the UPDATE

2nd ed.

THE CLOCK TICKS ON MATHS PREREQUISITES

Ian Chubb, Alan Finkel, Deb King, Geoff Prince, Scott Ryan & Terry Speed

HIGH-RISE SECURITY

Minimising crime risk with maths & stats

TERRY TAO

Q&A with Fields Medallist & friend of AMSI Professor Terry Tao

COMPLEX NETWORKS

Are YOU in control of your network or is your network in control of YOU?

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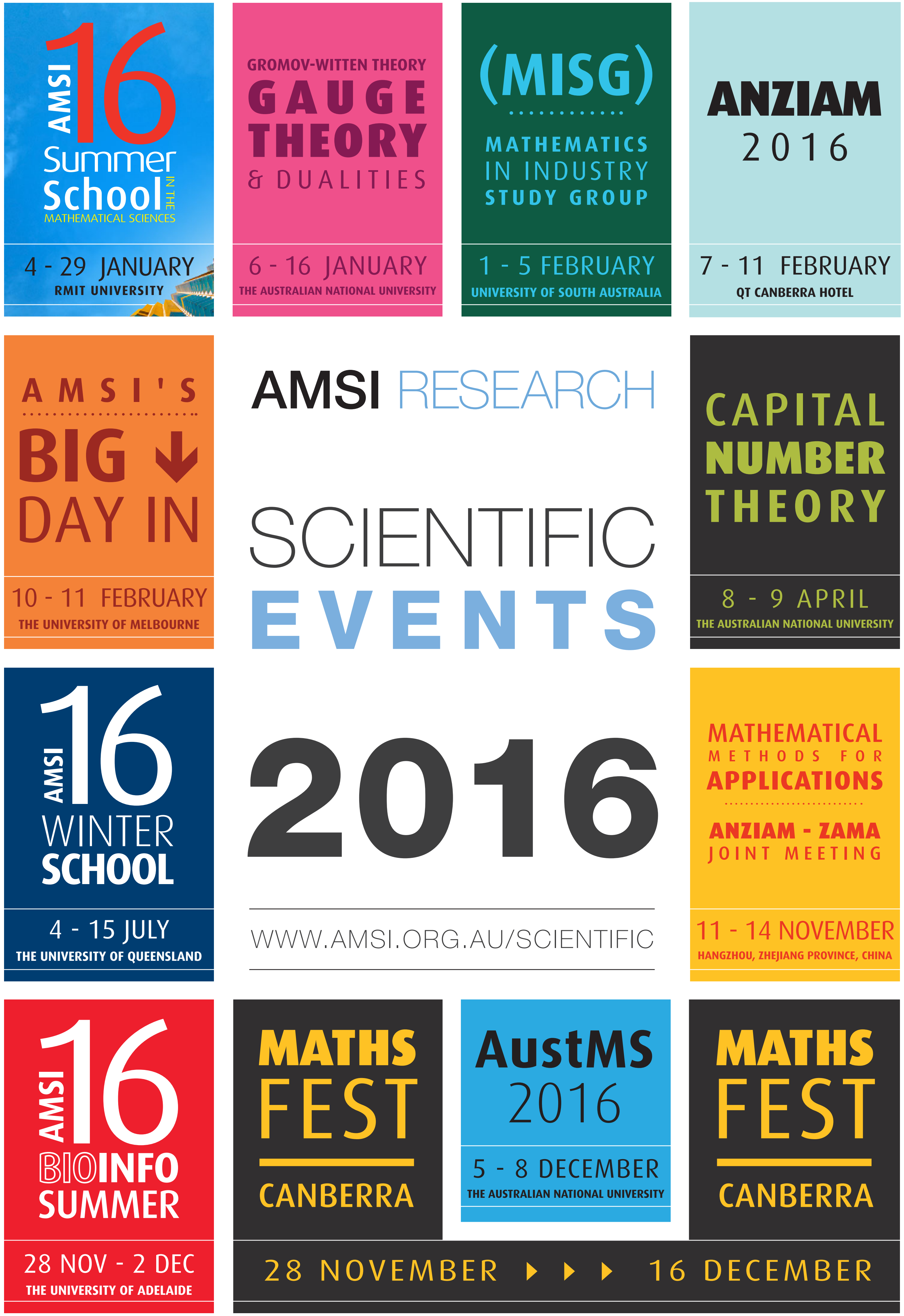

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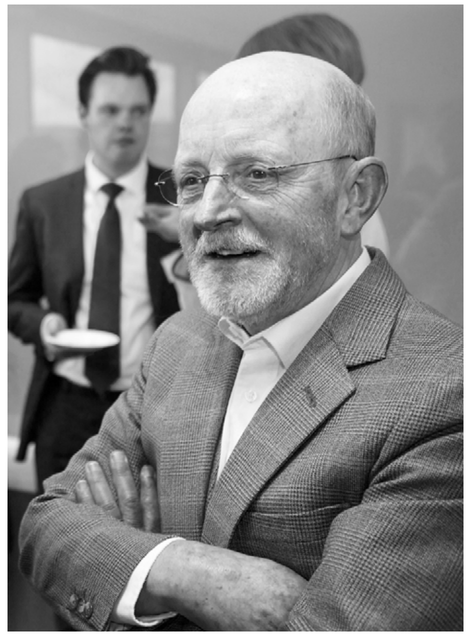
COVER IMAGE: JUSTUS KINDERMANN

A DOOR HAS OPENED FOR MATHEMATICS AND STATISTICS



PHOTOGRAPHY: MICHAEL SHAW

Momentous times! New Prime Minister, New Chief Scientist! And the departure of Ian Chubb, a great friend of the mathematical sciences who has exercised enormous influence on government and on the public perception of science.

A door has opened for mathematics and statistics, to grow our research capacity and to start turning around some of the chronic problems in our education pipeline. But it is not a time to relax. Australian governments are grappling with a national strategic plan for Science, Technology, Engineering and Mathematics (STEM). Of course planning is one thing, sticking with a STEM plan through multiple electoral cycles is another thing altogether. AMSI has played a significant part in raising awareness through its advocacy and policy building and we won't be letting up any time soon. Most recently we have made submissions to three major government reviews (which you can find at amsi.org.au), all of which will have a major impact on education and research. We will continue to pursue transformative change and its support from Malcolm Turnbull and Alan Finkel.

This issue of The Update is bursting with features. Both Ian Chubb and Alan Finkel tell us what they think about the burning issue of the moment – maths prerequisites for university science and engineering courses; along with Assistant Cabinet Secretary Senator Scott Ryan, Terry Speed and Deb King. Fields medallist Terry Tao talks about his life in mathematics and tells us why collaboration makes his world go round. We highlight a pilot project, delivered by AMSI Intern that investigates the factors influencing the risk of crime occurrences in high density housing and also feature a report on the 4th South Pacific Continuous Optimisation meeting held at Adelaide's University of South Australia in February of this year.

