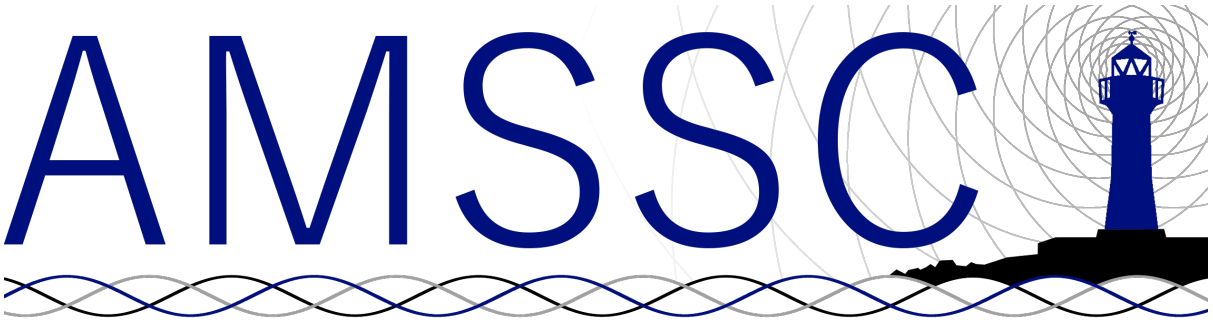








# Conference Booklet

University of Wollongong
December 6th–8th, 2017

# Contents

# Welcome to AMSSC17

Welcome to the 5th Australian Mathematical Sciences Student Conference! This is a student run event for the benefit of postgraduate students in the Australian mathematical community. This conference aims to encourage communication and foster strong relationships between young researchers throughout the mathematical sciences. Far from being a strictly academic event, the AMSSC also aims to provide an open environment and offers a social atmosphere where friendships are free to blossom.

As a participant, this an excellent platform for you to hone your presentation skills and advertise your research to your peers. It is also a perfect opportunity to steal a glimpse at the current state of research in areas outside your expertise. To this end, we urge you to attend as many of the presentations as possible, and to actively participate in discussions with your fellow students. Of course this is also a social event, so we encourage you to introduce yourself to as many of the other participants as possible.

Last but not least, thank you, the participants, for attending the AMSSC this year. It goes without saying that a student conference is nothing without any students. We trust that you will all have a fruitful and fantastic time here at the University of Wollongong!

## A note to the presenters

Each conference room is equipped with whiteboards, markers, a projector, and a computer with a PDF reader and Microsoft Powerpoint installed. If you will be using the computer, we ask that you load your presentation via USB, or otherwise, onto the provided computer in the break immediately preceding your presentation so that the sessions may run smoothly.

*The 2017 AMSSC Organising Committee*
*Tom Dyer*
*Ziwei Ke*
*Michael Mampusti*
*Alexander Mundey*
*Thomas Pedersen*

# AMSSC18: Will you answer the call?

We are strong believers that the AMSSC provides immense benefits for those who participate, and plays a significant role in shaping the future of the mathematical landscape. Naturally, we desire to develop and expand this conference in the years to come. For such ambitions to become reality, we must solidify the AMSSC as an annual conference in the Australian mathematical calender.

In this spirit, we encourage you to take up the organisation of the **2018 Australian Mathematical Sciences Student Conference**. Of course, the organisation of such a conference is not a walk in the park. However, there is a clear process for you to follow and a host of previous organisers who you will be able to consult. Organisation of this conference has been an invaluable experience, and we strongly encourage you to apply to host AMSSC18 at your home university.

To apply to host the next AMSSC, you will need:

- Some self-motivation,
- A reliable group of people to form an organising committee, and
- A rough understanding of the logistics of running this event at your university.

Some of the benefits of organising this event include:

- Valuable experience in filling applications for grants,
- Acquiring and strengthening organisational and communication skills, and
- The perfect addition to that already brilliant CV.

If you think that you, and a group of your peers, are up to the task of organising the next AMSSC, please feel free to chat with one of the current conference organisers. We ask that you prepare a hosting bid; a short report outlining why you would like to host the AMSSC, and why your university would be a suitable location for such an event. Official hosting bids are to be emailed to the conference email address (`amssc2017@gmail.com`) by the **15th February 2018**, and the successful application will be announced shortly after.

# Acknowledgements

We would like to give a big thanks to our sponsors, without which this conference would not have been possible.

## List of sponsors

- Australian Mathematical Society
- Australian Mathematical Sciences Institute
- Australian Signals Directorate
- School of Mathematics and Applied Statistics - University of Wollongong
- Institute for Mathematics and its Applications

We would also like to extend our thanks to members of the University who have been integral in the organisation of this conference, namely Megan Crowl and Adam Rennie. We would also like to thank the University of Wollongong for allowing us to use their facilities, and the University of Newcastle for hosting our website.

# List of Participants

## Keynote Speakers

| Name | Institution |
|---|---|
| Norman Do | Monash University |
| Melanie Roberts | IBM Research |
| Glen Wheeler | University of Wollongong |

