaders in the field. In this way AMSI are helping secure Australia's reputation at the forefront of scientific research. And they allow us budding mathematicians to delve deeper into mathematical research and get a taste for what's to come outside of academia."

- Anthony Clissold, Flinders University

RESEARCH PROJECTS

56 students were awarded 2013/14 AMSI Vacation Research Scholarships.

NAME	UNIVERSITY	PROJECT TOPIC
Axel Almet	The University of Melbourne	When push comes to shove: exclusion processes with nonlocal consequences
Patrick Andersen	University of Newcastle	New theory and algorithms for scheduling arc shutdown jobs in networks
Somasuntharam Arunasalam	The University of Sydney	Lie-Poisson symmetry reduction after regularisation of the n-Body Problem
Wayne Cheung	Monash University	Bayesian inference for cancer-related signaling networks
Anthony Clissold	Flinders University	Markov Decision Processes and the modelling of patient flows
Alastair Dyer	Monash University	How many ways are there to cover a sphere?
Lettisia George	La Trobe University	Geometric properties of heavy-tailed random fields.
Charles Gray	La Trobe University	The lattice of digraphs
Benjamin Hansford-Smith	University of Newcastle	Geometric group theory and topological groups
Shuhui He	University of Wollongong	Minimal surfaces
Ryan Heneghan	The University of Queensland	Exploring vaccination methods for an SIR epidemic on a random population network with household structure and varying rates of infectivity & severity
Mehrnaz Heydarinoori	RMIT University	Obstacle-influenced particulate deposition concentrations in wall-bounded flow
Helen Hunt	The University of Queensland	Investigation of manipulation of methods of difference construction for mutually nearly orthogonal latin squares
Hayden Johns	RMIT University	Operations research modelling for comparative analysis of the emergency department length of stay between stroke and cardiac patients
Melanie Kaasinen	Queensland University of Technology	Collective motion of a population of elongated cells
Jake Kays	Deakin University	Optimising potential Australian high-speed railway station locations
Luke Keating Hughes	The University of Adelaide	de Rham's Theorem via Čech cohomology
Ashim Khadka	RMIT University	Assessment of the effects of viscous fluid shear stress on an elastic membrane
Gleb Kotousov	Australian National University	PDE Metric Solution
Timothy Koussas	La Trobe University	Topological Graph Theory: Conway's Thrackle Conjecture
Rupert Kuveke	La Trobe University	Comparison of the performance of methods for finding Value-at-Risk
Thao Le	Monash University	Bayesian invasive species modelling allowing for increasing public awareness
Melissa Lee	The University of Western Australia	Some Configurations of an Affine Space and the game of SET
Ngo Nam Leung	RMIT University	Mathematical models for dog rabies that include the curtailing effect of human intervention

RESEARCH PROJECTS CONTINUED

NAME	UNIVERSITY	PROJECT TOPIC
Luran Li	The University of Queensland	Applying approximate dynamic programming to the elevator dispatching problem
Daniel Lin	Macquarie University	Enriched polynomial functors
Zhigen Wilson Lin	Monash University	Mathematical modelling of bone tissue regulation
Daniel Mahar	La Trobe University	Sensitivity of generalized least squares to correlation structure misspecificantions
Michael Mampusti	University of Wollongong	Software to produce fractal tilings of the plane
Jaimie McGlashan	Deakin University	Treatment planning optimisation of modulated arc therapy with burst mode
Angus McLure	Australian National University	Epidemiological modelling of Clostridium difficile
Michael Mcphail	The University of Western Australia	The statistical properties of complex networks
Thomas Moore	The University of Queensland	Modelling dynamic pattern formation on the cell cortex
Benedict Morrissey	Australian National University	Geometric Langlands Program
Liam Morrow	Queensland University of Technology	Series solutions of nonlinear differential equations
Adam Murray	The University of Queensland	The Willmore Energy
Ho Ka Ng	The University of Adelaide	The fundamental groupoid
Minh Huyen (Diana) Nguyen	The University of Sydney	Lie-Poisson symmetry reduction after regularisation of the n-Body Problem
Matthew Palermo	Griffith University	Analytical Solutions for Transcranial Direct Current Stimulation
Wai Pun	The University of Adelaide	Statistical decision theory
Stuart Roberts	RMIT University	Harvesting the Single Species Gompertz Population Model in a slowly varying environment
Christopher Ryba	The University of Sydney	Representation theory of the finite and affine Temperley-Lieb algebras in positive characteristic
Alex Simmons	Queensland University of Technology	Efficient preconditioning and method of lines techniques for solving nonlinear space-fractional differential equations on unstructured meshes
Justin Smallwood	The University of Melbourne	Drift estimation for diffusions observed on a spatial lattice
Will Stavely	Monash University	The algebra of knots
David Stojanovski	Monash University	A continuous model of bone formation
Michelle Strumila	Monash University	Topological quantum field theory and information
Shian Su	Walter and Eliza Hall Institute	Adding to the Galaxy of statistical methods for genomic analysis *
Ryann Sullivan	Deakin University	Real-time human activity recognition in augmented reality games
Makoto Suwama	The University of Sydney	Understanding hard cases in the general class group algorithm
Jackson Sweeney	Monash University	Numerical methods for an oil recovery model
Michael Van der Kolff	University of Wollongong	Totally disconnected, locally compact groups acting self-similarly on trees