I hope you enjoy this second edition of our new look bulletin. Of course the latest news about our program areas of Schools, Research, Higher Education and AMSI Intern can be found at amsi.org.au

Director

Prof. Geoff Prince FAustMS

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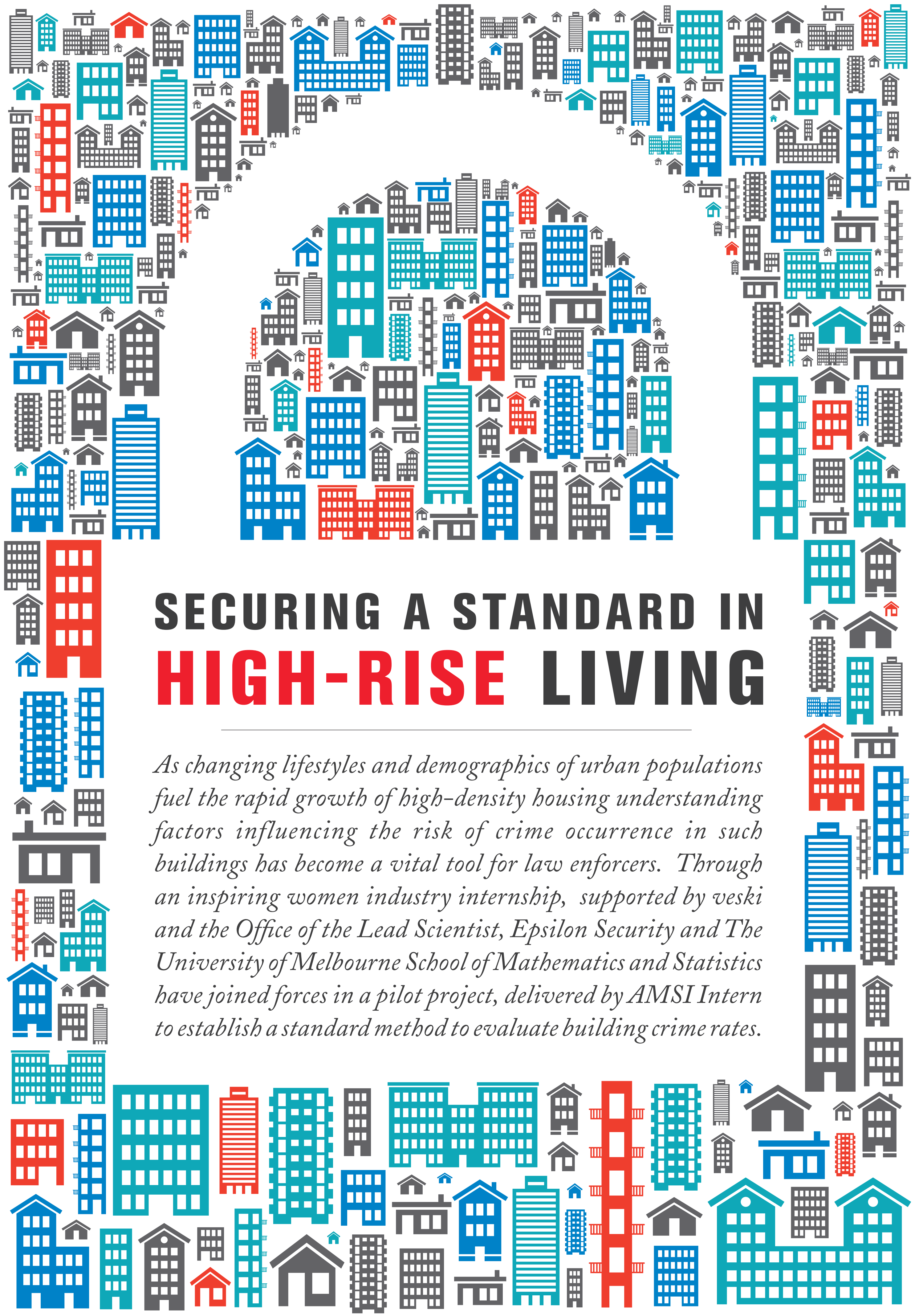


SECURING A STANDARD IN HIGH-RISE LIVING

As changing lifestyles and demographics of urban populations fuel the rapid growth of high-density housing understanding factors influencing the risk of crime occurrence in such buildings has become a vital tool for law enforcers. Through an inspiring women industry internship, supported by veski and the Office of the Lead Scientist, Epsilon Security and The University of Melbourne School of Mathematics and Statistics have joined forces in a pilot project, delivered by AMSI Intern to establish a standard method to evaluate building crime rates.

Before stepping down as Chief Commissioner of Victoria Police, Ken Lay urged a move away from traditional policing to more sophisticated approaches. With the changing lifestyles and demographics of Victorians and the rapid growth of high-density dwellings, such a move is critical. Victoria's love affair with high-rise apartment living is creating new challenges for law enforcers with a staggering 63 per cent of property related offences recorded by Victoria Police in 2014.

> "THE MAIN CONCERN IS THE LACK OF A STANDARD METHOD TO EVALUATE SECURITY LEVELS OF BUILDINGS FOR COMPARISONS. TO DO THIS WE NEED TO DEVELOP A DATA-DRIVEN COMPUTER MODEL TO ASSESS THE SECURITY RISK AND POTENTIAL CRIME EXPOSURE OF A BUILDING."

So, how can homebuyers and renters be sure their property is safe?

"Security systems have become a very important and integral part of both residential and commercial living," says Andrea Baratta, Managing Director at Epsilon Security.

"We have identified a gap in how the security of these buildings is managed," Andrea says. "The main concern is the lack of a standard method to evaluate security levels of buildings for comparisons. To do this we need to develop a data-driven computer model to assess the security risk and potential crime exposure of a building."

Andrea proposes a global risk measure be given to all new buildings. He believes this will provide a good starting point for residents seeking to understand how their property compares with others, as well as identify key risks and implement safety improvement solutions.

Epsilon Security accessed funding through an initiative by veski and the Victorian State Government to support Victorian female honours and masters STEM students through a short-term (4 month) tightly focused research internship.

The initiative was delivered by the AMSI Intern program and, in a pilot project, Epsilon Security has teamed up with statisticians from the University of Melbourne to develop modelling to assess property risk and identify safety solutions. Using Victorian crime data the team has been able to investigate demographic / geographical and other measureable variables related to communication, access and monitoring to evaluate the safety of apartment complexes.

"By looking at how a building is accessed, how it is managed, its existing protective measures and what suburb it is located in we can build a computer model to identify weaknesses in buildings and then give them comparative security scores," says Dr Davide Ferrari from The University of Melbourne's School of Mathematics and Statistics.

Working with master's student Puxue Qiao, Dr Ferrari has taken a step closer to achieving this after building a generalised mixed-effect model. These are useful in the social sciences because they are able to take into account both random and fixed effects. For this particular study, where measurements were to be made on clusters of related statistical units repeatedly, choosing a mixed-effect model was natural. Dr Ferrai explains that this type of model allowed them to make predictions of crime occurrences while also obtaining security ratings for each individual building.

"The data collection was done using an original survey through telephone interviews. In the analysis of the frequency of crime occurrences, we used Poisson regression models. A large proportion (36 per cent) of responses obtained for crime occurrences were concentrated at zero. To avoid failure accounting for these zeroes, the team adopted a zero-inflated Poisson model. This model allows for not only a discrete random variable with a Poisson distribution, but also a point mass at zero. We carried our numerical computations of fitting this mixed model using the R package glmmADMB," says Dr Ferrari.

Giovanni States,when creating a model to assign risk ratings to apartment buildings many variables must be taken into account. To ensure the model was sound, independent legal researcher Dr Giovanni Di Lieto came on board to assist with merging crime prevention literature from criminology in with the statistics. The big challenge, according to Dr Di Lieto, lay in exchanging the different research paradigms. "When we managed to blend our approaches, the significance of this project became not only its substance, but also its methodology. We are able to demonstrate how to effectively interlink industry and different domains of research,".

Qiao described the number of crime occurrences by using a zero-inflated Poisson regression model with mixed effects. A combination of predictors were selected using information theoretical criteria for model selection (Akaike and Bayesian information criteria). The prediction accuracy for the best two selected models were then assessed using independent samples by cross-validation techniques. Using the selected models, Dr Ferrari and Qiao first developed classification methods for the crime risk rating based on the Poisson mixture approach. This offered the most accuracy when predicting the response due to the complexity of the fixed and variable factors.

"The inspiring women industry internship enabled us to collaborate with Dr Ferrari and masters student Qiao to devise a statistically sound model for this project. Qiao also gained valuable industry experience – she was able to solve problems and produce tangible results that have an actual business context," says Andrea. "Something not nearly enough Australian students have the opportunity to do."