## Students

| Name | Institution |
|---|---|
| Xin An | University of Wollongong |
| Becky Armstrong | University of Sydney |
| Alex Bishop | University of Newcastle |
| Jacob Bradd | University of Wollongong |
| Elizabeth Bradford | University of South Australia |
| Kevin Aguyar Brix | University of Copenhagen |
| Mark Bugden | Australian National University |
| Timothy Bywaters | University of Sydney |
| Laura Cartwright | University of Wollongong |
| Alex Casella | University of Sydney |
| Andy Chu | University of Technology Sydney |
| Robert Culling | Australian National University |
| Tom Dyer | University of Wollongong |
| Russell Edson | University of Adelaide |
| Yoong Kuan Goh | University of Technology Sydney |
| Logan Haami | University of Technology Sydney |

| Name | Institution |
|---|---|
| Sean Harris | Australian National University |
| Shuhui He | University of Wollongong |
| Eric Hester | University of Sydney |
| David Hughes | University of Wollongong |
| Elisa Jager | University of Wollongong |
| Samuel Jelbart | University of Sydney |
| Ziwei Ke | University of Wollongong |
| Daniel Kon | University of Adelaide |
| Sha Lin | University of Wollongong |
| Lachlan MacDonald | University of Wollongong |
| Benjamin Maldon | University of Wollongong |
| Michael Mampusti | University of Wollongong |
| Rhys McDonald | University of Wollongong |
| Liam Morrow | Queensland University of Technology |
| Alexander Mundey | University of Wollongong |
| Jessica Murphy | University of Wollongong |
| Gennady Notowidigdo | University of New South Wales |
| Thomas Pedersen | University of Wollongong |
| Aiden Price | Queensland University of Technology |
| Kylie-Anne Richards | University of New South Wales |
| Nicholas Seaton | University of Wollongong |
| Kyle Stevens | University of Wollongong |
| Dominic Tate | University of Sydney |
| Christopher Taylor | La Trobe University |
| Quoc Duyet Tran | Royal Melbourne Institute of Technology |
| Eloise Tredenick | Queensland University of Technology |
| Kyle Wright | Australian National University |
| Yuhan Wu | University of Wollongong |
| Dong Yan | University of Wollongong |

# Keynote Speakers

## Dr. Melanie Roberts

IBM Research

From asymptotics to insurance research: a journey from student to professional mathematician

9:20 a.m. Wednesday 6th December, 20-G03

In this talk I will I trace the journey I took from mathematics student to professional mathematician with IBM Research – Australia. In particular, I will focus on the actions I took as a student that have helped me in my career, and importantly the things I wish I had done but didn't.

**Biography:** Melanie is a research scientist with the Predictive Resource Optimisation team at IBM Research - Australia and honorary research fellow with the University of Melbourne, working at the intersection of data and mathematical modelling. Melanie has experience with developing and implementing decision tools across emergency management, agriculture, water management and insurance. Her recent work is focussed on developing models to understand household-based risk from bushfires to assist communities in reducing their risk while maintaining the benefits of living in a bushland environment.

Melanie received her PhD in applied mathematics from the University of Western Australia in 2012, and holds degrees in mathematics, education and science communication.

Melanie holds a number of positions to advance the discipline of mathematics. She is Chair of the Victorian Branch of ANZIAM (Australian and New Zealand Industrial and Applied Mathematics), returning office for the ANZIAM executive, a member of the advisory committee for both the University of Wollongong School of Mathematics and Applied Statistics and the Australian Mathematical Society Membership Committee, a member of Mathematicians in Schools, and contributor to many outreach events.

**Dr. Norman Do**
Monash University

WHERE MY MATHS COMES FROM
9:00am Thursday 7th December, 20-G03

As you well know, the main vehicle for communicating mathematics research is via journal papers. And the culture of this medium is largely to present only the final polished product, without reference to the genesis, the motivation, the numerous dead ends, nor the personal stories behind the work. In this talk, I'll delve back into my publication record and tell the untold tales of how some of my papers came into existence. Along the way, you'll hear my mathematical origin story and learn about my research... but more importantly, you will see where my maths comes from.

**Biography:**

Norm Do completed a PhD at University of Melbourne before undertaking a post-doctoral fellowship at McGill University. He is currently a Lecturer and ARC DECRA Research Fellow at Monash University. His research lies at the interface of geometry, combinatorics and mathematical physics, although he is excited by most flavours of mathematics. Alongside his research, Norm is heavily involved in education and enrichment. For example, he regularly lectures at the National Mathematics Summer School and is the Chair of the Problems Committee for the Simon Marais Mathematics Competition.

# Dr. Glen Wheeler

University of Wollongong

Curvature flow, blood cells, bushfires, and being a mathematician

9:00am Friday 8th December, 20-G03

New advances in the field of geometric analysis have enabled exciting new applications. This talk explains two of these applications, while giving a sense of how I personally came to study these phenomena.

The first is to bushfires: conventional wisdom models an evolving fire front by Huygen's principle, which is known to be inaccurate in a variety of ways. One of these is for a wedge-shaped front. By comparing theoretical results with observed fires and experiments in fire tunnels, we show that by using a model that incorporates curvature, a more realistic evolution is obtained.

The second application is to the shape of red blood cells, in particular human red blood cells. Spherocytosis, the most common form of inherited anaemia in people with northern European ancestry, is a disease of the blood where blood cells assume a spherical shape. This is a serious condition that can be fatal, with the typical case requiring a lifetime of treatment. As blood cells are self-organising, it is possible to derive an equation that the shape satisfies. By investigating this equation, we can determine why blood cells are forming as spheres. Current results are preliminary, but indicate that this exciting new avenue has a lot of potential for new treatments and in the long-term a possible cure.

**Biography:**

Glen, born in Sydney, spent his childhood on farms in rural NSW learning to program on the C64 in GW Basic with lofty dreams of one day getting paid for it. After his undergraduate degree, and one year in industry, he realised that computer science was not really for him, and went back to study math.

One honours in measure theory and PhD in geometric analysis later, he found himself in Germany on an Alexander-von-Humboldt research fellowship. This was a followup to a DAAD fellowship awarded in 2008. After working in Germany for three years he returned to Australia, first as a postdoc, and then later in 2014 on a continuing position.

Since then he has been awarded an ARC DP and supervised one PhD student to completion, with five more on the way. He wishes to solve problems in geometry by any means necessary, which for him has meant PDE and in particular curvature flow. His published work is broad, with articles on topics from cryptography, error correcting codes, bushfires to his mainstay of geometric analysis. In geometric analysis he has around 20 published articles with collaborators from all around the world. He is a conference regular, both in terms of organisation of events and speaking, with particular focus on Germany, Poland, Japan, China, and the US.