* Work published - F1000Research website

RESEARCH PROJECTS CONTINUED

NAME	UNIVERSITY	PROPOSED PROJECT TOPIC
Krystyn Villaflores	La Trobe University	Absolute risk estimation using nested case-control data
Huon Wilson	The University of Sydney	Computing fast and accurate convolutions
Adam Wood	La Trobe University	Lines and circles in the three-dimensional Heisenberg group
Estefania Yap	RMIT University	A survey of developments for multi-objective programming
Adriana Zanca	The University of Melbourne	Trading Places: Agent exchange in diffusion processes

Student project reports can be viewed on the AMSI website: www.amsi.org.au/2013-14-vrs-recipients

Student blog posts are posted throughout the year on the AMSI Higher Education website: www.amsi.org.au/highered

"I most enjoyed being able to hear what my peers were researching and meeting like-minded students."

- Helen Hunt, The University of Queensland

BIG DAY IN CONFERENCE

CSIRO’s Big Day In Student Conference is an exciting opportunity for AMSI Vacation Research Scholarship Students to meet up with CSIRO Vacation Scholars and present their research in a conference setting.

Over two days students delivered conference style presentations about their work. We heard about statistical methods that streamline emergency department wait times, the algebra of knots, the geometric properties of heavy-tailed random fields and algorithms that could revolutionise significance testing.

Students also had the opportunity to quiz top CSIRO and AMSI staff about careers in mathematics and science and hear David Lovell's team convinced them that scientists have never had it so good at the comedy debate. Students also had plenty of time to network with icebreaker events and a conference dinner.

Congratulations to Melissa Lee, The University of Western Australia, and Thomas Moore, The University of Queensland (pictured below) who won the Cambridge University Press Book Prize for best student presentation.

The conference was held from 11 - 12 February at the UNSW Australia.

SUPERVISORS

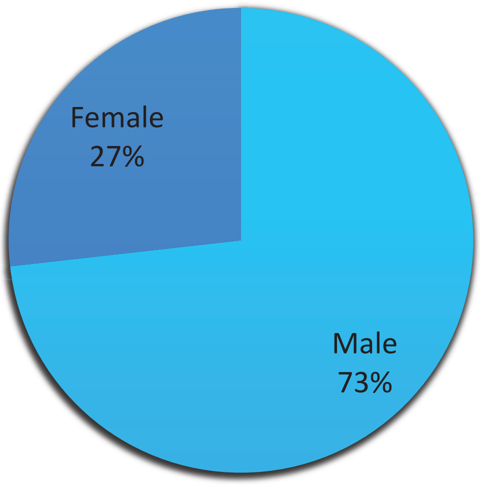
AMSI would like to express its appreciation to all the Vacation Research Scholarship supervisors who leant their time and expertise to the projects. Their contribution is integral to the success of the program.