Universities are drivers of innovation; and they play a key role in projects like this. Given the project's initial success, the team is applying for an ARC Linkage Project grant to continue their work with the objective of developing a fully automated tool for risk ratings in buildings. ■

Based on the results from the current project, Epsilon Security and the University of Melbourne School of Mathematics and Statistics are preparing an ARC Linkage research proposal that will target the development of a fully automated tool for risk rating in buildings.

www.amsiintern.org.au

THE TAO OF MATHS

FIELDS MEDALLIST AND MEMBER OF AMSI'S SCIENTIFIC ADVISORY COMMITTEE, PROFESSOR TERRY TAO TAKES TIME OUT OF HIS BUSY SCHEDULE AT UCLA TO GIVE US AN INSIGHT INTO WHAT'S EXCITING HIM IN MATHEMATICS, HIS RECENT COLLABORATIONS AND THE WAYS IN WHICH HE APPROACHES COMPLEX PROBLEMS.

What's exciting you in mathematics at the moment?
It changes a lot from year to year - there are so many things going on in different parts of mathematics, it seems! I can name two recent breakthroughs in the last year or two which have generated a bit of excitement. The first is the recent proof of the Kadison-Singer conjecture by Marcus, Spielman, and Srivastava, which used radically new methods (in particular, interlacing polynomials) to solve a notoriously difficult problem in operator algebras and matrix analysis. It looks like there are other applications of this method (for instance, to theoretical computer science). The other is the breakthrough result of Matomaki and Radziwill earlier this year in understanding short sums of multiplicative functions in number theory. This has made several open problems in number theory (e.g. the Chowla conjecture, a cousin of the twin prime conjecture) look much more within reach. Recently I was able to use the Matomaki-Radziwill theorems to prove some partial results towards the Chowla conjecture, which could in turn be used to settle a long standing conjecture of Erdos on the discrepancy of sequences. I'm confident that we'll be seeing other striking applications of Matomaki and Radziwill's results in the near future.

Why do you think women are underrepresented in mathematics?
That's a good question. Up to about the high school level, we seem to have fairly good parity these days; if anything, female maths students may even be slightly more numerous and a bit stronger. But then there is a lot of attrition at the undergraduate level and beyond. It seems there are a lot of reasons for this. One is that nearby disciplines (e.g. the life sciences) have much better gender balance and this can be more attractive than a discipline where one is in the minority. Another is the relative lack of high-profile female role models in mathematics, though there are excellent top female mathematicians who do their heroic best to counteract this. Then there is the fact that the graduate and postdoctoral portions of one's career in mathematics can be rough on people who are also trying to start or raise a family. There are some little positive steps in these directions (for instance, child care availability is now taken as a serious issue in mathematics departments, institutes, and conferences, and more efforts are being made to overcome conscious or unconscious biases against minority candidates in hiring and in giving presentations), but there is still a long way to go here. →

From a personal perspective what are your top three open problems in mathematics? What are their prospects for resolution?
Well, this is very subjective, and depends a lot on what you mean by "top". There are statements which would have enormous implications if they could be definitively proved (e.g. the six remaining Millennium prize problems), but the likelihood of actually doing so is so remote, I don't think these are the problems that we should be devoting the bulk of our mathematical manpower to attacking. (Though I do like to keep tinkering with an approach I have to disproving global regularity for the Navier-Stokes equations...) My philosophy is to focus on those open problems that are only a little bit out of reach of current techniques and methods - problems that require "only" one new breakthrough to solve, rather than a half-dozen. In number theory, I think the twin prime conjecture is getting close to this level of feasibility; in analysis, the Kakeya conjecture has already had much headway made against it from the previous four or five breakthroughs in the area, and one can hope that just one more is needed to finish it off. More ambitiously, I think the soliton resolution conjecture in PDE would be a fantastic result to settle, though this is currently well out of reach except in very special cases (e.g. completely integrable equations, perturbative data, or other very symmetric and special equations).

"MY PHILOSOPHY IS TO FOCUS ON THOSE OPEN PROBLEMS THAT ARE ONLY A LITTLE BIT OUT OF REACH OF CURRENT TECHNIQUES AND METHODS - PROBLEMS THAT REQUIRE "ONLY" ONE NEW BREAKTHROUGH TO SOLVE, RATHER THAN A HALF-DOZEN."

I read somewhere recently that as a child you thought that research was driven by a committee posing problems. Do you think the free ranging, creative side of mathematics comes off second best to problem solving for kids and adolescents with an interest in maths?
Well, I think even problem solving comes off as second best to the computation-intensive mathematics one sees in schoolwork. Certainly when I was a child, the only glimpses I saw of true mathematical research were in some more advanced level books I got from the library, or the informal discussions I had with some active and retired mathematicians in Adelaide. One big plus in today's world though is that, with the internet, one can now listen to public lectures or other talks by some very good mathematical speakers, or see good examples of accessible mathematical writing online. Even just the mathematics section on Wikipedia is a wonderful resource which I would have very much enjoyed as a child. So it seems the hard part is to locate the kids with a potential interest in mathematics and inspire them to go explore for themselves.

When it comes to collaboration are you a workshop person? Or do you have a different MO?
I love collaboration; most of my papers are joint, and most of the mathematics I have learnt, I have learnt from my various co-authors. But the style is different for each co-author. One of them, for instance, likes to stick to the famous Hardy-Littlewood rules of collaboration (which include such counterintuitive rules that there is no obligation to respond to any research communication from the other author). I work with some authors almost exclusively by email, others by trying to secure a week at some conducive location where we can brainstorm at a blackboard. More recently, I've been involved with massively collaborative "polymath" projects where dozens of mathematics communicate through wikis and blogs to attack a single problem. Not every collaboration style is suited for every problem, but they are all fun!

You have a very different approach to Andrew Wiles say, did you ever make a conscious decision to have broad mathematical interests?
Actually I think it was my co-authors that helped me broaden the most. When I was a postgraduate student I was initially rather narrowly focused on harmonic analysis. But my co-author Allen Knutson got me interested in algebraic combinatorics and representation theory. My co-author Mark Keel got me into PDE, my co-author Ben Green got me into analytic number theory and additive combinatorics, my co-author Emmanuel Candes got me into signal processing, and so forth. I have a great respect for those mathematicians who drill deeply into a single field and extract some very profound results as a consequence, but I have always been more comfortable with entering a new field (usually with the assistance of a collaborator in that area) and seeing if any ideas or results from a previous one can be profitably applied to this new one.

What advice would you give to a philanthropist with deep pockets who wanted to invest in mathematics?
Well, that is certainly very admirable! I think as far as greatest need is concerned, prizes, scholarships and grants for junior mathematicians, e.g. to be able to attend conferences and have the opportunity to work with leaders in the field, are the most important. But unfortunately these don't get nearly as much publicity and notice as the larger prizes that go to more established people for more visible accomplishments. It seems that a good compromise is to combine the two - to couple a larger prize with some smaller prizes aimed at junior mathematicians.

Which parts of maths do you think pay the greatest social dividend? Should we divert talent from say, the finance sector, into these areas and if so how?
Well, progress in mathematics isn't just a matter of throwing money and resources into a given area; sometimes a field is just not yet ripe for dramatic progress, needing a little bit of serendipity to have someone find the key insight. Even very pure areas of mathematics can unexpectedly have tangible real world impact; I and several others had done some purely theoretical work on random matrices, for instance, that ended up being useful for compressed sensing, which is now used for instance to speed up MRI scans. The other thing is that while we certainly do need good people in mathematical research, not every person who is talented in, say, mathematical finance, would also be suitable for this; there are some qualities (e.g. the need to "play", almost to the point of obsession, with mathematical concepts and problems) that are useful in research but perhaps not in other areas. So I don't think we should actively try to divert people from a career that they already enjoy and are successful at, but we can certainly raise awareness that there are many areas of both pure and applied mathematics which need good people and which can be rewarding in many ways. ■

Terry is a long term member of AMSI's Scientific Advisory Committee and AMSI's first director, Garth Gaudry, was Terry's mentor as a student at Flinders University. Terry continues to be a strong advocate for the Australian mathematical sciences community.