# Conference Timetable

## Wednesday 6th December

| Room: | 20-G03 | 20-G02 |
|---|---|---|
| **8:30 - 9:00** | Registration (Atrium of Building 20) | |
| **9:00 - 9:20** | Opening (20-G03) | |
| **9:20 - 10:20** | Melanie Roberts (20-G03)<br>"From asymptotics to insurance research:<br>a journey from student to<br>professional mathematician" | |
| **10:20 - 10:50** | Morning Tea | |
| **10:50 - 11:20** | Mark Bugden | Eric Hester |
| **11:20 - 11:50** | Timothy Bywaters | Russell Edson |
| **12:50 - 12:20** | Robert Culling | Daniel Kon |
| **12:20 - 1:50** | Lunch | |
| **1:50 - 2:20** | | Quoc Duyet Tran |
| **2:20 - 2:50** | Thomas Pedersen | Xin An |
| **2:50 - 3:20** | Alex Bishop | Benjamin Maldon |
| **3:20 - 3:50** | Afternoon Tea | |
| **3:50 - 4:20** | Aiden Price | Kylie-Anne Richards |
| **4:20 - 4:50** | Becky Armstrong | Dong Yan |
| **4:50 - 5:20** | Goh Yoong Kuan | Elisa Jager |

# Thursday 7th December

| Room: | 20-G03 | 20-G02 |
|---|---|---|
| **9:00 - 10:00** | Norman Do (20-G03)<br>"Where my maths comes from" | |
| **10:00 - 10:30** | Morning Tea | |
| **10:30 - 11:00** | ASD Presentation (20-G03) | |
| **11:00 - 11:30** | Christopher Taylor | Laura Cartwright |
| **11:30 - 12:00** | Lachlan MacDonald | Eloise Tredenick |
| **12:00 - 12:30** | Nicholas Seaton | Samuel Jelbart |
| **12:30 - 2:00** | Lunch | |
| **2:00 - 2:30** | Alex Casella | Sha Lin |
| **2:30 - 3:00** | Dominic Tate | Liam Morrow |
| **3:00 - 3:30** | Afternoon Tea | |
| **3:30 - 4:00** | Rhys McDonald | Ziwei Ke |
| **4:00 - 4:30** | Gennady Notowidigdo | Yuhan Wu |
| **6:00** | Conference Dinner<br>"levelone @harbourfront" | |

# Friday 8th December

| **Room:** | **20-G03** | **20-G02** |
|---|---|---|
| **9:00 - 10:00** | Glen Wheeler (20-G03)<br>"Curvature flow, blood cells, bushfires,<br>and being a mathematician" | |
| **10:00 - 10:30** | Morning Tea | |
| **10:30 - 11:00** | Alexander Mundey | Elizabeth Bradford |
| **11:00 - 11:30** | Michael Mampusti | Kyle Stevens |
| **11:30 - 12:00** | | Tom Dyer |
| **12:15 - 12:45** | Closing (20-G03) | |

# Talk Abstracts

## Peaking dispersive shock waves governed by the Whitham equation

**Xin An** (University of Wollongong)

Dispersive shock waves (DSWs), also termed undular bores in fluid mechanics, governed by the nonlocal Whitham equation are studied in order to investigate short wavelength effects that lead to peaking and cusping waves within the DSW. This is done by combining the weak nonlinearity of the Korteweg-de Vries equation with full linear dispersion relations. The dispersion relations considered are those for surface gravity waves, the intermediate long wave equation and a model dispersion relation introduced by Whitham to investigate the $120^o$ peaked Stokes wave of highest amplitude. A dispersive shock fitting method is used to find the leading (solitary wave) and trailing (linear wave) edges of the DSW. This method is found to produce results in excellent agreement with numerical solutions up until the lead solitary wave of the DSW reaches its highest amplitude. Numerical solutions show that the DSW becomes a multi-phase wavetrain after the highest amplitude is reached.

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## Groupoidology

**Becky Armstrong** (University of Sydney)

Have you ever wished that groups could have more than one identity? Have you ever wondered what would happen if certain group elements were banned from being multiplied together? Join us on an exciting adventure into the marvellous world of groupoidology, where such weirdness is not only possible, but celebrated! Together, we will discover many surprising examples of these crazy structures called groupoids, and consider the applications of groupoids to various fields of mathematics. Prepare to be shocked and amazed as you suddenly realise that groupoids have been staring you in the face for your entire mathematical life, just waiting for you to begin investigating and loving them.

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## Geodesic Growth of the Fabrykowski-Gupta Group

**Alex Bishop** (University of Newcastle)

An open question in geometric group theory is whether there exists a group with intermediate geodesic growth. That is, a group for which the function which counts the number of length $n$ geodesics (i.e. minimal length word representations of group elements) grows faster than any polynomial and slower than any exponential; a potential example for this property is the Fabrykowski-Gupta group.

This presentation will introduce an efficient algorithm for computing the geodesics of the Fabrykowski-Gupta group with the objective being to provide a computation-based experimental method for studying the geodesic growth of this and similar examples. The complexity of this algorithm will be given and it will be shown to be a massive improvement over the complexity of the previously known brute-force method which has been used in the literature.

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## Recursive algorithms for inversion of linear operator pencils

**Elizabeth Bradford** (University of South Australia)

There are numerous examples of systems that can be represented by linear equations. In many cases the system coefficient is an operator that depends on an unknown parameter. We are interested in what happens to the solution when we change this parameter. If the coefficient is a linear operator pencil which depends on a single complex parameter and the resolvent is analytic on a deleted neighbourhood of the origin, the resolvent can be calculated by different procedures. We calculate the resolvent matrix using different recursive procedures which, for finite dimensional problems, will terminate after a finite number of steps. We will briefly compare the different methods.