NAME	UNIVERSITY
Dr Babak Abbasi	RMIT University
Assoc. Prof. John Bamberg	The University of Western Australia
Prof. Vladimir Bazhanov	Australian National University
Prof. Gleb Beliakov	Deakin University
Prof. Natashia Boland	University of Newcastle
Prof. Peter Bouwknegt	Australian National University
Dr Pascal Buenzli	Monash University
Dr Michael Bulmer	The University of Queensland
Dr Grant Cairns	La Trobe University
Prof. Brian Davey	La Trobe University
Dr Stephen Davis	RMIT University
Dr Yan Ding	RMIT University
Dr Norman Do	Monash University
Dr Steve Donnelly	The University of Sydney
Dr Diane Donovan	The University of Queensland
Dr Jérôme Droniou	Monash University
Dr Holger Dullin	The University of Sydney
Dr Murray Elder	University of Newcastle
Prof. Jerzy Filar	Flinders University
Dr Sargon Gabriel	RMIT University
Prof. Barry Hughes	The University of Melbourne
Assoc. Prof. Peter Johnston	Griffith University
Dr Owen Jones	The University of Melbourne
Assoc. Prof. Paul Kabaila	La Trobe University
Dr Uri Keich	The University of Sydney
Dr Jonathan Keith	Monash University
Prof. Kerry Landman	The University of Melbourne
Prof. Gustav Lehrer	The University of Sydney
Dr Vicky Mak	Deakin University

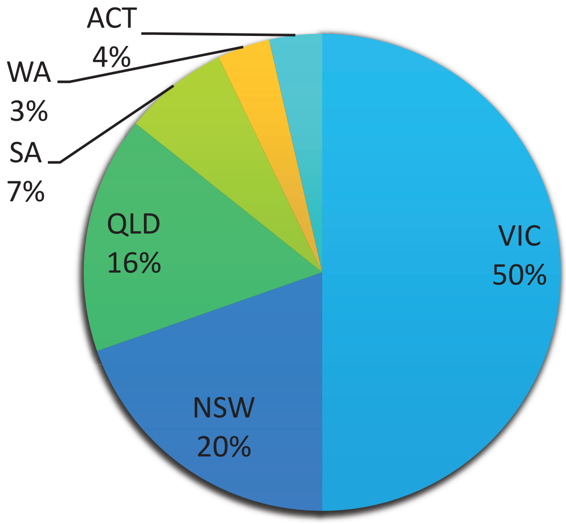
NAME	UNIVERSITY
Dr Daniel Mathews	Monash University
Dr Paul McCann	The University of Adelaide
Prof. Scott McCue	Queensland University of Technology
Prof. Geoffry Mercer	Australian National University
Dr Kali Nepal	Deakin University
Dr Zoltan Neufeld	The University of Queensland
Dr Huy Nguyen	The University of Queensland
Dr Yuri Nikolayevsky	La Trobe University
Dr Andriy Olenko	La Trobe University
Dr Melih Ozlen	RMIT University
Dr Jane Pitkenthly	La Trobe University
Prof. Phil Pollett	The University of Queensland
Dr Luke Prendergast	La Trobe University
Assoc. Prof. Jacqui Ramagge	University of Wollongong
Dr Matt Ritchie	Walter and Eliza Hall Institute of Medical Research
Dr Agus Salim	La Trobe University
Assoc. Prof. John Shepherd	RMIT University
Assoc. Prof. Matthew Simpson	Queensland University of Technology
Prof. Michael Small	The University of Western Australia
Prof. Patty Solomon	The University of Adelaide
Dr Danny Stevenson	The University of Adelaide
Dr Mark Weber	Macquarie University
Dr Sam Webster	University of Wollongong
Dr Valentina-Mira Wheeler	University of Wollongong
Dr Glen Wheeler	University of Wollongong
Dr Michael Whittaker	University of New South Wales
Prof George Willis	University of Newcastle
Dr Qianqian Yang	Queensland University of Technology