PREREQUISITES

THE CLOCK IS TICKING

AMSI Director Geoff Prince exposes the consequences of our retreat from prerequisites. Take his quiz then read on.

Q1. *How did it come to pass that only 14% of Australia's science degrees have Year 12 intermediate maths as a prerequisite?*

Q2. *Did we plan it?*

Q3. *Were market forces responsible?*

Q4. *Did we consider the medium and long term consequences?*

Q5. *Is it in our students' best interests?*

Q6. *Does it improve university pass rates, timely completions, learning outcomes?*

Q7. *Does it encourage the pursuit of maths in schools?*

IMAGE: JUSTUS KINDERMANN

[Q1: ANY OF THE FOLLOWING - WE WERE ASLEEP, IT'S NOT OUR FAULT, THAT CAN'T BE TRUE, ETC.; Q2: NO; Q3: YES; Q4: NO; Q5: NO; Q6: APPARENTLY NOT; Q7: NO.]

The excerpt from Douglas Adams' *The Restaurant at the end of the Universe*, paints a grim picture about removing maths prerequisites and all consequences of unthinking devotion to market forces.

So what is the Maths Event Horizon? It's the point in time at which we can no longer communicate with the outside world because we don't know any maths! I'm not sure that we can estimate when it will occur, but unless we put some repelling terms into the right hand side of the equation we will cross it and drop into an almighty ***MATHS HOLE!***

Let's suppose that the maths hole equation can be run backwards. This would mean the re-introduction of almost universal maths prerequisites in another 20 years! We can't wait that long but we certainly can't bring back prerequisites tomorrow, next year or the year after. Why? Because the education system couldn't cope. It has been starved of maths-qualified teachers for so long there aren't enough, especially in regional, remote and low SES areas, to mount the classes. But this should not stop us announcing a re-introduction well in advance as a pull factor to improving the situation.

Of course we need more than one measure to bring us back from this precipice. We will have to start re-training the large number of out-of-field maths teachers, disrupt the ATAR gaming that goes on in our schools and convince young women that maths saves lives. But most of all we will have to do a much better job of promoting mathematics and statistics to the community, government and the private sector. This is the responsibility of practising mathematicians and statisticians alone.

DOUGLAS ADAMS

The Restaurant at the End of the Universe

"Many years ago, this was a thriving, happy planet – people, cities, shops, a normal world. Except that on the high streets of these cities there were slightly more shoe shops than one might have thought necessary. And slowly, insidiously, the numbers of these shoe shops were increasing. It's a well-known economic phenomenon but tragic to see it in operation, for the more shoe shops there were, the more shoes they had to make and the worse and more unwearable they became. And the worse they were to wear, the more people had to buy to keep themselves shod, and the more the shops proliferated until the whole economy of the place passed what I believe is the termed the Shoe Event Horizon, and it became no longer economically possible to build anything other than shoe shops. Result – collapse, ruin and famine. Most of the population died out. Those few who had the right kind of genetic instability mutated into birds – you've seen one of them – who cursed their feet, cursed the ground, and vowed that none should walk on it again. Unhappy lot."

In August this year, The Australian Mathematical Sciences Institute released its annual Discipline Profile of the Mathematical Sciences highlighting trends as they apply to school education, higher education, research, research training and engagement with industry. Broadly, the 2015 data shows the demand for mathematical and statistical skills at all levels far outstrips supply. This poses an immense challenge to securing Australia's future skills base.

Based on this, AMSI's policy document '**Vision for a Maths Nation**' identified key priorities for intervention by Australian governments and for action by peak bodies. These priorities must be addressed as the Commonwealth plans and implements its 'Vision for a Science Nation'.

Highest priority must be placed on the restoration of maths prerequisites from their historic low and in turn increase the declining interest in advanced mathematics courses at Year 12 level.

OVER 20 YEARS WE HAVE SEEN

Widespread removal of prerequisites and their replacement by dubious "assumed knowledge" advice,

Widespread university course realignments to cope with increasing numbers of less mathematically literate students,

Reduced graduation rates in the mathematical sciences (see Section 3.3 of the 2015 Discipline Profile), which is all the more apparent when seen in an international context (see Table 3.23 of the 2015 Discipline Profile),

Stagnating interest in engineering and science courses, and a concentration of university based research to a small number of institutions dangerously narrowing the support base for research training (see Section 4.2 of the 2015 Discipline Profile),

Reduced intake of mathematically qualified graduates into teacher training programs and reduced numbers of qualified secondary school teachers, especially in regional and low SES areas, leading to fewer students in calculus-based mathematics subjects at Year 12. (see Section 2.3 of the 2015 Discipline Profile),

The unavailability of these school subjects in many regional and low SES areas.

UNIVERSITIES MUST PHASE IN RESTORATION OF MATHS PREREQUISITES

Our future as a high technology, research driven economy depends on reversing this 20 year trend. ➔

For further information download AMSI's Discipline Profile and 'Vision for a Maths Nation' Policy document

WWW.AMSI.ORG.AU/DISCIPLINE-PROFILE-2015

Declining numbers of Year 12 students choosing to study intermediate or advanced mathematics is one of the greatest challenges to the health of Australia's STEM disciplines. Alarmingly, only 14 per cent of science degrees have intermediate mathematics as a prerequisite with only Victoria and Queensland requiring this standard, yet there continues to be an assumption that students still obtain this content knowledge.

This reactive policy has sent a negative and misleading message to schools about the value of these subjects. Australian STEM leaders discuss their views on mathematics prerequisites for science degrees.

IAN CHUBB

Australia's Chief Scientist

AUSTRALIA'S CURRENT CHIEF SCIENTIST

Many great minds have contemplated over the centuries what the purpose of education should be. It is perhaps the most important question that any society can strive to answer, because it is really a measure of our capacity to think beyond ourselves to the needs of a different world.

If we were sensible, we would want to pass that test with flying colours; and most of all in the STEM disciplines so vital to our future prosperity.

We would do many things a lot more intelligently, efficiently and ambitiously if we made the future a habit of mind: like recognising teaching as a high-value profession, and investing in the best possible training and career-long support.

We could go so far as to say that every science, mathematics and ICT class should be taught by a person qualified in the subject; in a well-equipped science, mathematics or ICT classroom.

I have never understood why these two things are thought so impossible by so many well-intentioned people.

But even if these eminently sensible things are somehow too hard, surely we ought to be able to at least agree that the skills pipeline is long; that school education should adequately prepare you for further education; and that the pre-requisites attached to university courses send signals that influence student choices.

What does it say to you that no fewer than 12 Australian universities do not require a student to study mathematics, at even the most basic level, to enrol in a science degree?

What does it say to you that 18 Australian universities do not indicate a need for mathematical literacy to study commerce?

It says to me that this country is failing the test of the future, discouraging students from performing at the level of their potential and setting up far too many for disappointment in study, and in life.

We can and ought do better.

ALAN FINKEL

President, Australian Academy of Technology & Engineering
Chancellor, Monash University

AUSTRALIA'S NEXT CHIEF SCIENTIST

Mathematics and physics are like mother's milk and reading. That is, they are the essential nutrition and language of science and engineering.

I refer to both mathematics and physics despite the question being solely about mathematics because I feel equally strongly about the fundamental contribution of both. Without mathematics one cannot express the relationships between forces and effects, whether they be between the neutrons and protons inside the nucleus of an atom or between an aircraft carrier's propellers and the water it thrusts behind. Without physics one cannot express the interactions between atoms and molecules that are the underpinning of chemistry and molecular biology.

I did postgraduate and postdoctoral research in electronic engineering and neuroscience. It would have been impossible for me to pursue my particular interests in electrical and chemical signalling between nerve cells and the enabling electronic instrumentation without a sound understanding of mathematics and physics.

Even now that I am in the governance rather than the coal-face period of my career I still find that the ability to reason mathematically and perform mental arithmetic gives me an advantage in discussions ranging from return on investment rates through to the analysis of statements of financial performance.

Most academics teaching in science or engineering would find it easier to teach and challenge their first-year students if the students had a sound background in mathematics and physics. There is no pedagogical benefit in having dropped prerequisites in recent decades. The fact that prerequisites in mathematics and physics are rarely imposed is related to overstretched university finances, necessitating a competitive approach to recruiting students. It represents a market failure.

I cannot see how this market failure can be corrected by the industry itself even if 100% of teaching academics at 100% of universities were to appeal to their university administration for action. Instead, well-considered government intervention is likely to be the only way to restore prerequisites in mathematics and physics.

14% REQUIRED INTERMEDIATE MATHEMATICS PREREQUISITE

SCIENCE

59% REQUIRED INTERMEDIATE MATHEMATICS PREREQUISITE

ENGINEERING

13% REQUIRED INTERMEDIATE MATHEMATICS PREREQUISITE

COMMERCE

SOURCE: DATA COLLECTED BY THE FYMATHS NETWORK, 2015

DEB KING

Coordinator of Learning & Teaching Innovation, School of Mathematics and Statistics, The University of Melbourne

THE ACADEMIC

Science and technology impact on almost every facet of modern life. From the production of the food we eat to the way we communicate around the globe, scientific advances are clearly evident. What may not be so clear is that these innovations rely on high-level mathematics skills. From physics to engineering to biology, mathematical modelling and data analysis play increasingly essential roles.

In spite of this, over the last two decades the majority of Australian universities have relaxed their mathematics entry requirements for science and engineering degrees. In an attempt to increase enrolments, intermediate level mathematics (that is, a subject which involves calculus) has been removed as an entry requirement and is now considered as recommended background or assumed knowledge. In some quarters, the removal of prerequisites has been seen as positive, allowing students who may not have studied mathematics entry to these degrees. But a more significant, though perhaps unintended, consequence, is that the number of students studying intermediate and advanced level mathematics nationally, has been in constant decline over this period.

Many students now choose to take, or are advised to take, easier mathematics subjects or none at all to increase their ATAR score, since it stands (along with English) as the entry requirement. Universities have allowed this to happen. By removing mathematics as a prerequisite we have led students to believe that it is not important for their course. But this is simply not true.

What students aren't told is that as a result of their choices, they will commence their tertiary studies in science and engineering seriously underprepared. For some bridging subjects, which may be additional to their course requirements and may carry extra fees, are required to fill in the gaps. For others, the lack of mathematical background limits the pathways that are open to them within their degrees.

In an educational environment that refers to students as clients, this smacks of false advertising.

We need to change our messaging as a matter of urgency. By clearly stating the mathematics requirements of courses like science and engineering we will make a good start. But if we also explain how students should understand mathematics and why it is needed, we will exhibit the academic leadership that is expected of us.

SCOTT RYAN

Liberal Senator for Victoria, Assistant Cabinet Secretary,
former Parliamentary Secretary for Education & Training

THE SENATOR

In 2003, Australia was performing better than most of our international counterparts in mathematical literacy. Out of the countries tested, only five significantly outperformed Australia. Fast-forward just under a decade to 2012 and Australia is now outperformed by twelve other countries. This decline is concerning.

While there is no silver bullet to address this, the decline in the study of mathematics at higher levels of secondary school is particularly concerning. This can be attributed to a number of factors, but we cannot dismiss changes to prerequisite requirements at tertiary institutions. This has also contributed to a perceived fall in the value and importance of mathematics amongst secondary school students.

It is therefore important that we all commit to re-establishing the importance of mathematics. Many Australian universities have dropped mathematics as a prerequisite to science degrees, instead opting for an 'assumed knowledge' model. So, while mathematics as a year 12 subject is not an official prerequisite, knowledge in the subject definitely is. It concerns me that without mathematics as an official pre-requisite, secondary students will not realise its necessity and will go onto tertiary education without key knowledge to do well in the important first year of transition from school.

Another important step is to continue to elevate the importance of mathematics in our primary schools. We know that a great teacher will help drive the study of mathematics in later years. I have seen first-hand what the passion of a teacher can achieve in a classroom. The Government's initiative in requiring primary school teachers to graduate with a specialisation in either science, a language, or mathematics will go a long way to embed the passion for mathematics in young students that will see them through to their final years in secondary education.

TERRY SPEED

Laboratory head, Walter & Eliza Hall Institute of Medical Research

THE RESEARCHER

Having mathematics pre-requisites for science, commerce and engineering degrees is not just a good idea, it is fundamentally important. Why? Because almost every aspect of these broad subject areas is becoming increasingly quantitative, more computational, reliant on larger and larger volumes of data, and we need people who understand what is being done.

Think of genome science. All of the sub-disciplines of biology make extensive use of DNA data on the genomes of organisms: genetics, evolution, ecology, molecular biology, virology, bacteriology, zoology, botany, the list goes on. The subject of bioinformatics helps biologists deal with all this DNA data, and that subject rests squarely on mathematics. Without strong mathematical, statistical and computational skills, users of the tools and techniques of bioinformatics will be limited to clicking on options that they do not understand. This is not the kind of biological science Australia needs.

Think of financial data. Do we want our portfolios managed, our currencies traded, our assets priced by individuals who do not understand the theory behind the formulae they use?

Think of engineering. Do we want our traffic managed, our skyscrapers built, our power resources distributed, our risks controlled by people unskilled in the mathematical derivations that underlie these tasks.

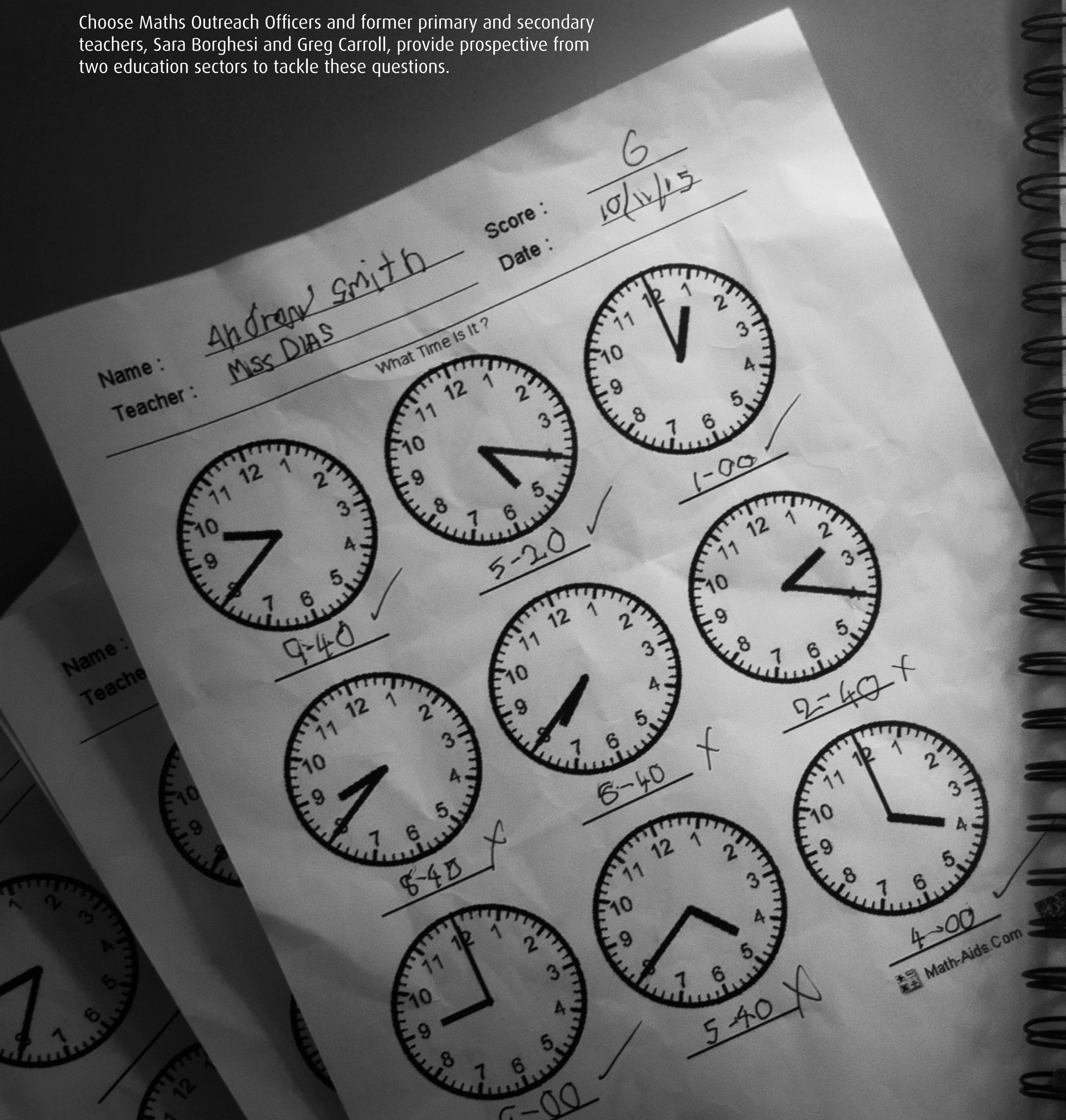
The Flixborough disaster was an explosion at a chemical plant in England in 1974, which killed 28 people and seriously injured 36; the rupturing of a temporary bypass pipe caused it. At a symposium about engineering risks a few years later, an engineer (D. Andrews) said:

"The man who designed the notorious pipe at Flixborough did not just guess its dimensions: he used a formula. This formula was well known and easy to understand and use. We know now that the formula used was wrong, because the pipe failed. We know also that we could have known that the formula was inappropriate because the circumstances of its application differed from the assumptions from which the formula was predicated."

Catastrophes like this can occur in many areas of science, commerce and engineering. This is why we need people that understand the derivations of the formulae they use. This is why we need mathematics prerequisites. →

From industry, health, agriculture and business to climate change, mathematics continues to play a key role in shaping our world and how we live in it. As we seek to skill Australia for the future, the demand for STEM skills is on the rise, with over 75 per cent of the nation's fastest growing job areas, including IT, Engineering and Bioinformatics requiring high level science, technology, engineering and mathematics. Why then, with the possibilities seemingly endless, are we seeing a decline in the number of Australian students pursuing high-level mathematics? Do we need to better equip teachers with the skills to educate for the future, is it time to re-think university pre-requisites, or does maths simply have a PR problem? AMSI looks at the state of mathematics education within the primary and secondary education sectors.

Choose Maths Outreach Officers and former primary and secondary teachers, Sara Borghesi and Greg Carroll, provide prospective from two education sectors to tackle these questions.



PRIMARY SECTOR

Sara Borghesi

Most of us can point to at least one teacher whose ability to illuminate their subject with passion and depth of knowledge, inspired and shaped our learning. These teachers know that effective classroom outcomes require not just confidence and skill, but also a deep understanding of the subject matter and curriculum. Why then, despite the clear link between content knowledge and classroom teaching standards, are we not equipping teachers to educate students for a future where skills such as mathematics will be vital?

Perhaps some of the problem lies with current university pre-requisites, which mean maths experience and expertise cannot be assumed in Australian pre-service primary teachers. Acceptance into Australian teaching degrees varies from state to state, with most undergraduate degrees not requiring students to have undertaken any level of mathematics on entry. In Victoria students only need a satisfactory completion of Units 1 and 2 of any mathematics, while in Queensland entry requires four units of mathematics. A Master of Education, the most popular entry pathway for teaching in Australia, also has no mathematics pre-requisites. So how do we address this gap in mathematical knowledge amongst our educators?

A first priority must be to retain students in the study of mathematics, something that could be achieved by making mathematics required learning in the later years of secondary school for intending teachers. This is particularly important for primary teachers, as improving content knowledge may help reduce anxiety around mathematics. We also need to look at how we sell mathematics, not only to potential teachers but also current educators, parents and students, to increase awareness of mathematical career pathways.

Importantly, the release of recommendations from the Ministerial Advisory Group on Teacher Education's report Action Now: Classroom Ready Teachers has highlighted the need to provide pre-service teachers with opportunities to become education leaders. As a first step, the Australian Government will introduce a national test for pre-service teacher education students from 2016. This will require future teachers to pass a literacy and numeracy test prior to commencing their final professional experience placement, ensuring they graduate with levels at least equivalent to those of the top 30 per cent of the population.

SECONDARY SECTOR

Greg Carroll

"So what do you do?" my young female optometrist asked.

I began to explain I worked at AMSI and one of our goals was to work with mathematics teachers across Australia to ... Before I got a chance to go any further she chimed in,

"Well, that is really necessary as I stopped listening in mathematics when I was about 14."

I explained that keeping capable young women like herself studying mathematics was one of our main targets and she replied,

"It will be hard to combat the peer pressure. My group of friends did not think mathematics was cool and being cool was very important. Anyway, none of us were planning on going into the careers where we would be going to use mathematics anyway."

Why was that I asked,

"Mathematics was only required for engineering and the hard sciences, which are of no interest to girls" she said.

This was an intelligent young woman and yet she still had a very limited view of how mathematics supported study in so many fields.

The reality is it is not only girls who are abandoning STEM subjects. As a Year 11 and 12 coordinator and then campus principal in a senior school, I have been involved in many similar conversations with both male and female students over the years.

"The course I want to do only requires a 25 in any mathematics, why would I do the hard mathematics? I will get a better mark in the lower mathematics with less effort. No need to do the advanced mathematics."

How and why do these ideas arise and what factors are perpetuating this notion? One of the obvious determiners in the subject selection of Year 11 and 12 students are university prerequisites, or rather the lack of pre-requisites in many cases. Understandably individual students, careers advisors and schools have short horizons and the focus is upon achieving an ATAR that will enable students to be accepted into their tertiary course of choice. Any content knowledge they may require for successful tertiary study is rarely a consideration.

The removal of prerequisites for many courses has assisted the tertiary sector to increase enrolments. At the same time, however, there has been an alarming drop in the number of students choosing to study high-level mathematics in Year 12. Australia has witnessed an increasing number of enrolments in the lower level Year 12 mathematics subjects. Whilst there are many contributing factors, it is hard to ignore the numbers.

The then Victorian Minister for Education Martin Dixon said, "One reason for the shift away from the more challenging mathematics subjects was that universities had changed their pre-requisites for some courses."

The lack of students studying high-level mathematics is "an issue of national importance", according to Australia's Chief Scientist Ian Chubb. Choose Maths will be working with individuals and schools to educate them about the potential of mathematics to increase career options for young Australians.

The worry is that the attitude of schools and students may not change without a lead from the Universities. Universities placing a higher value on the study of mathematics will provide a tangible reason for selecting Year 12 mathematics units with more mathematical rigour. ■

AMSI and the BHP Billiton Foundation is actively working with schools to deliver Choose Maths, a five-year national program that will turn around public perception of mathematics and statistics as a career choice for girls and young women. Choose Maths will have a focus on mathematics education in primary and secondary schools and will contribute to the health of the mathematics pipeline in Australia from school through university and out to industry and the workplace.

TO READ MORE ABOUT THE CHOOSE MATHS PROGRAM VISIT WWW.CHOOSEMATHS.ORG.AU

COMPLEX NETWORKS

WHAT MAKES YOU, YOU?

The world around us is brimming with structures consisting of discrete and relatable entities, explains AMSI Summer School 2016 Senior Lecturer Dr Stephen Davis, RMIT University.

Are you really you? I mean, is it really you who determines your political opinions, your religious beliefs and your perception of what a normal healthy weight is, or is it your social context whereby your perception of what is normal and `right' is dictated by your friends and family? The answer is that your social network probably plays a much larger role than you realise.

In the study of health and disease, the way our social network affects our behaviour has had the profound outcome that diseases such as obesity can be mathematically modelled as if infectious, and obesity spreads through human social networks much like a virus does.

Complex Networks is an emerging area in the mathematical sciences that develops and applies mathematical and statistical tools to large network data.

Research into networks from disparate fields, ranging from gene-regulation networks in biology to the Internet to food webs in ecology, led to the stunning discovery that all real complex networks have a common topology: (i) they consist of many nodes with few connections and some nodes that are mega-enormous connected hubs, (ii) if A -> B and A -> C then it is highly likely that B -> C, and (iii) they are all much easier to `get around' than you'd think, which is the concept popularly known in human society as Six Degrees of Separation.

The consequences for health and disease are again profound, the presence of hubs in sexual networks for example led early theoreticians to the rather panicky conclusion that sexually-transmitted diseases such as HIV AIDS cannot be controlled. In fact, such distributions of connectedness can mean that public health measures can be directed at those most responsible for disease transmission. Even if these individuals are unknown a clever strategy is possible: take a random sample, don't vaccinate the random individuals but do vaccinate one of their friends, since most edges lead to a highly connected person chances are that you start `hitting' the hubs in the network.

Connectedness and disease actually do go hand in hand. If you are a highly social person (a hub in your social network) it is now known that you are more likely to get sick and you'll be one of the first to get sick when something is going around. So if you are a social butterfly, make sure you get the flu vaccine!

YOUR EGO NETWORK

The following exercise will characterise your local network and along the way tell you something about yourself and the way you manage your relationships. Start by drawing a solid circle that represents yourself and then place similar circles around you that represent family, friends or colleagues that you interact with regularly. Depending on how many there are you might restrict yourself to people you have spoken with for more than one minute in the past week. Next, draw links between yourself and your contacts such that your node looks like the centre of a wheel, with spokes coming outwards.

Now the more difficult bit. Draw additional links between your contacts if you think they would know each other on a first-name basis. The number of links you draw divided by the number of possible links between your contacts puts you on a scale where high values close to 1 indicate a `small-town' effect (everybody knows everybody) and where a low value (close to 0) indicates just the opposite, that you tend to keep your relationships all apart and separate. If you have m contacts, then the number of possible contacts between them is easily calculated as(1/2) m(m-1).

When this exercise is carried out with a group of people invariably two things happen. Firstly there is a wide range of values, and secondly there is a pause in the class, a moment of self-reflection as people consider what they have just learnt about themselves.

PHOTOGRAPHY: MICHAEL SHAW

YOUR IMPORTANCE

In January 1994, during a Premiere magazine interview, actor Kevin Bacon commented that he had worked with everybody in Hollywood or someone who's worked with them. The statement prompted a lengthy newsgroup thread amusingly titled "Kevin Bacon is the Center of the Hollywood Universe", Bacon numbers and the trivia game Six Degrees of Kevin Bacon, popular amongst film aficionados. The latter has your opponent name a Hollywood actor and you must then link the actor to Kevin Bacon via actors who have appeared in the same film.

How to identify `important' nodes in a network is one of the key questions that arise in Complex Networks. The centrality that Kevin Bacon claimed in the movie-actor network – that every actor is one or two `hops' away from him – turned out not to be terribly true, he isn't in the top 100 actors ranked in terms of closeness.

The simplest measure of importance is to count the number of links each node has, which is akin to ranking academics by a raw count of their publications or actors by a raw count of films they appear in. This is dissatisfying at a number of levels and there has long been debate that it is who you are connected to not how many connections you have, or it is the loss of network function that would ensue if you were deleted from the network, or it is the number of times a path between two nodes has to pass through you. Dear Kevin had no idea what sort of can of worms he was opening up!

DEEPER TRUTH

The researchers that first discovered the commonality in topological structure of real networks, i.e. that the presence of hubs was ubiquitous, also argued that a particular mechanism was responsible. First, they noted that all real networks are not static but grow over time. Second, when a new node emerges then it preferentially links to those nodes in the network that are already well connected. This is known as preferential attachment, or the rich get richer.

The concept is biblical – see Matthew 25:29 - but strange to think that things are this simple and that there is no room for any measures of quality. Surely, for example, citations go to high quality papers! We can mathematically prove that preferential attachment does generate realistic networks with so-called heavy-tailed distributions for the number of links each node has, but somewhat reassuringly so does an alternative model, the `good get richer' model where nodes are allocated an intrinsic fitness. In the latter model the chances of a link appearing depends on some combination of these fitness values.

Perhaps most exciting about the study of real complex networks is their ability to shed light on the fundamental principles that govern self-organising structure, principles as relevant to online social sites as they are to gene regulation and brain function. Indeed, it has been discovered already that all real networks have community structure and all types of networks have sets of motifs, which are small subgraphs that recur repeatedly as building blocks that the larger network is made up of.

It will be fascinating to see what complex networks will next reveal about the world around us, about society and about ourselves. ■

CONNECTEDNESS AND DISEASE ACTUALLY DO GO HAND IN HAND. IF YOU ARE A HIGHLY SOCIAL PERSON (A HUB IN YOUR SOCIAL NETWORK) IT IS NOW KNOWN THAT YOU ARE MORE LIKELY TO GET SICK AND YOU'LL BE ONE OF THE FIRST TO GET SICK WHEN SOMETHING IS GOING AROUND. SO IF YOU ARE A SOCIAL BUTTERFLY, MAKE SURE YOU GET THE FLU VACCINE!

4th SOUTH PACIFIC CONTINUOUS OPTIMISATION MEETING

Prof. Henri Bonnel, *University of New Caledonia, Noumea, New Caledonia* **Prof. Jonathan M. Borwein,** *University of Newcastle, AustMS and ANZIAM member* **Assoc. Prof. Regina S. Burachik,** *University of South Australia, AustMS and ANZIAM member* **Dr C. Yalçın Kaya,** *University of South Australia, AustMS and ANZIAM member*

With one of Australia's most beautiful regions at their doorstep and a rich scientific program exploring continuous optimisation, global research leaders and students gathered at Adelaide's University of South Australia for SPCOM 2015. Organising committee members Assoc. Prof. Regina Burachik and Dr Yalcin Kaya shared some of the meeting's highlights with AMSI.

Broadly speaking, the mathematical field of optimisation involves determining an optimal scenario (relative to some criteria) among a collection of alternatives.

For example, the determination of the most efficient route between two locations, where "route" and "location" can have many abstract and concrete meanings, or the most economical use of resources in production processes. Optimisation problems can involve thousands of variables and minimise or maximise many "objective functions".

Mathematical optimisation is a broad and rich research area in its own right and it has equally broad application. In economic terms it is critical to productivity growth and competitive advantage. In social terms it is important in health care, transport planning and communication networks, to name just a few.

The fourth edition of the successful South Pacific meetings, this year's event addressed a diverse audience, from those early in their career to senior researchers. Featuring lectures, the Fitzpatrick Workshop, two half-day tutorials on numerical optimisation, and a student poster session, the topics ranged from variational analysis, optimal control theory, convex analysis, numerical optimisation, vector optimisation, stochastic optimisation, functional analysis, and their applications.

A common theme at this year's SPCOM was the numerical approaches to several types of optimisation problems.

The meeting started with the two warm-up tutorials by José Mario Martínez and Claudia Sagastizábal. Martínez delivered the morning tutorial on numerical smooth optimisation. The afternoon tutorial, on numerical non-smooth optimisation, was delivered by Sagastizábal.

Terry Rockafellar, a world leader in convex analysis and optimisation, opened the second day of the conference with a stellar talk on how stochastic variational inequalities can provide the right framework for studying problems of optimisation and equilibrium in a stochastic setting. (The word stochastic here refers to problems with a degree of randomness or indeterminacy. For more detail see the Technical Report opposite.) The attendees also had a chance to celebrate Terry Rockafellar's 80th birthday (not a random event!) during the meeting banquet, by means of live piano performances, singing and dancing.

Boris Mordukhovich and Asen Dontchev gave talks at the leading edge of research in variational analysis. This subject grew from the classical calculus of variations where differential equations, such as Newton's equations in mechanics, are framed as a variational principle which identifies the solution of the differential equations as providing a minimum of some "action integral". Mordukhovich discussed a new application of variational analysis to monotonicity properties in both global and local frameworks. Dontchev spoke of recent advances in the study of Lipschitz properties of solutions, of paramount importance in sensitivity studies of constrained optimisation problems.

The Fitzpatrick Workshop was certainly another highlight and celebrated 25 years of the publication of a seminal paper on maximal monotone operators by the late Australian mathematician Simon Fitzpatrick. Fitzpatrick's paper introduced a key tool in functional analysis, with important implications in mathematical optimisation. An objective of this workshop was to understand, after a quarter of a century, what open questions posed in this paper have been solved, and what questions remain open. Stephen Simons gave a keynote talk on Fitzpatrick's contributions to functional analysis, introducing a new theoretical framework, which gives a generalisation of Brezis-Browder theorem on linear relations. Most of the results Simons presented are consequences of Simon Fitzpatrick's seminal 1988 paper. Simons' fascinating talk was followed by Adly, Borwein, Boţ and Burachik.

SPCOM 2015 not only covered insightful scientific research and outcomes. It also gave the guests much needed time to meet and socialise with fellow colleagues and field experts. The mid-week winery tour to McLaren Vale was a great success.

The event attracted plenty of praise from attendees for its perfect blend of scientific research and social gatherings and the chance to explore some of the best of South Australia. ■

> "The conference was a spectacular success scientifically and socially, and of course especially for me!"
>
> *Emeritus Professor Terry Rockafellar, University of Washington*

FITZPATRICK WORKSHOP

Simon Fitzpatrick was an outstanding Australian mathematician. His contributions have an increasing impact in functional analysis, both in theoretical and applied aspects. The now celebrated Fitzpatrick function,

$$F_T(x,x^*) = \sup_{y^*\in T(y)} \langle y^*-x^*, x-y\rangle + \langle x,x^*\rangle$$

where T is a maximally monotone map, has been cited and used extensively in wide range of applications from PDEs to modern economic theory. It has become a fundamental tool in maximal monotone theory. The Fitzpatrick function was unnoticed for several years until Martínez-Legaz and Théra rediscovered it in 2001. This function provides a bridge between certain monotone phenomena and convex functions. This allows use of powerful variational techniques for studying problems such as (i) first-order monotone flows, (ii) nonlinear evolutionary PDEs and (iii) quasilinear models in continuum mechanics, electromagnetism and heat conduction. In a surprisingly different field, Flam has recently given an economic interpretation of the Fitzpatrick function in terms of a supply curve, which couples prices to quantities in a non-Walrasian market.

In terms of theoretical advances, the Fitzpatrick function has led to considerable simplifications of the proofs of some classical properties involving maximally monotone operators. For example, Simons and Zalinescu used it to obtain a new and short proof of Rockafellar's characterisation of maximal monotone operators. Within the theory of maximally monotone maps, Burachik and Svaiter used it to define a one-to-one correspondence between a family of convex functions associated with a maximally monotone operator, and a family of enlargements of these operators. These enlargements, in turn, generated a new way for the efficient approximation and analysis of variational inequality problems. Marques Alves and Svaiter have used it recently to define a new constraint qualification ensuring maximality of the sum of maximally monotone operators in non-reflexive Banach spaces.

Stephen Simons opened the workshop with a plenary talk in which, using concepts emanating from Fitzpatrick's work, he obtained a generalisation of Rockafellar's theorem on the maximal monotonicity of subdifferentials, and, among other results, he obtained an extension of Brezis-Browder theorem to non-reflexive Banach spaces (Brezis-Browder theorem proves that, in a reflexive Banach space, the adjoint of a linear monotone mapping with closed graph is monotone if and only if the original mapping is maximally monotone). The plenary talk was followed by four 20-minute talks by Jonathan Borwein, Samir Adly, Radu Boţ and Regina Burachik. Borwein's talk introduced the strong Fitzpatrick inequality and used it to define a gap function for the monotone inclusion problem and variational inequalities. Boţ then furnished new duality results for certain convex optimisation problems. Adly showed how nonsmoothness naturally arises in dynamical systems, such as those induced by electrical circuits, and some problems from mechanics and lastly Burachik presented a new family of enlargements, which is inspired by Fitzpatrick's 1988 paper and every member of this family is structurally closer to the epsilon-subdifferential enlargement.

STOCHASTIC VARIATIONAL INEQUALITIES & OTHER STOCHASTIC PROBLEMS

Variational inequality modeling, analysis and computations are important for many applications, but most of the subject has been developed in a deterministic setting. In recent years research has proceeded on a track to incorporate stochasticity in one way or another. However, the main focus has been on a rather limited idea of what a stochastic variational inequality might be. As variational inequalities are especially tuned to capturing conditions for optimality and equilibrium, stochastic variational inequalities ought to provide such service for problems of optimisation and equilibrium in a stochastic setting. Therefore they ought to be able to deal with multistage decision processes involving recourse actions, which has so far hardly been the case. Terry Rockafellar showed it is possible to accommodate this by bringing in the tools of nonanticipativity and its martingale dualisation. Roger Wets then put these new contributions into a historical perspective in his plenary talk, which described the highlights of Rockafellar's results. To reinforce the stochastic flavor, Claudia Sagastizábal's plenary talk covered a new variant of bundle methods, which has "on-demand" accuracy, and Jong Shi Pang's plenary talk concerned Nash equilibria for games with stochastic recourse functions.

THEORY & APPLICATIONS OF NUMERICAL OPTIMISATION

A common denominator in most talks at SPCOM was the numerical approaches to several types of optimisation problems. Some talks encompassed theory, some applications, and some others both theory and applications. An example of the latter type was Boţ's plenary talk, which showed us how duality can be exploited for solving complexly structured nonsmooth optimisation problems. Jeya Jeyakumar presented new results in global polynomial optimisation. José Mario Martínez presented new results on sequential optimality conditions for differentiable constrained optimisation. Helmut Maurer spoke about optimal control problems from biology and biomedicine whose solutions exhibit bang-bang and singular control. Xiaoqi Yang presented first- and second-order necessary conditions for nonlinear programming problems from the viewpoint of exact penalty functions. He also presented an interior point method to solve the L_p relaxed penalty problem, together with promising numerical experiments.

The meeting was generously sponsored by University of South Australia (UniSA), School of Information Technology and Mathematical Sciences (ITMS) at UniSA, Centre for Industrial and Applied Mathematics (CIAM) at UniSA, Australian Mathematical Sciences Institute (AMSI), Centre for Computer Assisted Research Mathematics (CARMA) at the University of Newcastle, University of New Caledonia, Australian Mathematical Society (AustMS), Australian and New Zealand Industrial and Applied Mathematics (ANZIAM), and ARC Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS).

THIS IS AN EDITED VERSION OF ASSOC. PROF. REGINA BURACHIK AND DR C. YALÇIN KAYA'S REPORT ON THE 4TH SOUTH PACIFIC CONTINUOUS OPTIMISATION MEETING

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