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## Photon Spheres in 5 dimensions

**Mark Bugden** (Australian National University)

Black holes are an interesting class of objects in Einstein's theory of gravity, general relativity. Around spherically symmetric black holes, there is a radius at which light may orbit, forming a surface called a photon sphere. Rotating black holes have more interesting photon spheres, where orbits are not confined to lie in a plane. In this talk, I will speak about my work (in progress) in generalising these orbits to higher dimensional spacetimes. My talk will include plenty of pretty pictures.

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## Totally disconnected locally compact groups

**Timothy Bywaters** (University of Sydney)

In the early 90's, Willis revitalised the study of totally disconnected locally compact groups which had been dormant for around 60 years. Since then, tremendous progress has been made which has affected the study of group theory in general. We will introduce these groups whilst giving concrete examples, core theorems and applications to other areas of mathematics.

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## Fantastic homologies and where to find them

**Laura Cartwright** (University of Wollongong)

Persistent homology is a relatively young, yet increasingly popular branch of topological data analysis, which is designed to detect "topological signals" in point cloud data sets. I will begin by briefly covering the mathematical background needed to discuss later work, before introducing a hypothesis test for detecting topological signals which are significantly different to those we "expect" under a null hypothesis. This test uses a functional test statistic known as the accumulated persistence function; a function of the lifetimes and mean ages of topological signals detected in the data. I will demonstrate the use of this test on simulated data sets of circles that represent a collection of cells.

---

## On Convex Projective Structures: Part I

**Alex Casella** (University of Sydney)

In 1892, Klein and Lie had this idea to think about geometries as properties of a space which are invariant under a group of transformations. For example, we can think about the planar euclidean geometry as an $(\mathbf{R}^2, O(2) \ltimes \mathbf{R}^2)$–structure, or 2–dimensional hyperbolic geometry as an $(\mathbf{H}^2, \mathrm{PGL}(2, \mathbf{R}))$–structure. In this talk, we will focus on projective geometry, namely $(\mathbf{RP}^2, \mathrm{PGL}(3, \mathbf{R}))$–structures. We will introduce the audience to the notions of convexity, marking, ends and framing. Then we will define the moduli space $\mathcal{T}_3^+(S)$ of framed marked convex projective structures on a surface $S$. We will conclude with Fock and Goncharov's characterisation of $\mathcal{T}_3^+(S)$ by positive real numbers.

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## $\mathbb{R}_+$-Algebras in the Plane

**Robert Culling** (Australian National University)

The plane has a natural algebra structure over the real numbers. One can ask: how many real sub-algebras does the plane have? It turns out there are only two. In this talk we will discuss the more interesting case of algebras over the positive reals which live in the plane.

---

## Interaction of graphene oxide structures

**Tom Dyer** (University of Wollongong)

You may have heard of graphene, the "miracle material" with exceptional properties in just about everything including its excellent electronic and thermal conductivity and unrivaled tensile strength. Graphene oxide is an oxidated graphene sheet. It is a less desirable material with weaker electronic properties but retains once big advantage, its hydrophillic nature. This allows it to disperse in water forming a liquid crystal structure which can be dried to form thin films or spun into fibres potentially paving the way for mass-production. We will construct a continuum model for graphene oxide and investigate the interaction forces between graphene oxide sheets and carbon nanotubes in thin films.

---

## Couple periodic patches to simulate Kuramoto-Sivashinsky dynamics

**Russell Edson** (University of Adelaide)

Many dynamical systems in our world are multiscale systems; the physics for the system are accurately modelled at much finer scales than the coarse scales at which we make observations. Often no useful closures exist to bridge the different scales, and we must resort to simulating the microscale directly. However, microscale simulation to resolve large scale system dynamics is prohibitively expensive.
The patch dynamics framework promises efficient and parallelizable simulation of macroscale system behaviour. A patch scheme for a multiscale system simulates the expensive microscale only in small patches of the spatial domain. Coupling the patches together across unsimulated space empowers accurate prediction of the emergent macroscale dynamics.
Here we construct a patch scheme for the one-dimensional Kuramoto-Sivashinsky PDE. Assume we have a 'black-box' microscale simulation code for the PDE with periodic boundary conditions. Small patches of periodic microscale simulation are coupled together by controlled forcing in designated action regions. Automated tuning of the action region locations and forcing strengths produces a patch scheme that accurately resolves

the macroscale nonlinearity, and demonstrates the effectiveness of the patch dynamics methodology for simulating complex multiscale systems.

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## Pattern Avoiding Permutations

**Goh Yoong Kuan** (University of Technology Sydney)

The research interest in pattern avoiding permutations is inspired by Donald Knuth's work in stack-sorting. According to Knuth, a permutation can be sorted by passing through a single infinite stack if and only if it avoids a sub-permutation pattern 231. Murphy extended Knuth's research by using two infinite stacks in series and found out that the basis for generated permutations is infinite but Elder proved that the basis is finite when one of the stack is limited to depth two and the permutations are algebraic. My research is to investigate the permutations generated by a stack of depth 3 and an infinite stack in series. It is to determine the basis and nature of the permutations in term of formal language.

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## On the interaction of vortices and internal waves in the dead-water problem

**Eric Hester** (University of Sydney)

Dead water refers to an increase in resistance experienced by boats in density-stratified waters. The problem has been documented since antiquity, and studied scientifically for over a century. These investigations have revealed the role of internal waves in generating drag, though many details remain unclear. For the first time, we study dead water using state-of-the-art numerical simulations. We reproduce the effect and show it is greatest in strongly nonlinear regimes poorly modelled by current theory. We also find a coherent trailing vortex strongly coupled to the wave and boat dynamics. This robust structure is consistent with sailors accounts, but has been overlooked in previous studies. We expect these results to lead to actionable ways to mitigate dead water in the real world. Our studies also relate to work on the flocking of birds, where vortex interactions play a significant role in flight efficiency.

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## Exploring Changes in Temperature Variability in Australia

**Elisa Jager** (University of Wollongong)

There is a recognised trend of warming mean temperatures in Australia and globally but the issue of what is happening with the variability and the higher order moments

of temperature distributions is still unresolved. The standard approach of using gridded data to run models and study historical trends obscures these factors due to interpolation of measurements smoothing the distributions. Non-direct methods of studying the distribution are being applied here to raw daily max and min temperature data from 112 Australian stations. These include a study of the statistics of record breaks, quantile regression, seasonal curve phase shifts and looking at the effects of temporal resolution of measurements. The end goal is to look for any possible effects on agricultural yields in Australia form these shifts in behaviour.

---

## Towards a More General Theory for Slow-Fast Systems

**Samuel Jelbart** (University of Sydney)

Geometric singular perturbation theory (GSPT) provides a well-established framework for the study of slow-fast dynamical systems. For the most part, however, this framework has been applied only for systems in which the slow-fast structure derives from a separation of slow/fast variables. Not all slow-fast systems have such a structure, however, and as such applications of GSPT to slow-fast systems without such a structure are rare in the literature. We show how traditional GSPT can be generalised so that it may be applicable to a larger class of problems, and illustrate the method by applying it to prove results about relaxation oscillation and canard explosion in a planar slow-fast system that cannot be treated using the traditional framework.

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## Pricing European-style Options with the Adomian Decomposition Method

**Ziwei Ke** (University of Wollongong)

European option prices can be obtained by solving the well-known Black-Scholes (BS) equation. Adomian Decomposition Method(ADM), as one of the popular numerical techniques, provides us an efficient way to solve partial differential equations. However, because of the non-differentiability of the payoff function of the vanilla European option, applying ADM to the BS equation is difficult. Previous works on this project, which assume the payoff function is differentiable or estimate the payoff function by a differentiable one, has been proved to be wrong and a new, correct way is urgently required. In this talk, I will present our new modified ADM, which can solve the BS equation successfully. Further, I will extend our technique to pricing digital options and European options under the Vasicek interest rate model. Numerical results show that the solution obtained from our new algorithm is accurate.

---

## Squeezing Biomarkers out of a Stone

**Daniel Kon** (University of Adelaide)

One way to diagnose disease is to use a blood test to detect certain proteins known as biomarkers. Mass spectrometry is one technology for discovering high quality biomarkers that discriminate between diseased and healthy states of a human. A limitation of the technology is missing data. I model the missingness mechanism in a proteomic mass spectrometry dataset in order to extract as much information as possible from the dataset and thereby find the best biomarkers for disease diagnosis.

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## Pricing puttable convertible bonds with integral equation approaches

**Sha Lin** (University of Wollongong)

American-style puttable convertible bonds are often priced with various numerical solutions because the predominant complexity arises from the determination of the two free boundaries together with the bond price. In this paper, two forms of integral equation are derived to price a puttable convertible bond on a single underlying asset. The first form is obtained under the Black-Scholes framework by using an incomplete Fourier transform. However, this integral equation formulation possesses a discontinuity along both free boundaries. An even worse problem is that this representation contains two first-order derivatives of the unknown exercise prices, which demands a higher smoothness of the interpolation functions used in the numerical solution procedure. Thus, a second integral equation formulation is developed based on the first form to overcome those problems. Numerical experiments are conducted to show several interesting properties of puttable convertible bonds.

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## Foliations and holonomy

**Lachlan MacDonald** (University of Wollongong)

Foliations are a formulation of the notion of "layered space", in which we study how higher dimensional objects are composed of lower dimensional layers. One of the key features of foliations is their holonomy, which encodes how these layers are twisting and coalescing about one another. I will discuss these concepts and my study of them using operator algebra techniques and differential geometry.

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## Pressing Charges - Analytical Solutions to the Diffusion Model of Dye-Sensitized Solar Cells

**Benjamin Maldon** (University of Wollongong)

Dye-Sensitized Solar Cells (DSSCs) have proven to be a fascinating solution to the renewable energy problem, yet their efficiencies leave more to be desired. In this talk, we will look at the ever dominant diffusion model and deduce an analytical solution.

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## An Equilibrium State of Mind

**Michael Mampusti** (University of Wollongong)

This talk is based on systems at equilibrium; a particular state of a system which does not change over time. We briefly motivate a particular class of dynamical systems inspired from quantum dynamical systems, and how KMS (Kubo-Martin-Schwinger) states describe equilibrium in such a framework. We finish off with an application to iterated function systems, and outline how dynamical information is encoded in the KMS state structure.

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## KMS states of the Twisted Toeplitz Algebra

**Rhys McDonald** (University of Wollongong)

We extend the characterisation of the KMS states of the Toeplitz Algebra to the twisted case.

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## A numerical scheme for investigating interfacial instabilities in simply and doubly connected geometries

**Liam Morrow** (Queensland University of Technology)

Significant attention has be devoted to studying the evolution of bubbles in a Hele-Shaw cell, which is an experimental apparatus consisting of two flat plates separated by a small gap filled with a viscous fluid. When an inviscid fluid is injected into the viscous fluid, fingering patterns develop due to the Saffman-Taylor instability. Here we consider an analogous three-dimensional porous media model, which describes an expanding bubble in a saturated porous medium. Recent studies into both the two and three-dimensional versions of this problem reveal that the development of these interfacial instabilities can be controlled by implementing a time-dependent injection

rate of the inviscid fluid. Here we present a robust level set based numerical scheme to solve this nonlinear moving boundary problem, and use it to investigate the effectiveness of these time-dependent injection strategies. We consider the evolution of invicid bubbles surrounded by a finite amount of viscous fluid such that we now have two interfaces; an inner and outer. By extending our numerical method to incorporate doubly connected geometries, we investigate the instabilities which develop and the interaction between these two interfaces.

---

## A non-commutative approach to fractal geometry

**Alexander Mundey** (University of Wollongong)

Iterated function systems are one of the most common methods of generating fractals. The dynamical system one gets from an iterated function system is often complex and chaotic in nature, however the topological aspects of this dynamical system are little understood.

In this talk we will try to understand these systems using operator algebras. We will see how to encode the dynamics of an iterated function system within a non-commutative algebra of operators. Then, using the techniques of non-commutative geometry, we will see how we can extract dynamical invariants of the system from our algebra.

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## On the $C^*$-algebras of a graph of groups : Part I

**Jessica Murphy** (University of Wollongong)

Firstly we provide an introduction into graph of groups $C^*$-algebras. We then provide an example of a graph of groups $C^*$-algebra and concretely identify it.

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## Tetrahedron centres in a general metrical framework

**Gennady Notowidigdo** (University of New South Wales)

The centroid, circumcentre and orthocentre of a general triangle is a well- known exercise in geometry (Figure 1); from these three points, we can derive2 the Euler line of a general triangle, as well as its nine-point centre (Figure 2). In fact, one can compute all these centres in a general geometrical framework, which is represented by an arbitrary symmetric bilinear form.

We will be drawing on similar methods to study the various centres of a general tetrahedron over an arbitrary symmetric bilinear form. The centroid and circumcentre can be calculated without problem, but orthocentres may not exist for certain tetrahedra.

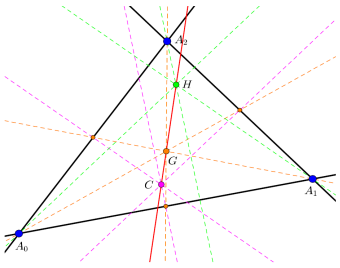


Figure 1: Tetrahedron centres

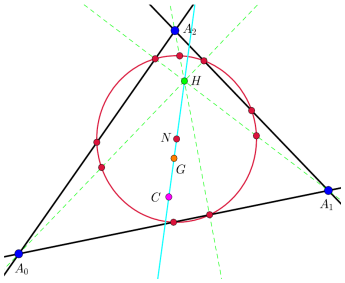


Figure 2: Nine-point centre

While we will deal with this problem at the end, we replace this with the Monge point. Like with the triangle, we can derive the Euler line that passes through the centroid, circumcentre and the Monge point, as well as an analog for the nine-point centre of a triangle. In addition, we will examine certain formulas regarding the circumcentre.

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## On the $C^*$-algebras of a graph of groups : Part II

**Thomas Pedersen** (University of Wollongong)

Graphs of groups, consisting of an undirected graph with associated vertex and edge groups, were introduced by Bass and Serre in the 1970's. The study of these objects is interesting because they have a one-to-one correspondence with orientation-preserving group actions on trees. We discuss several $C^*$-algebras that can be constructed from a graph of groups, and explore parallels between these and the directed graph $C^*$-algebras established in the 1980's and 90's.

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## Refining the Search Space of Alltop Functions

**Aiden Price** (Queensland University of Technology)

Alltop functions have applications to code-division multiple access (CDMA) systems and mutually unbiased bases (MUBs). Alltop functions construct MUBs and CDMA signal sets, and this motivates the continued search for further Alltop functions. The discovery of further Alltop functions is hindered by the computational complexity of verification. This paper narrows the search space through the introduction of a generalized Dembowski-Ostrom (gDO) polynomial and provides a verification process for Alltop monomials with a reduced computational complexity. Computational results lead to the conjecture that there are no further Alltop monomials.

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## Modelling the limit order book using marked Hawkes self-exciting point processes

**Kylie-Anne Richards** (University of New South Wales)

Increased activity and temporal clustering in the limit order book (LOB) can be characterized by an increase in intensity of events. Understanding and forecasting fluctuations in the intensity is informative to high frequency financial applications. The Hawkes self-exciting point process can be used to successfully model the dynamics of the intensity function by allowing for irregularly spaced time sequences, a multivariate framework, multiple dependent marks and the ability to capture the impact of marks on intensity. A critical first step to successfully apply these models to the LOB is suitably defining events in terms of the number of limit order book levels and types of orders. Based on extensive data analysis, recommendations are made. Likewise, selection of marks that impact the intensity function is challenging and the literature provides little guidance. Based on a review of the LOB literature potential marks are identified and screened using a novel mark detection method based on the likelihood score statistic. Comparisons of exponential and power-law decay functions are presented. Fitting marks with a likelihood based method presents substantial identifiability issues which are investigated via simulation for a variety of model formulations. Application is made to futures data with various underlying asset classes.

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## Morita equivalence, Dixmier-Douady Theory and their associated Brauer group

**Nicholas Seaton** (University of Wollongong)

In this talk I will briefly discuss the Dixmier-Douady classification of continuous trace $C^*$-algebras. This associates such a $C^*$-algebra $A$ with a cohomology class in $H^3(T;\mathbb{Z})$, where $T$ is the spectrum of $A$. With this I will construct a Brauer group of $T$, which provides a simpler tool for understanding Morita equivalence between these $C^*$-algebras. I will close by explaining my current research which involves Dixmier-Douady theory for Fell algebras and its associated Brauer group.

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## FUNdamentals of Mathematics

**Kyle Stevens** (University of Wollongong)

Mathematics has been used for recreational purposes since its inception. This talk aims to introduce the concept of mathematics used for recreation as well as a few interesting problems/puzzles. The benefits of this type of mathematics as well as some methods on finding inspiration to try your own will also be discussed.

## On Convex Projective Structures, Part II

**Dominic Tate** (University of Sydney)

In 2007 Fock and Goncharov devised an elegant means of parameterising the space of framed convex projective structures on a non-compact surface $S$ of negative Euler characteristic. This is a generalization of the classical Teichmüller space which has been the subject of extensive study in the field of geometric topology and complex analysis and more recently cluster algebras and dynamical systems.

I use the work of Fock and Goncharov to present a new proof of Marquis' (2011) result showing that the dimension of the subspace of convex projective structures on $S$, where $S$ has $n > 0$ ends and genus $g > 0$, is $16g - 16 + 6n$. To this end I explore elementary proofs of Marquis' results in determining conditions for a surface to have finite area in Hilbert geometry and the relationship between this geometry and the $\mathrm{SL}(3, \mathbb{R})$-character variety.

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## Lattices of subgraphs

**Christopher Taylor** (La Trobe University)

It is well known that the powerset of a set forms a Boolean algebra. Conversely, every complete and atomic Boolean algebra is isomorphic a powerset lattice. More generally, one may wish to characterise the structure of the subobjects of an object in some given class. We investigate this problem for graphs, and completely characterise the algebraic structure of lattices of subgraphs.

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## Weighted inter-rater agreement measures for ordinal outcomes in the context of 2 raters

**Quoc Duyet Tran** (Royal Melbourne Institute of Technology)

Most of the data in diagnosing are ordinal data, and this research focuses on this type of data to estimate the agreement beyond chance between 2 raters by using different kinds of kappa coefficients and various weighting schemes applied. Our most important contribution is to identify which measure and weight are the most suitable method and how they affect the value of Kappa, the degree (or level) of agreement, the number of population, the correlation structure and the number of categories. The first section aims to create a $R \times R$ contingency table (R-categorical scale) of 2 raters by using Monte Carlo simulation. Next, we employed multiple methods to test the efficiency of measures, weights, sample sizes, number of categories, and degree of agreements on the value of

agreement coefficient. Turning to the next part of this research, mean absolute error and mean square error are estimated for all cases to analyze the impacts of various weighting schemes and methods applied. Finally, the results are visualization and interpretation. In conclusion, we conclude that Krippendorff's Alpha is the best measure among those methods while quadratic and ordinal weights are more capable to use with ordinal data rather than others. Furthermore, it seems to me that all measures are well estimated Kappa values and have a very small mean error in the high degree of agreement situation.

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## Nonlinear Porous Diffusion Modeling of Ionic Agrochemicals in Astomatous Plant Cuticle Aqueous Pores: A Mechanistic Approach

**Eloise Tredenick** (Queensland University of Technology)

The agriculture industry requires improved efficacy of sprays being applied to crops. More efficacious sprays provide many environmental and financial benefits. The plant leaf cuticle is known to be the main barrier to diffusion of agrochemicals within the leaf. The importance of a mathematical model to simulate uptake of agrochemicals in plant cuticles has been noted, as the results of each uptake experiments are specific to each formulation of active ingredient and plant species.

In this work we develop a mathematical model and numerical simulation for the uptake of ionic agrochemicals through aqueous pores in plant cuticles. We propose a nonlinear porous diffusion model of ionic agrochemicals in isolated cuticles, which provides additions to a simple diffusion model through the incorporation of parameters capable of simulating plant species' variations, evaporation of surface droplet solutions and swelling of the aqueous pores with water. The model could feasibly be adapted to other ionic active ingredients diffusing through other plant species' cuticles. We validate our theoretical results against appropriate experimental data, discuss the key sensitivities in the model and relate theoretical predictions to appropriate physical mechanisms.

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## TBA

**Kyle Wright** (Australian National University)

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## A sixth order flow of plane curves with boundary conditions

**Yuhan Wu** (University of Wollongong)

We show that small energy curves under a particular sixth curvature flow with generalised Neumann boundary condition between parallel lines converge exponentially in infinite time to straight lines.

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## Solving Heston PDE numerically by using the ADI scheme

**Dong Yan** (University of Wollongong)

In finance, the celebrated Black-Scholes option pricing model(1973) is derived under several restrictive assumptions, such as assumption on constant volatility, market completeness, no transaction costs and continuous trading. Whereas the Heston model is derived a stochastic volatility by relaxing the assumption of constant volatility. For my talk, I will show how to derive the Heston partial differential equation by delta-hedging method, and solve the PDE numerically by using the ADI scheme, then compare the result obtained from the ADI scheme with the analytical result.

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# Transport Information

A general guide to transport around the University of Wollongong can be found under the transport section on our website.

### Bus

There is a free bus service around the centre of Wollongong which stops at the university. The routes are numbered **55A** (anticlockwise) and **55C** (clockwise). They run every 10 minutes between 7am and 6pm, and run every 20 minutes between 6pm and 10pm. It takes approximately 10-15 minutes travel time from the Wollongong CBD to the university on the 55C. A route map can be found at `http://www.premierillawarra.com.au/pdf/gongshuttlemap.pdf`

There is another free bus service, route **9N**, which runs between North Wollongong station and the University of Wollongong. This service runs every 15 minutes.

### Parking

For those with cars, general parking on campus costs $9.60 per day. Coin and credit card operated ticket machines are located throughout the campus. The machines do not give change. Alternatively, street parking in the surrounding suburb of Keiraville is free however, some areas only allow 2 hour parking.

### Taxi

Taxis in Wollongong may be booked by calling 131 008.

### Walking

For those who prefer to travel by foot, the University of Wollongong main campus is approximately a 45 minute walk from the Wollongong CBD.

# Conference Dinner

The conference dinner will be held at

```
levelone @harbourfront
Level 1/2 Endeavour Dr
Wollongong NSW 2500
```

**Booking time:** 6 p.m.

**Getting there:** The restaurant is located on Wollongong harbour, at the base of flagstaff hill (the hill with the big lighthouse on it). It is within walking distance of most accommodation in the centre of Wollongong. For those catching the bus in, the free 55A/C buses stop on the corner of Cliff Rd and Harbour St (pictured below), and run until 10 p.m.