PARTICIPANTS

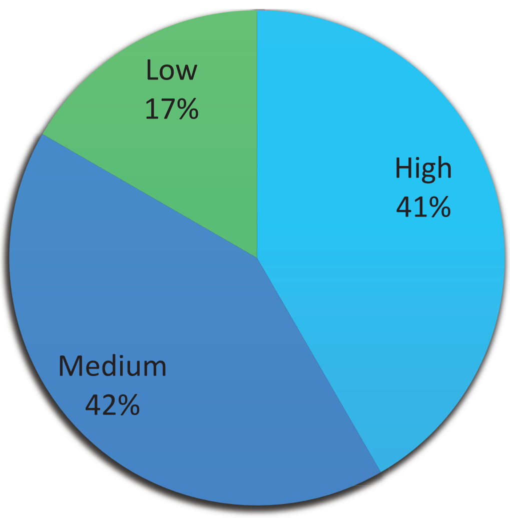
BREAKDOWN BY GENDER



BREAKDOWN BY STATE



BREAKDOWN BY SOCIECONOMIC STATUS



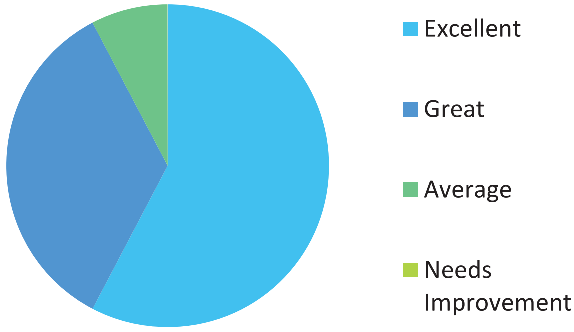
BREAKDOWN BY UNIVERSITY

Monash University	8
La Trobe University	7
RMIT University	6
The University of Queensland	5
The University of Sydney	5
Deakin University	3
Queensland University of Technology	3
The University of Adelaide	3
The University of Melbourne	3
Australian National University	2
The University of Western Australia	2
University of Newcastle	2
Flinders University	1
Griffith University	1
Macquarie University	1
Total	**56**

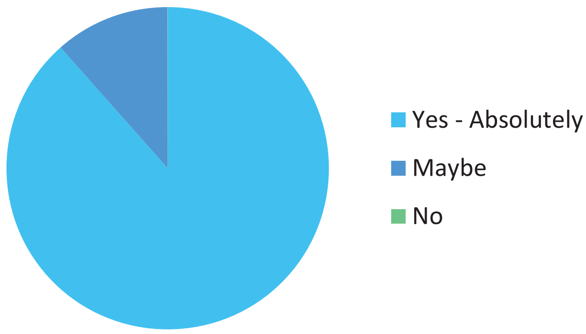
ABORIGINAL AND TORRES STRAIT ISLANDER PARTICIPATION: 0

FEEDBACK

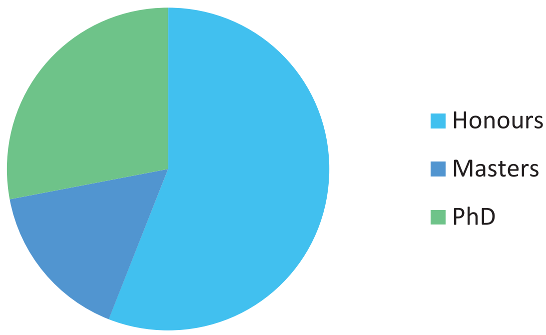
HOW WOULD YOU RATE THE SCHOLARSHIP PROGRAM OVERALL?



WOULD YOU RECOMMEND THIS PROGRAM TO A FRIEND?



THE PROGRAM IS DESIGNED TO GIVE YOU A TASTE OF ACADEMIC RESEARCH, AFTER YOUR EXPERIENCE THIS SUMMER DO YOU EXPECT TO COMPLETE



Drilling for oil - efficiently

Suppose we want to extract some oil from an underground reservoir.

We drill a well, and the oil is initially driven out of the reservoir by natural mechanisms. Unfortunately, these natural mechanisms don't last forever, so eventually we have to confront the problem of extracting what remains of the oil. The solution is to drill a secondary well elsewhere in the reservoir. We then pump a second fluid, called a solvent, into this secondary well, displacing the oil towards our original production well.

There are three basic processes at work in this system. Firstly, fluid is pumped in and out of the reservoir via the two wells. This is simple to model since it is localised - the wells themselves are typically much smaller than the reservoir. Second is the transport of fluid mass by that fluid's bulk motion, known as advection. As an example, consider water flowing down a river. Finally, the spreading of a fluid from regions of high concentration to regions of low concentration, this is known as diffusion. Consider for example if some ink were spilled into a lake. The ink would undergo diffusion and slowly disperse throughout the water.

These three processes, when coupled with the fact that there are two fluids present, result in some very complex equations. In fact, these equations cannot be solved exactly. However, finding ways to approximate their solution allows us to figure out, amongst other things, how much oil can be extracted in a given period of time, what kind of solvent to use, and where to drill our secondary well.

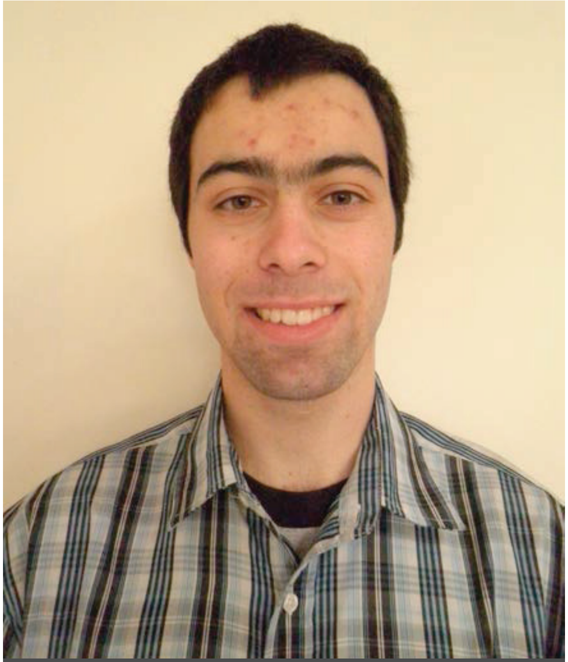
In this project I studied and implemented codes for two methods of finding approximate solutions to these equations: the modified method of characteristics, or MMOC, and the Eulerian-Lagrangian localised adjoint method, or ELLAM.

My tests yielded some interesting results. The ELLAM handled advection and diffusion very well, but had severe difficulties handling the injection well. Moreover, the results produced by my code did not agree with those published in the paper, which originally presented the ELLAM. I was able to confirm my results by slightly modifying a code by another author for a similar method, so at this stage I have some very strong doubts as to the veracity of the results published in the original paper.

The MMOC, on the other hand, produced very good results even with injection and production wells. It was not without problems though; it sometimes produced large, unrealistic spikes in solvent concentration. In future, it would be worth investigating whether aspects of the MMOC could be combined with other methods that do not have this problem. The hope is that a combined method will produce superior results to any of the methods we have at present.

Jackson Sweeney
Monash University

Life or death, mathematics helps our hospital systems



ANTHONY CLISSOLD
FLINDERS UNIVERSITY

Anthony Clissold took a "Career-Chooser" survey when he was in Year 10. And, his two most compatible suitors were determined to be statisticians or actuaries. These results coupled with enthusiastic passionate mathematics teachers at high school made Anthony's pathway to a Bachelor of Science with a mathematics major pretty obvious.

'I want to be able to get up, go to work and help somebody with what I do,' Anthony said. 'And mathematics allows me to do that; in a more secretive behind the scenes way.'

Anthony enjoys the maths and stats that are hidden in nearly every facet of modern existence. Especially those in fantasy sports: "I love the idea of setting up teams under mathematical constraints, then buying or selling players depending on their real world performance to turn a profit."

Throughout the last year of his undergraduate degree Anthony worked as a research assistant on a project investigating patient flow optimisation within hospitals. So, when this project was offered under an AMSI Vacation Research Scholarship (VRS) Anthony jumped at the opportunity.

'The AMSI VRS was a great way for me to practically apply my research to everyday human problems that have a positive effect on the community,' Anthony said.

Over the course of his VRS Anthony continued his work on developing a computerised decision support tool. Using data obtained over a calendar week Anthony made a computer program to aide with decision-making in situations where outcomes are partly random and partly under the control of a decision maker.

Anthony said, 'the nerdy name for it is a Markov Decision Process. What I did was use dynamic programming approaches to find an optimal solution to the Markov Decision Process.' He concluded: 'I prefer to tell people: "I get paid to make graphs!" It is easier for people to relate to, and is almost what I do.'

From fantasy sport to making our emergency hospital rooms run more efficiently Anthony knows first hand the importance of mathematics and statistics. He believes that it is imperative to Australia's future that the mathematical sciences are held in esteem and receive adequate funding.