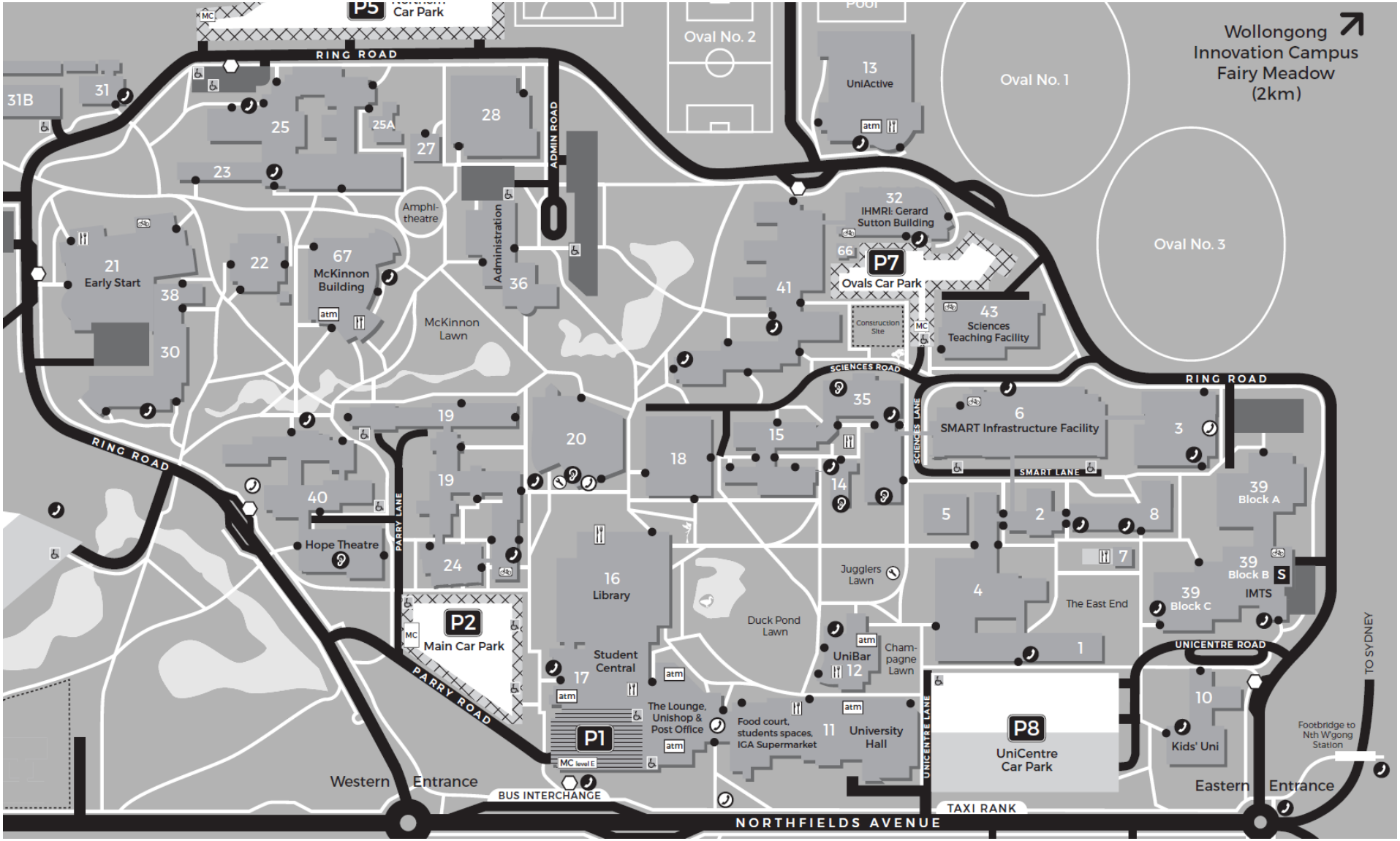
# Campus Map

The map across the page is oriented to face north.

**Key places:**

- Conference registration and talks will be held in **Building 20** which is located towards the centre of the campus.
- **Food outlets** can be found in the food court just south of the duck pond lawn. There is also a supermarket (IGA) located near the food court.
- The closest **cafés** to our venue are Panizi (located ouside building 20), Out for Lunch (located near the Unishop), and Rush 2 (located near the food court).
- The **UniBar** is located to the east of the duck pond lawn. The UniBar also sells food.
- The free **55A/C** buses as well as the **9/9N** North Gong shuttle stop at the bus interchange which can be found at the bottom of the campus map.

An interactive map of the campus can be found at `http://www.uow.edu.au/about/campusmap/index.html`


Wollongong Innovation Campus Fairy Meadow (2km)
P5 Car Park
RING ROAD
ADMIN ROAD
Oval No. 2
Oval No. 1
Oval No. 3
13 UniActive
31B
31
25
25A
27
28
23
Amphi-theatre
Administration
32 IHMRI: Gerard Sutton Building
66
P7 Ovals Car Park
43 Sciences Teaching Facility
Construction Site
21 Early Start
22
67 McKinnon Building
38
30
McKinnon Lawn
36
41
SCIENCES ROAD
SCIENCES LANE
6 SMART Infrastructure Facility
SMART LANE
3
35
19
20
18
15
14
5
2
8
39 Block A
39 Block B
S
IMTS
39 Block C
7
4
The East End
1
40
Hope Theatre
PARRY LANE
24
16 Library
Jugglers Lawn
Duck Pond Lawn
Student Central
17
UniBar
12
Cham-pagne Lawn
P2 Main Car Park
PARRY ROAD
The Lounge, Unishop & Post Office
Food court, students spaces, IGA Supermarket
11 University Hall
P1
MC level E
UNICENTRE ROAD
UNICENTRE LANE
P8 UniCentre Car Park
10
Kids' Uni
TO SYDNEY
Footbridge to Nth W'gong Station
Western Entrance
BUS INTERCHANGE
TAXI RANK
Eastern Entrance
NORTHFIELDS AVENUE