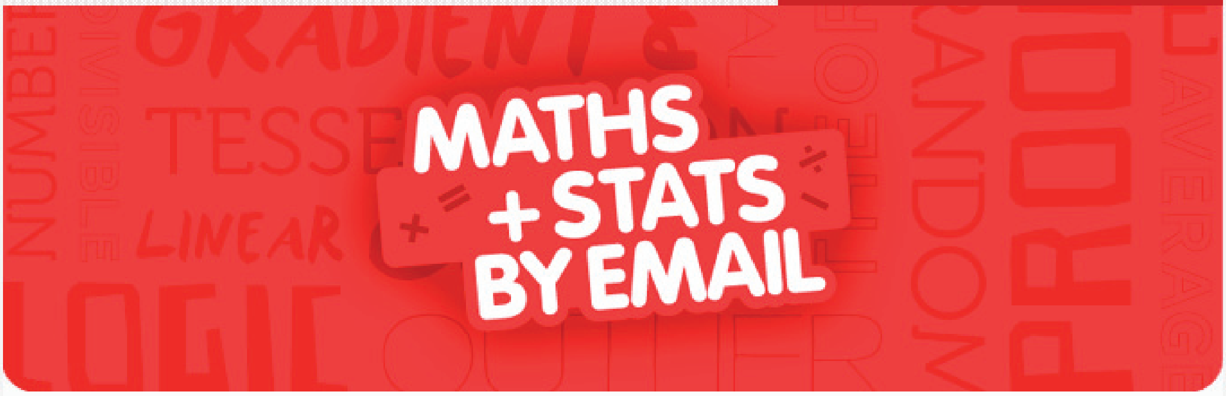
'AMSI programs provide the next generation of mathematicians the opportunity to pursue their interests and be inspired by world leaders in the field. In this way AMSI are helping secure Australia's reputation at the forefront of scientific research. And they allow us budding mathematicians to delve deeper into mathematical research and get a taste for what's to come outside of academia,' Anthony concluded.

FEATURED PROJECT

Australian Bureau of Statistics

AMSI
AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

13 AUGUST 2013



Article: The maths of lab-grown livers

Scientists researching liver disease need a lot of liver samples for experiments. As such, it would be useful to be able to grow liver tissue in the lab. A new simulation, written by mathematician Thomas Brown, could help make lab-grown liver samples a reality.

Currently, researchers put liver cells in flat dishes in the hope of forming tissue. Over time, these cells tend to clump together in groups called aggregates. However, scientists don't fully understand why or how these aggregates form. To investigate, Thomas wrote a computer program to simulate aggregation.

To represent the dish, Thomas started with a grid of squares. A single (simulated) liver cell fills exactly one of these squares. Then he worked out some rules to explain how liver cells might move.

Thomas gave his cells a way to sense nearby cells. They could 'look' in four different directions (up, down, left, right) and count the cells in that direction. Each cell used that information to create a computer-simulated dice to choose which direction to travel in. For example, if the cell spotted more cells to the left, the virtual dice had left written on more of its sides. Each cell's movement was random, but they tended to move towards other cells.

Thomas put several simulated cells into his square grid dish. Then he made each cell look, make a dice, roll it and move in that direction. This process was repeated over and over to see what would happen. Over hundreds of cycles, Thomas' simulated cells moved together to form groups. These groups looked similar to the aggregates that real liver cells form. By adjusting how far his cells could 'see' Thomas was able to refine his model even further.

Running a computer program is a lot faster than growing a dish full of cells. So a good simulation of cell aggregation makes it easier to test different ways of growing liver aggregates. Thomas wrote his program in just five weeks, while studying at the Australian Mathematical Sciences Institute's Vacation Research School. With a bit more research time, this model might make a big difference for a lot of researchers.

More information

Engineering livers

An interview with Thomas

Like Tweet

FEEDBACK

The best thing about the Big Day In was…

"…the opportunities to meet students and professors from other universities around Australia."

- Rupert Kuveke, La Trobe University

"…connecting with other students who had similar mathematical projects."

- Charles Gray, La Trobe University

"…the opportunity for like-minded students from differing STEM disciplines to meet, share ideas and in the long run, maintain life-long links with each other. In a world with increasing demands for scientific skills such an event is integral to forge such links, which may lead to collaborations in the long run."

- Sargon Gabriel, RMIT

"…hearing other students talk about cutting-edge research."

- Daniel Mathews, Monash University

"…meeting like-minded students."

- Helen Hunt, The University of Queensland

"…the chance to see the broad range of mathematics that people had been working on and the opportunity to present my work."

- Adam Wood, La Trobe University

Australian Mathematical Sciences Institute

Simi Henderson
Research and Higher Education Manager
c/o University of Melbourne VIC 3010

simi@amsi.org.au
www.amsi.org.au

AMSI
AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE