Australian Mathematical Society
Australian and New Zealand Industrial and Applied Mathematics

The 59th ANZIAM Conference
5 February – 9 February 2023

Conference Sponsors

The talk abstracts in this volume were typeset by their authors. Only minor typographical changes have been made by the editors. The opinions, findings, conclusions, and recommendations in this book are those of the individual authors.

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1 Acknowledgement of Country

We acknowledge the Gimuy Walaburra Yidinji and Yirrangangi peoples as the Traditional Custodians of the local land, seas, and waterways and surrounding areas. We pay respect to their Elders both past and present.

2 Conference Code of Conduct

The conference is dedicated to providing a harassment-free conference experience for everyone, regardless of gender, gender identity and expression, age, sexual orientation, disability, physical appearance, body size, race, ethnicity, religion (or lack thereof), or technology choices. We do not tolerate harassment of conference participants in any form. Sexual language and imagery are not appropriate for any conference venue, including talks, workshops, parties and online media.

Agreeing to the following ANZIAM 2023 Conference Code of Conduct is a condition of registration.

ANZIAM is committed to a professional, open, productive and respectful exchange of ideas. These aims require a community and environment that fosters inclusion, provides mutual respect, and embraces diversity. All members of ANZIAM and attendees and sponsors at ANZIAM-endorsed meetings are required to agree to the following code of conduct.

Harassment in any form will not be tolerated. This includes, but is not limited to, speech or behaviour (whether in person, in presentations, or in online discussions) that intimidates, creates discomfort, prevents or interferes with a person's participation or opportunity for participation in ANZIAM's vision and mission. We aim for ANZIAM to be an organisation where harassment in any form does not happen, including but not limited to harassment based on race, gender, religion, age, colour, national or ethnic origin, ancestry, disability, parental status, caring responsibilities, marital status, sexual orientation, or gender identity. Harassment includes but is not limited to verbal comments that reinforce social structures of domination; sexual images in public spaces; deliberate intimidation, stalking, or following; unwelcome photography or recording; sustained disruption of talks or other events; inappropriate physical contact; unwelcome sexual attention; and advocating for or encouraging any of the above behaviour.

ANZIAM will take seriously all reports of breaches of this code of conduct, and treat all parties with respect and due process without presupposition of guilt. Complaints will be handled with sensitivity, discretion, and confidentiality to the extent allowed by the circumstances and as required by law. If an ANZIAM member engages in harassing behaviour, the Executive Committee may take any action they deem appropriate, including warning the offender or expulsion from the Society.

All event participants have a responsibility to speak out against breaches of this code of conduct. Depending on the situation, this could mean raising it with the transgressor, or reporting the behaviour to someone. This could include a conference organiser or a representative to be designated nearer the conference.

3 Welcome

On behalf of the local organizing committee of ANZIAM 2023, we welcome you to the beautiful city of Cairns, the gateway to Australia's Great Barrier Reef and Wet Tropics World Heritage Rainforest.

As always, this annual international conference encourages collaboration and information sharing between applied mathematicians across all areas and research levels. It is also a flagship activity of Australia and New Zealand Industrial and Applied Mathematics division of The Australian Mathematical Society dedicated to promoting the advancement and dissemination of knowledge in all areas of applied and industrial mathematics.

After two years of holding this event online, we rejoice this coming together in person again. Much has changed since the beginning of the Covid pandemic, and it is with pride that we note the important contribution of Applied Mathematics in helping societies manage this crisis.

Moreover, Applied Mathematicians are tackling other imminent challenges. These include, but are not limited to, the conservation of the precious Great Barrier Reef, finding strategies to confront climate change and identifying beneficial applications of AI across a wide spectrum of disciplines; notably, as a new tool of Applied and Industrial Mathematics.

Over the next few days, as we huddle around our computers and projection screens sharing our research findings, it is humbling to reflect that we are meeting on ancient land. For many millennia people huddled around fireplaces in this land and shared knowledge and insights of the natural phenomena they experienced.

We therefore acknowledge the Gimuy Walaburra Yidinji and Yirrangangi peoples as the Traditional Custodians of the local land, seas, and waterways and surrounding areas. We pay respect to their Elders both past and present.

We wish you all a wonderful meeting!

Co-chairs of ANZIAM 2023: Em. Prof. Jerzy A. Filar and Dr. Dietmar Oelz

School of Mathematics and Physics

The University of Queensland

4 Conference Details and History

4.1 Organising committee

- Dietmar Oelz (UQ) — Co-chair
- Jerzy Filar (UQ) — Co-chair
- Mahdi Abolghasemi (UQ)
- Pascal Buenzli (QUT) — Secretary
- Meagan Carney (UQ) — Webmaster
- Duy-Minh Dang (UQ) — Treasurer
- Alistair Falconer (UQ) — Student representative
- Cecilia Gonzalez Tokman (UQ) — WIMSIG lunch and program committee
- Matthew Holden (UQ) — Program committee and social media & activities
- Roxanne Jemison (UQ) — Administration
- Peter Johnston (Griffith University)
- Jacob Rogers (CSIRO)
- Thomas Taimre (UQ) — Program committee and booklet editor
- Slava Vaisman (UQ) — Program committee and booklet editor
- Nan Ye (UQ) — Sponsorships

4.2 Invited speakers committee

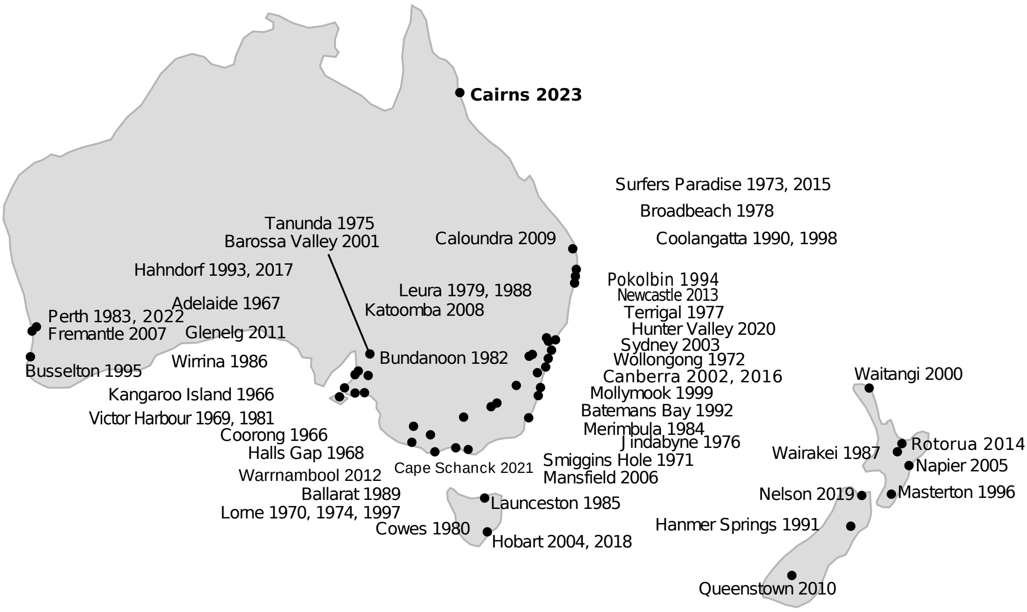
- Regina Burachik (University of South Australia)
- Debora Correa (The University of Western Australia)
- Jerome Droniou (Monash University)
- Jerzy Filar (The University of Queensland)
- Gary Froyland (Chair, The University of New South Wales)
- Adrianne Jenner (Queensland University of Technology)
- Nalini Joshi (The University of Sydney)
- Vivien Kirk (The University of Auckland)
- Malgorzata O'Reilly (The University of Tasmania)
- Sergey Suslov (Swinburne University of Technology)

4.3 Invited speakers

- Konstantin Avrachenkov, INRIA, Sophia-Antipolis, France
- Philip Broadbridge, La Trobe University
- Elliot Carr, Queensland University of Technology
- Cecilia Gonzalez-Tokman, University of Queensland

- James McCaw, University of Melbourne
- Claudia Sagastizábal, IMECC-Unicamp and CEMEAI, Brazil
- Tim Sauer, George Mason University, Fairfax, VA, USA
- Katharine Turner, Australian National University

4.4 Past conference locations



1966	Kangaroo Island (Aug)	1985	Launceston	2005	Napier
1966	Coorong (Dec)	1986	Wirrina	2006	Mansfield
1967	Adelaide	1987	Wairakei	2007	Fremantle
1968	Halls Gap	1988	Leura	2008	Katoomba
1969	Victor Harbor	1989	Ballarat	2009	Caloundra
1970	Lorne	1990	Coolangatta	2010	Queenstown
1971	Smiggin Holes	1991	Hanmer Springs	2011	Glenelg
1972	Wollongong	1992	Batemans Bay	2012	Warrnambool
1973	Surfers Paradise	1993	Hahndorf	2013	Newcastle
1974	Lorne	1994	Pokolbin	2014	Rotorua
1975	Tanunda	1995	Busselton	2015	Surfers Paradise
1976	Jindabyne	1996	Masterton	2016	Canberra
1977	Terrigal	1997	Lorne	2017	Hahndorf
1978	Broadbeach	1998	Coolangatta	2018	Hobart
1979	Leura	1999	Mollymook	2019	Nelson
1980	Cowes	2000	Waitangi	2020	Hunter Valley
1981	Victor Harbor	2001	Barossa Valley	2021	Cape Schanck[1]
1982	Bundanoon	2002	Canberra	2022	Perth[1]
1983	Perth	2003	Sydney	2023	Cairns
1984	Merimbula	2004	Hobart		

1

[1]Held online due to COVID-19 travel restrictions.

4.5 The ANZIAM Medal

The ANZIAM Medal is awarded on the basis of research achievements or activities enhancing Applied or Industrial Mathematics and contributions to ANZIAM. The first award was made in 1995. Past recipients are listed below.

1995	Renfrey Potts	U. Adelaide
1997	Ian Sloan	UNSW
1999	Ernie Tuck	U. Adelaide
2001	Charles Pearce	U. Adelaide
2004	Roger Grimshaw	Loughborough U.
2006	Graeme Wake	Massey U.
2008	James Hill	UoW
2010	Bob Anderssen	CSIRO
2012	Robert McKibbin	Massey U.
2014	Kerry Landman	U. Melbourne
2016	Frank de Hoog	CSIRO Canberra
2018	Phil Howlett	UniSA
2019	Peter Taylor	U. Melbourne
2020	Larry Forbes	U. Tasmania
2021	Nalini Joshi	Sydney U.
2022	Philip Broadbridge	La Trobe U.

4.6 The E. O. Tuck Medal

In honour of the late Ernest Oliver Tuck, FAustMS, FTSE and FAA, ANZIAM has instituted a mid-career award for outstanding research and distinguished service to the field of Applied Mathematics. The inaugural E. O. Tuck Medals were presented at ANZIAM 2013. Past recipients are listed below.

2013	Geoffry Mercer	ANU
	Shaun Hendy	VUW and Callaghan Innovation
2015	Troy Farrell	QUT
2017	Kate Smith-Miles	Monash U.
2018	Yvonne Stokes	U. Adelaide
2019	Scott McCue	QUT
2020	Matthew Simpson	QUT
2021	Michael Plank	U. Canterbury
2022	James McCaw	U. Melbourne

4.7 The J. H. Michell Medal

The J. H. Michell Medal is awarded to outstanding new researchers who have carried out distinguished research in Applied or Industrial Mathematics, where a significant proportion of the research work has been carried out in Australia or New Zealand. Past recipients are listed below.

1999	Harvinder Sidhu	UNSW
2000	Antoinette Tordesillas	U. Melbourne
2001	Nigel Bean	U. Adelaide
2002	Stephen Lucas	UniSA
2004	Mark Nelson	UoW
2006	Sanjeeva Balasuriya	U. Sydney
2007	Yvonne Stokes	U. Adelaide
2008	Carlo Laing	Massey U.
2009	Scott McCue	QUT
2011	Frances Kuo	UNSW
2012	Matthew Simpson	QUT
2013	Terence O'Kane	CMAR CSIRO
2014	Ngamta Thamwattana	UoW
2015	Barry Cox	U. Adelaide
2016	Joshua Ross	U. Adelaide
2017	Alys Clark	U. Auckland
2018	Claire Postlethwaite	U. Auckland
2019	Ryan Loxton	Curtin U.
2020	Jennifer Flegg	U. Melbourne
2021	Lewis Mitchell	U. Adelaide
2022	Elliot Carr	QUT

4.8 The T. M. Cherry Student Prize

A student prize was introduced in 1969 at Victor Harbor and is awarded annually for the best student talk presented at the conference. In May 1976, ANZIAM (then the Division of Applied Mathematics) adopted the title "T.M. Cherry Student Prize" in honour of one of Australia's leading scientists, Professor Sir Thomas MacFarland Cherry. Past recipients are listed below.

1969	R. Jones	U. Adelaide
1970	J. Rickard	UCL
1971	J. Jones	Mount Stromlo
1974	R. P. Oertel	U. Adelaide
1975	R. E. Robinson	U. Sydney
1976	J. P. Abbott	ANU
1977	J. Finnigan	CSIRO
	S. Bhaskaran	U. Adelaide
1978	B. Hughes	ANU
	P. Robinson	UQ
1979	J. R. Coleby	U. Adelaide
	B. Hughes	ANU
1980	M. Lukas	ANU
1981	A. Plank	UNSW
1982	G. Fulford	UoW
	J. Gear	U. Melbourne
1983	P. Kovesi	UWA
1984	A. Kucera	UoW
	S. Wright	UQ
1985	G. Fulford	UoW
	F. Murrell	U. Melbourne
1986	A. Becker	Monash U.
	K. Thalassoudis	U. Adelaide
1988	W. Henry	ANU
1987	M. Rumsewicz	U. Adelaide
1989	M. Myerscough	U. Oxford
	J. Roberts	U. Melbourne
1990	J. Best	UoW
1991	S. K. Lucas	U. Sydney
1992	S. F. Brown	UoW
1993	D. Standingford	U. Adelaide
1994	B. Barnes	Monash U.
1995	A. Buryak	ANU
1996	A. Gore	U. Newcastle
	D. Scullen	U. Adelaide
1997	S. Cummins	Monash U.
1998	J. Clark	U. Sydney
	T. Gourlay	U. Adelaide
1999	E. Ostrovskaya	ANU
2000	C. Reid	Massey U.
2001	M. Haese	U. Adelaide
2002	V. Gubernov	ADFA
	W. Megill	UBC/UoW
2003	Not awarded	
2004	K. Mustapha	UNSW
2005	J. Looker	U. Melbourne
2006	C. Fricke	U. Melbourne
2007	S. Harper	Massey U.
2008	E. Button	U. Melbourne
	M. Haythorpe	UniSA
2009	S. Cohen	U. Adelaide
2010	L. Mitchell	U. Sydney
2011	S. Butler	U. Sydney
	J. Caffrey	U. Melbourne
2012	J. Nassios	U. Melbourne
2013	D. Khoury	UNSW
	T. Vo	U. Sydney
2014	M. Chan	U. Sydney
2015	H. Tronnolone	U. Adelaide
2016	D. Arnold	U. Adelaide
	A. Jenner	U. Sydney
2017	C. Miller	U Melbourne
	E. Hester	U. Sydney
2018	N. Fadai	U. Oxford
	E. Trendenick	QUT
2019	E. Musoke	U. Auckland
	C. Li	UWA
2020	R. Croker	U. Adelaide
2021	A. Browning	QUT
	R. Valani	Monash
2022	A. Zanca	U. Melbourne
	M. Denes	UNSW

4.9 The Cherry Ripe Prize

Since 1995 the students have run an alternative competition for the best non-student talk. Past recipients are listed below.

1995	Natashia Boland	U. Melbourne
1996	Andrew Pullan	U. Auckland
1997	Neville de Mestre	Bond U.
1998	David Stump	UQ
1999	Mark McGuinness	VUW
2000	Joseph Monaghan	Monash U.
	Andy Philpott	U. Auckland
2001	Phil Broadbridge	UoW
2002	Ernie Tuck	U. Adelaide
	Larry Forbes	U. Tasmania
2004	Stephen Lucas	UniSA
2005	Kerry Landman	U. Melbourne
2006	Vicky Mak	Deakin U.
	James Sneyd	U. Auckland
2007	Geoffry Mercer	USW
2008	Neville de Mestre	Bond U.
2009	Philip Maini	U. Oxford
2010	Larry Forbes	U. Tasmania
2011	Larry Forbes	U. Tasmania
	Darren Crowdy	Imperial College
2012	Martin Wechselberger	U. Sydney
2013	Scott McCue	QUT
	Sheehan Olver	U. Sydney
2014	Peter Kim	U. Sydney
2015	Not awarded	
2016	Matthew Simpson	QUT
	Melanie Roberts	IBM Research Australia
2017	Christopher Green	QUT
2018	Christopher Lustri	Macquarie U.
2019	Raúl Rojas	Freie Universität Berlin
2020	Mike Meylan	U. Newcastle
	Peter Taylor	U. Melbourne
2021	J. Nathan Kutz	Washington
2022	Jennifer Flegg	U. Melbourne
	Adrianne Jenner	QUT

4.10 The A. F. Pillow Applied Mathematics Top-up Scholarship

The A. F. Pillow Applied Mathematics Trust offers an annual "top-up" scholarship to a student holding either an Australian Postgraduate Award (APA) or equivalent award for full-time research in Applied Mathematics leading to the award of a PhD. The aim of the A. F. Pillow Applied Mathematics Top-up Scholarship is to increase the quality of postgraduate students in the field of Applied Mathematics in Australia. Past recipients are listed below.

2009	Christopher Lustri	QUT
2010	Alex Badran	UoW
2011	Michael Dallaston	QUT
2012	Hayden Tronnolone	U. Adelaide
2013	Lisa Mayo	QUT
2014	Audrey Markowskei	Macquarie U.
2015	Pouya Baniasadi	Flinders U.
2016	Alexander Tam	U. Adelaide
2017	Jody Fisher	Flinders U.
2019	Jesse Sharp	QUT
2020	Matthew Berry	UoW
2022	Eugene Tam	UWA

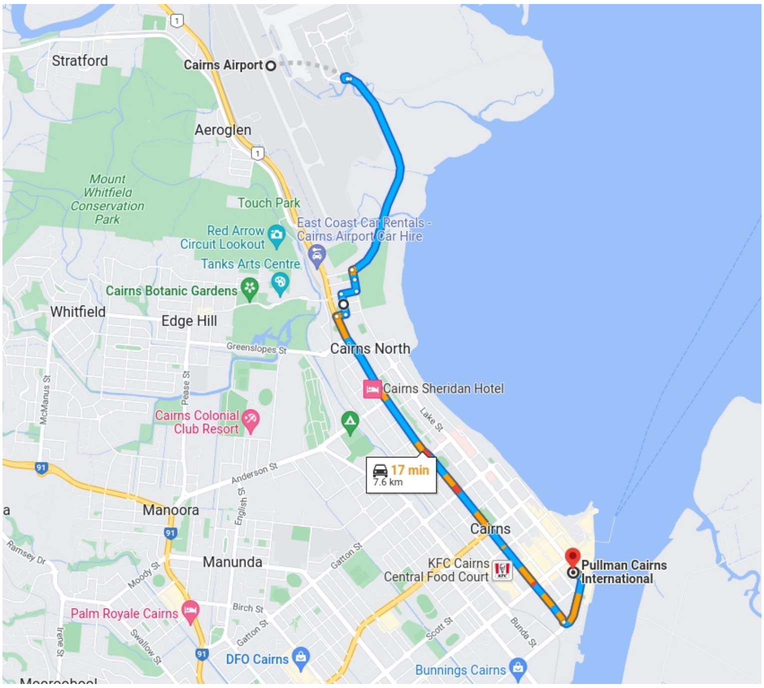
4.11 Acknowledgements

The Organising Committee gratefully acknowledges John Banks (The University of Melbourne) for his help with developing and maintaining the online conference registration system.

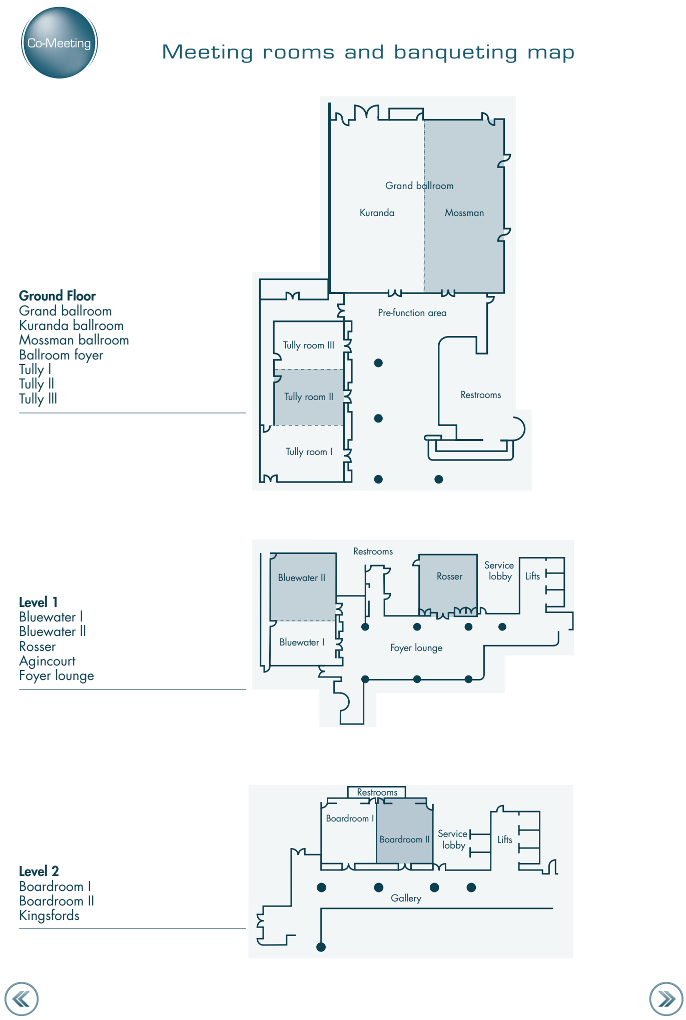
5 Conference Venue

ANZIAM 2023 is being held at the Pullman Cairns International Hotel, 17 Abbott St, Cairns City, Queensland 4870, Australia. Pullman Cairns International is approximately 8 kilometres or 15 minutes by Taxi from the Airport. The hotel reflects the spirit of Far North Queensland and exudes the architectural style and grandeur of the city's rich past.

The registration desk will be open from 4–6 pm on Sunday 5 February and from 8–8:30 am on Monday 6 February.



The Conference rooms are Grand Ballroom (plenary and parallel session, and, it will be refitted for the conference dinner), and parallel sessions will be held in Tully 1, Tully 2, and Tully 3.



The hotel has a stunning grand colonial architecture, 321 beautifully appointed and spacious rooms with balconies, open air rooftop pool deck, 24 hour fitness center & sauna, multi-award winning culinary team and luxury day spa and beauty centre.

6 Conference Events

6.1 Student barbecue

We're inviting students to join us to network and discuss ongoing research projects and future collaboration opportunities.

- Date: 6 February, 6:30pm – 8:30pm
- Cost: Free
- Location: The Pier Bar, 1 Pierpoint Road, Cairns
- Join us: All ANZIAM 2023 registrants are welcome to attend.

6.2 LGBTQIA+ and Allies social event

- Date: 7 February 2023, 7:40am – 8:40am
- Cost: Free
- Location: Kingsford's Lounge
- Join us: All ANZIAM 2023 registrants are welcome to attend.

6.3 Women in Mathematics Special Interest Group (WIMSIG) Lunch

This lunch supports women, trans and gender diverse people, particularly early-career researchers, to enter and establish careers in mathematics.

You'll hear about the careers of the ANZIAM 2023 women plenary speakers, discuss issues concerning women, trans and gender diverse people in mathematics in Australia and New Zealand, and network with fellow WIMSIG members and supporters.

- Date: 7 February 2023, 1pm – 2:30pm
- Cost: Free
- Location: Bluewater 1 & 2
- Join us: All ANZIAM 2023 registrants, regardless of gender or WIMSIG membership, are welcome to attend.

Please note: signup for the WIMSIG Lunch will remain open until capacity for the event is reached.

6.4 Mathematical Biology special interest group meeting

Join us for this one day meeting titled 'Methods and real-world applications of mathematical biology' which takes place after the main conference.

- Date: 10 February 2023, 8:30am – 1:30pm
- Cost: $45 AUD
- Location: Cairns RSL Club, 115–119 The Esplanade, Cairns, Qld, 4870 (Note Cairns RSL Club is only a short 10-minute walk from the Pullman Cairns International)
- Join us: All ANZIAM 2023 registrants are welcome to attend.

7 Plenary Lectures and Invited Speakers Information

Invited plenary lectures will held in the Grand Ballroom and will be 50 min in duration including approximately 10 min for questions.

Day/Time (AWST)	Speaker	Invited talk title
Monday 9:00	Timothy Sauer	Prevalence and Observability in Dynamical (and Nondynamical) Systems
Monday 14:00	Katharine Turner	Topological Transforms for use in Statistical Shape Analysis
Tuesday 8:40	Elliot Carr	Random Walks with Absorbing Boundaries
Tuesday 11:20	Philip Broadbridge	Conditionally Integrable PDE Systems: Applications to Populations and Quantum Measurement
Wednesday 8:20	Konstantin Avrachenkov	Graph Clustering Problem: Beyond Binary Interactions
Wednesday 14:00	Cecilia Gonzalez-Tokman	A Journey into Random Dynamical Systems and Multiplicative Ergodic Theory
Wednesday 16:00	Nan Ye	Machine Learning: A New Tool for Mathematicians
Thursday 8:40	Claudia Sagastizábal	A Nonsmooth Optimizer's Perspective of Splitting Methods
Thursday 12:00	James McCaw	Infectious Disease Dynamics

Prevalence and Observability in Dynamical (and Nondynamical) Systems

Timothy Sauer
George Mason University, Fairfax, VA, USA

The concept of prevalence, as a means of giving mathematical precision to informal instances of “almost every”, has been useful over the last few decades in dynamical systems theory. We survey a number of prototypical applications, including more recent examples, some of them non-dynamical. In particular, connections to ecological models, dynamical networks and their observability will be discussed.

Topological Transforms for use in Statistical Shape Analysis

Katharine Turner
Australian National University

Persistent homology and other topological summaries like Euler curves provides quantitative methods to characterise geometric shape. One common filtration, inspired by Morse theory in pure mathematics, is via increasing sublevel sets of a height function with respect to some direction. By calculating the evolution of topology under a height filtration we capture information about geometry of a shape with respect to this specific direction. The Persistent Homology Transform (and its variants) basically expand on this idea by considering the height functions in all directions. These topological transforms have nice theoretical properties, in particular they completely describe compact nice subsets of Euclidean space, and can provide new metrics for quantitatively measuring the difference between geometric objects.

This talk will assume no prior familiarity with persistent homology, and will introduce these topological transforms, outline some related theory and briefly mention some applications in the literature.

Random Walks with Absorbing Boundaries

Elliot Carr
Queensland University of Technology

Random walks are fundamental to numerous applications across physics, biology, ecology and medicine. In this talk, I will consider the classical problem of a particle undergoing a random walk until it reaches an absorbing boundary and is removed from the system. In particular, I will describe mathematical techniques for studying two fundamental properties of such problems: (1) probability the particle remains in the system over time and (2) mean time taken for the particle to exit the system. The first half of the talk will show how to construct simple accurate approximations to (1) on radially-symmetric domains. The second half of the talk will show how perturbation theory can be used to calculate (2) on irregular domains. In both cases, results will be compared with averaged data from repeated random walk simulations.

Conditionally Integrable PDE Systems: Applications to Populations and Quantum Measurement

Philip Broadbridge
La Trobe University

After combining a conditionally integrable nonlinear PDE with a single constraint, it reduces to a linear PDE with one fewer variables.

There is such a class of $n+1$-dimensional reaction-diffusion equations that reduces to the linear Helmholtz equation. The nonlinear diffusion may be of any fractional or integer order. Any target reaction function can be assumed. This has many applications, including fisheries modelling. Real fish mobility data from Australia, South Africa and Spain have been incorporated.

Another conditionally integrable system is the forced Madelüng-Burgers fluid velocity field in 3+1 dimensions, which reduces to the linear Schrödinger equation only when the fluid is irrotational. Measurement may introduce vorticity which induces energy dissipation until quantum equilibrium is restored.

Graph Clustering Problem: Beyond Binary Interactions

Konstantin Avrachenkov
INRIA, Sophia-Antipolis, France

A classical setting of graph clustering consists of partitioning the vertices of a graph into tight-knit clusters. Nowadays, the underlying challenge is frequently called the "community recovery problem" due to its numerous applications in diverse domains such as sociology, neuroscience, bibliography and recommender systems, just to name a few. A benchmark model for graph clustering problem is a Stochastic Block Model (SBM), which is an inhomogeneous version of the Erdos-Renyi random graph. In this talk I discuss several generalizations of SBM that go beyond binary interactions modelled by simple graphs. Specifically, I consider a network, where the observed interactions belong to a general measurable interaction space. This can represent categorical and vector-valued interactions, including time series or spatial point patterns. I present sharp information-theoretic criteria for the strong cluster recovery in terms of data sparsity, the statistical similarity between intra- and inter-block interaction distributions, and the shape and size of the interaction space. This general framework makes it possible to study temporal networks when both the number of nodes and the time horizon go to infinity, and when the temporal interaction patterns are correlated over time. An efficient spectral algorithm to recover clusters will be presented and demonstrated on real-life and synthetic network examples. In some applications, the framework of hypergraphs is more appropriate than the framework of simple graphs or even graphs with weighted edges. The recovery conditions for the hypergraph clustering are also available. Finally, I discuss the case of clustering geometric graphs when the standard Fiedler-vector based algorithms may not be applicable and one needs to look deeper inside the graph spectrum.

A Journey into Random Dynamical Systems and Multiplicative Ergodic Theory

Cecilia Gonzalez-Tokman
University of Queensland

Random (or non-autonomous) dynamical systems are flexible mathematical models for the study of complicated systems whose evolution is affected by external factors, such as seasonal influences and random effects. Multiplicative ergodic theory provides fundamental information for the study of transport phenomena in such systems, including long-term behaviour, mixing rates and coherent structures. In this talk, we will take a journey into random dynamical systems and multiplicative ergodic theory, guided in part by questions arising from the investigation of oceanic and atmospheric flows.

Machine Learning: A New Tool for Mathematicians

Nan Ye
University of Queensland

Machine learning is gaining more popularity among applied mathematicians as a modelling tool. In this talk, I will give an introduction to core ideas of machine learning with an emphasis on the important sub-field of deep learning. I will then cover several important applications of machine learning for mathematical modeling, including multiphysics problems, fluid modelling, inverse problems, combinatorial optimization problems.

A Nonsmooth Optimizer's Perspective of Splitting Methods

Claudia Sagastizábal
IMECC-Unicamp and CEMEAI, Brazil

For large-scale optimization, popular approaches such as the ADMM and the Progressive Hedging algorithm exploit separable structures by solving in parallel individual sub-problems which are then coordinated by performing a simple algebraic step (typically, a projection onto a linear subspace).

While parallelism is the strength of all Douglas-Rachford-like splitting methods, their weak points are the adjustment of certain proximal parameter and the lack of a fully implementable stopping test. These difficulties, which date back to Spingarn's method of partial inverses, stem from the very design of these approaches, which were created to find zeroes of operators.

We discuss how to endow some splitting methods with an optimization perspective that introduces knowledge about the objective function throughout the iterative process. The resulting new family of methods à la bundle incorporates a projective step to coordinate parallel information while allowing the variation of the proximal parameters and the construction of a reliable stopping test. A Bundle Progressive Hedging algorithm, derived from the general theory, illustrates the interest of the proposal.

Credit to co-authors will be given during the talk.

Infectious Disease Dynamics

James McCaw
University of Melbourne

Infectious disease dynamics is the study of how pathogens replicate within a host and of how they spread from host to host. The foundational mathematical descriptions of both of these processes are similar. In virus dynamics, the Target cell–Infectious cell–Virus (TIV) model describes the non-linear dynamics of viral infection, in which exponential growth of an invading pathogen is limited by the availability of the host's susceptible target cells. In epidemiology, the Susceptible–Infectious–Removed (SIR) model describes an invading pathogen, with the size of an epidemic wave limited by susceptible depletion. At both scales additional factors, such as the immune response or behavioural changes, drive changes in the dynamics of infection. Modelling at both these scales has driven biological and epidemiological discovery and supported clinical and public health research for numerous infectious diseases of global importance.

In this talk I will cover three broad topics: 1) how both the rigorous mathematical analysis of simple abstracted models and the computationally intensive study of highly complex more realistic models contribute to infectious disease dynamics research; 2) Bayesian statistical inference as an approach to model-based data analysis; 3) the use of mathematical models in policy development and decision-making.

8 Conference Events at a Glance

	Sun	Mon	Tue	Wed	Thu
07:40			LGBTQIA+ + Allies Breakfast, Kingsford's lounge		
08:00					
08:20				Plenary talk: Avrachenkov	
08:30		Conference opening			
08:40			Plenary talk: Carr		Plenary talk: Sagastizábal
09:00		Plenary talk: Sauer			
09:20				group picture	
09:40			Sessions	Sessions	Sessions
10:00		Morning Tea			
10:20		Sessions			
10:40				Morning Tea	Morning Tea
11:00			Morning Tea	Sessions	Sessions
11:20			Plenary talk: Broadbridge		
11:40					
12:00					Plenary talk: McCaw
12:20			Sessions		
12:40					
12:50					Closing remarks.
13:00		Lunch	WIMSIG Lunch, Bluewater 1 and 2	Lunch	Lunch
14:00		Plenary talk: Turner		Plenary talk: Gonzalez-Tokman	
14:30					
15:00		Sessions		Sessions	
15:20					
15:40		Afternoon Tea		Afternoon Tea	
16:00	Registration	Sessions		Sessions	
16:20					
16:40					
17:00					
17:20					
17:40					
18:00					
18:30		Student Social Event in: The Pier Bar, 1 Pierpoint Road, Cairns		Conference Dinner	
19:00			ANZIAM Annual General Meeting (in Tully 1)		
20:30					
21:00			ANZIAM Executive Meeting (in Tully 1)		
22:00					

9 Contributed Talks by Session

The duration of each contributed talk will be 15 minutes with 5 minutes for questions and handover. Contributed talks will be held in the Grand Ballroom, Tully 1, Tully 2, and Tully 3. We have done our best to allocate talks to appropriate sessions. We apologise for any mistakes.

Plenary Lectures in Grand Ballroom

▷ Mon 6 February

09:00 Timothy Sauer (George Mason University)
Prevalence and Observability in Dynamical (and Nondynamical) Systems
Ballroom (p. 118)

14:00 Katharine Turner (Australian National University)
Topological Transforms for Use in Statistical Shape Analysis
Ballroom (p. 130)

▷ Tue 7 February

08:40 Elliot J. Carr (Queensland University of Technology)
Random Walks with Absorbing Boundaries
(p. 61)

11:20 Philip Broadbridge (La Trobe University)
Conditionally Integrable PDE Systems: Applications to Populations and Quantum Measurement.
Ballroom (p. 58)

▷ Wed 8 February

08:20 Konstantin Avrachenkov (INRIA Sophia Antipolis)
Graph Clustering Problem: Beyond Binary Interactions
Ballroom (p. 54)

14:00 Cecilia Gonzalez-Tokman (The University of Queensland)
A Journey Into Random Dynamical Systems and Multiplicative Ergodic Theory
(p. 72)

▷ Thu 9 February

08:40 Claudia Sagastizábal (IMECC-Unicamp and CEMEAI, Brazil)
A Nonsmooth Optimizer's Perspective of Splitting Methods
(p. 117)

12:00 James McCaw (The University of Melbourne)
Infectious Disease Dynamics
Ballroom (p. 96)

Session 2: Fluid Dynamics

Contributed Talks

▷ Tue 7 February

10:20 Steven Kedda (None)
Self-Similarity and Fractalisation in Interfacial Hydrodynamics
Tully 3 (p. 86)

10:40 Keith Chan (Monash University)
A Comparison of Weakly Nonlinear Theory to Forced Internal Solitary Waves Using Spectral Methods
Tully 3 (p. 63)

12:20 Madeleine Cockerill (University of Tasmania)
Large Amplitude Non-Spherical Bubbles
Tully 3 (p. 63)

12:40 Nitay Ben Shachar (The University of Melbourne)
Near-Continuum Oscillatory Gas Flows with Finite Gas-Surface Accommodation
Tully 3 (p. 56)

▷ Wed 8 February

11:00 Brendan Harding (Victoria University of Wellington)
Inertial Migration of Spherical Particles in Curved Ducts at Moderate Dean Numbers
Tully 3 (p. 75)

11:20 Andrey Pototsky (Swinburne University of Technology)
Nonlinear Periodic and Solitary Rolling Waves in Falling Two-Layer Viscous Liquid Films
Tully 3 (p. 115)

11:40 Eunice Blessica Yuwono (The University of Adelaide)
Mathematical Modelling of Heat Conduction in Extrusion
Tully 3 (p. 140)

12:00 Laura Karantgis (La Trobe University)
Modelling Rainfall Induced Landslides with Smoothed Particle Hydrodynamics
Tully 3 (p. 84)

12:20 Larry Forbes (University of Tasmania)
The Completed Boussinesq Model for Fluid Flow
Tully 3 (p. 71)

12:40 Kaname Matsue (Kyushu University)
Dynamics of Hydrodynamically Unstable Premixed Flames in a Gravitational Field
Tully 3 (p. 95)

▷ Thu 9 February

11:00 Rahil Valani (The University of Adelaide)
Inertial Particle Focusing in Curved Ducts: Bifurcations and Dynamics
Tully 2 (p. 131)

11:20 Edward Hinton (The University of Melbourne)
Mechanisms by Which Buoyancy Segregation Can Suppress Viscous Fingering
Tully 2 (p. 79)

Session 3: Machine Learning

Keynote Talks

▷ Wed 8 February

16:00 Nan Ye (The University of Queensland)
Machine Learning as a New Tool for Applied Mathematicians: a Tutorial
Ballroom (p. 140)

Contributed Talks

▷ Mon 6 February

16:40 Jonathan Wilton (The University of Queensland)
Positive-Unlabeled Learning Using Random Forests via Recursive Greedy Risk Minimization
Tully 2 (p. 137)

17:00 Yunpei Wu (Kyushu University)
An Operator Analysis Approach to the Stochastic Differential Equation Diffusion Generative Model
Tully 2 (p. 137)

17:20 Jacinta Holloway-Brown (None)
Stochastic Spatial Random Forest for Detecting Remotely Sensed Forest Cover Change Despite Missing Data
Tully 2 (p. 81)

▷ Wed 8 February

17:00 Marcus Hoerger (The University of Queensland)
Tractable Online POMDP Planning: Challenges and Methods
Ballroom (p. 80)

Session 4: Mathematical Epidemiology

Contributed Talks

▷ Mon 6 February

10:20 David James Warne (Queensland University of Technology)
Bayesian Uncertainty Quantification to Identify Vaccine Hesitancy Behaviours
Tully 3 (p. 134)

10:40 Pratyush Kumar Kollepara (La Trobe University)
Which Lockdowns Are the Best Lockdowns?
Tully 3 (p. 86)

11:00 Md Nurul Anwar (The University of Melbourne)
Effect of Radical Cure Treatment on P. Vivax Malaria Transmission via Mass Drug Administration
Tully 3 (p. 52)

11:20 Punya Alahakoon (The University of Melbourne)
Use of Bayesian Stochastic Hierarchical Models in Epidemiology
Tully 3 (p. 51)

11:40 Simon Johnstone-Robertson (RMIT University)
The Establishment of Japanese Encephalitis Virus in Australia
Tully 3 (p. 83)

12:00 Lucinda Harrison (The University of Melbourne)
Modelling the Environmental Niche of Japanese Encephalitis Virus in Australia
Tully 3 (p. 76)

12:20 Maame Akua Korsah (The University of Melbourne)
Mathematical Modelling and Approximation for Optimizing Intervention Strategies for Malaria Elimination
Tully 3 (p. 87)

12:40 Somya Mehra (The University of Melbourne)
A Strategy for Constructing Tractable Epidemic Models of Malarial Superinfection
Tully 3 (p. 100)

15:00 Eva Stadler (UNSW Sydney)
Efficacy of Monoclonal Antibody Therapy for COVID-19
Tully 3 (p. 121)

15:20 Ruarai Tobin (The University of Melbourne)
Forecasting the Impact of COVID-19 on Australian Hospitals
Tully 3 (p. 129)

16:00 Dion O'Neale (The University of Auckland)
How Can We Choose Suitable Case Isolation Settings to Reduce Spread of Infectious Disease?
Tully 3 (p. 109)

16:20 Isobel Abell (The University of Melbourne)
Why'd You Have to Go and Make Things So Complicated?
Tully 3 (p. 45)

16:40 Thomas Harris (The University of Melbourne)
Correlation of Viral Loads in Disease Transmission Chains Could Bias Early Estimates of the Reproduction Number
Tully 3 (p. 76)

17:00 Nefel Tellioglu (The University of Melbourne)
Evaluation of the Effectiveness of Mass Drug Administration Strategies for Reducing Scabies Burden in Monrovia, Liberia: an Agent-Based Modelling Approach
Tully 3 (p. 127)

▷ Tue 7 February

09:40 Thao Phuong Le (The University of Melbourne)
Modelling the Impact of Hybrid Immunity on Future COVID-19 Epidemic Waves
Tully 3 (p. 90)

10:00 Cameron Zachreson (The University of Melbourne)
Agent-Based Modelling of SARS-CoV-2 Transmission in Quarantine Facilities
Tully 3 (p. 141)

▷ Wed 8 February

15:00 Michael Plank (University of Canterbury)
Simulation-Based Inference and Communicating Uncertainty in Epidemiological Models
Tully 3 (p. 113)

15:20 Roslyn Hickson (CSIRO and James Cook University)
Exploring the Interactions Between Policy and Human Mobility Patterns During the COVID Pandemic Through Flight Data: an Australian Case Study
Tully 3 (p. 79)

17:00 Giorgia Vattiato (University of Auckland)
The Making of New Zealand's COVID-19 Frankenstein's Monster Model
Tully 3 (p. 132)

17:20 Pantea Pooladvand (UNSW Sydney)
The Role of Cultural Innovation in the Emergence of New Diseases
Tully 3 (p. 114)

▷ Thu 9 February

09:40 Michael Meehan (James Cook University)
Replicating Superspreader Dynamics with Simple Epidemic Models
Tully 1 (p. 99)

10:00 Kylie Ainslie (Dutch National Institute of Public Health and the Environment (RIVM))
Determining the Trade-Offs Between Different COVID-19 Control Strategies in the Netherlands: a Counterfactual Analysis
Tully 1 (p. 49)

10:20 Kylie Ainslie (Dutch National Institute of Public Health and the Environment (RIVM))
A Scenario Modelling Analysis to Anticipate the Impact of COVID-19 Vaccination in Adolescents and Children on Disease Outcomes in the Netherlands, Summer 2021
Tully 1 (p. 48)

11:00 Emily Harvey (The University of Auckland)
Modelling Spread of SARS-CoV-2 to Household Contacts and the Impact of Household Quarantine and Testing
Tully 1 (p. 77)

11:20 Joel Miller (La Trobe University)
The Impact of a Single Individual in an Epidemic
Tully 1 (p. 103)

11:40 Andrew Black (The University of Adelaide)
Efficient Estimation of Epidemic Final Size Probabilities
Tully 1 (p. 56)

Session 5: Climate Modelling

Contributed Talks

▷ Mon 6 February

11:40 Sergey A. Suslov (Swinburne University of Technology)
Modular Modelling of Hurricanes: the Role of Ocean Spray Polidispersity
Tully 2 (p. 123)

12:00 Ruethaichanok Kardkasem (The University of Queensland)
Extreme Precipitation Events in the East Coast of Australia
Tully 2 (p. 85)

12:20 Milton Mondal (Swinburne University of Technology)
The Effect of Combination of Two Periodically Driving Force Due to Solar Radiation and Sea Surface Temperature in the Bloom Dynamics
Tully 2 (p. 105)

12:40 Andrew Axelsen (University of Tasmania)
Finite Time Analysis of Crises in a Chaotically Forced Ocean Model
Tully 2 (p. 54)

▷ Wed 8 February

15:00 Noa Kraitzman (Macquarie University)
Slow Migration of Brine Inclusions in First-Year Sea Ice
Tully 2 (p. 87)

15:20 Jordan Pitt (The University of Adelaide)
The Reduction in Wave Energy in Ice Covered Oceans
Tully 2 (p. 112)

17:00 Terence O'Kane (CSIRO)
A Framework for Regime Dependent Causal Graphs for Assessing Climate Risk
Tully 2 (p. 108)

Session 6: Financial Mathematics

Contributed Talks

▷ Tue 7 February

09:40 Zhou Zhou (The University of Sydney)
Time Inconsistency, Precommitment and Equilibrium Strategies for a Stackelberg Game
Ballroom (p. 143)

10:00 Yawen Zheng (University of Wollongong)
A Generalized Approach for Pricing American Options Under Regime-Switching Model
Ballroom (p. 142)

10:20 Xihao He (The Chinese University of Hong Kong)
A Mean-Field Version of Bank-El Karoui'S Representation of Stochastic Processes
Ballroom (p. 78)

10:40 Yu Tian (Monash University)
The Retirement Income Market in Australia
Ballroom (p. 128)

12:20 Chao Zhou (National University of Singapore)
Large Ranking Games with Diffusion Control
Ballroom (p. 142)

12:40 Lin Ai (None)
Parasian Over Parisian, How Much Earlier Should One Exercise?
Ballroom (p. 47)

Session 7: Mathematical Ecology and Conservation

Contributed Talks

▷ Mon 6 February

17:20 Kate Helmstedt (Queensland University of Technology)
The Mathematics of Protecting Antarctic Biodiversity
Tully 3 (p. 78)

▷ Tue 7 February

09:40 Thomas Taimre (The University of Queensland)
Rare-Event Simulation Techniques for Structured Fisheries Models
Tully 2 (p. 123)

10:00 Jun Ju (The University of Queensland)
Model-Based Offline Reinforcement Learning for Sustainable Fishery Management
Tully 2 (p. 84)

10:20 Matthew Holden (The University of Queensland)
Value of Model Complexity for Fisheries Management
Tully 2 (p. 80)

10:40 Manuela Mendiolar (The University of Queensland)
Balanced Harvest in an Age-Structured Fishery Model
Tully 2 (p. 102)

12:20 Tace Stewart (Queensland University of Technology)
Conservation Planning in the Presence of Cumulative Disasters
Tully 2 (p. 122)

12:40 Cailan Jeynes-Smith (Queensland University of Technology)
Adaptation in Ecosystems: Lessons from Cellular Signalling Networks
Tully 2 (p. 82)

▷ Wed 8 February

09:40 Luz Pascal (Queensland University of Technology)
Technology Development for Conservation Purposes as an Adaptive Management Problem
Tully 2 (p. 111)

10:00 Elise Mills (Queensland University of Technology)
A Generalised Sigmoid Population Growth Model with Energy Dependence: Application to Quantify a Tipping Point for Antarctic Shallow Seabed Algae
Tully 2 (p. 104)

10:20 Daniel Longmuir (CSIRO)
Little Red Flying Foxes Under the Hood: Using Metapopulation Models to Investigate Population Dynamics
Tully 2 (p. 92)

17:20 Simon Watt (UNSW Canberra)
Modelling of a Five Reactor Activated Sludge Cascade Process
Tully 2 (p. 135)

▷ Thu 9 February

09:40 Douglas Brumley (The University of Melbourne)
The Role of Bacterial Chemotaxis in Microbial Symbiosis
Tully 3 (p. 59)

10:20 Morenikeji Deborah Akinlotan (Queensland University of Technology)
Beyond Expected Values: Making Environmental Decisions Using Value of Information Analysis When Measurement Outcome Matters
Tully 3 (p. 50)

11:00 Christopher Baker (The University of Melbourne)
Modelling Species Abundance and Dynamics Using Removal Data
Tully 3 (p. 55)

11:20 Melanie Roberts (None)
Introducing HARP - a New Metric to Describe Hysteresis
Tully 3 (p. 116)

11:40 Bree Martin (The University of Queensland)
Bayesian Belief Network Modelling for the Great Barrier Reef
Tully 3 (p. 95)

Session 8: Dynamical Systems

Contributed Talks

▷ Mon 6 February

10:20 Gary Froyland (University of New South Wales)
Bathymetry Imposes a Global Pattern of Cross-Front Transport in the Southern Ocean
Tully 2 (p. 71)

10:40 Sean McGowan (The University of Adelaide)
Compensating Model Error Using Koopman Operator Theory
Tully 2 (p. 97)

11:00 Stuart-James Burney (UNSW Sydney)
Solutions of Delay Differential Equations
Tully 2 (p. 60)

11:20 Lachlan Burton (The University of Sydney)
Escape Time Statistics in Dissipative Chaotic Scattering
Tully 2 (p. 60)

15:00 Liam Blake (The University of Adelaide)
A Computable Characterisation of Model Uncertainty
Tully 2 (p. 57)

15:20 Timothy Earl Figueroa Lapuz (The University of Sydney)
A Geometric Analysis of Biochemical Reaction Networks
Tully 2 (p. 89)

▷ Wed 8 February

09:40 Hinke Osinga (The University of Auckland)
Heterodimensional Cycles as Organising Centres of Complicated Dynamics
Tully 3 (p. 110)

10:00 Eugene Tan (The University of Western Australia)
Selecting Embedding Delays: a New Method Using Persistent Homology
Tully 3 (p. 126)

10:20 Bernd Krauskopf (University of Auckland)
The Structure of Accumulating Global Bifurcations of Two Coupled Phase-Amplitude Oscillators
Tully 3 (p. 88)

12:20 Serena Dipierro (The University of Western Australia)
Civil Wars: a New Lotka-Volterra Competitive System
Tully 2 (p. 67)

12:40 Courtney Rose Quinn (University of Tasmania)
Finite-Time Dynamics, Hyperbolicity, and Regime Behaviour
Tully 2 (p. 116)

17:20 Rahil Valani (The University of Adelaide)
Attractor-driven Matter
Tully 1 (p. 131)

Session 9: Partial Differential Equations

Contributed Talks

▷ Wed 8 February

11:00 Scott McCue (Queensland University of Technology)
Interpreting Burgers' Equation in the Complex Plane
Tully 2 (p. 96)

11:20 Luke Filippini (Queensland University of Technology)
Simplified Models of Diffusive Transport in Radially-Symmetric Media
Tully 2 (p. 70)

11:40 Gene Nakauchi (Queensland University of Technology)
Propagating Fronts for a Fisher-KPP-Type Moving Boundary Problem
Tully 2 (p. 106)

12:00 Thomas Miller (University of South Australia)
Properties of a Non-Classical Symmetry Solution to a Reaction Diffusion Equation with a Region of Negative Diffusivity
Tully 2 (p. 103)

▷ Thu 9 February

09:40 Mark Joseph McGuinness (Victoria University of Wellington)
Reflections at the Interface
Tully 2 (p. 98)

10:00 Bronwyn Hajek (University of South Australia)
Time-Dependent Solutions of a Fisher-KPP-Like Equation
Tully 2 (p. 74)

10:20 Hiroshi Takase (Kyushu University)
Inverse Problems for First-Order Hyperbolic Equations
Tully 2 (p. 124)

Session 10: Networks, Operations Research and Logistics

Contributed Talks

▷ Tue 7 February

12:20 Syarifah Nordin (Universiti Teknologi Malaysia)
Multiple Criteria Decision Making for Technology Value Index and Technology Commercial Index in Patent Selection
Tully 1 (p. 108)

12:40 Liam Timms (The University of Queensland)
A Room Inventory Model for Operating Room Planning and Scheduling
Tully 1 (p. 129)

Session 11: Scientific Computing and Numerical Analysis

Contributed Talks

▷ Mon 6 February

16:00 Kyria Wawryk (Monash University)
Towards Optimal Space-Time Discretizations of Reachable Sets of Control Systems
Tully 2 (p. 135)

16:20 Kholod Mandoora (Monash University)
Exponential Integrators for the Investigation of the Stability of Nonlinear Waves.
Tully 2 (p. 94)

▷ Tue 7 February

10:40 Boris Baeumer (University of Otago)
A Resolvent Positive Finite Difference Scheme of Order Alpha for Fractional Derivatives on Bounded Domains
Tully 1 (p. 55)

▷ Wed 8 February

17:00 Lauren Smith (The University of Auckland)
Data Assimilation for Networks of Coupled Oscillators
Tully 1 (p. 120)

Session 12: Optimisation

Contributed Talks

▷ Mon 6 February

15:00 Amin Karimi (None)
Two-Echelon Location Routing Problem with Delivery Options Under a Stochastic Environment
Tully 1 (p. 85)

15:20 Achini Erandi Madduma Wellalage (The University of Melbourne)
Staff Shift Scheduling for a Blood Donor Centre
Tully 1 (p. 94)

16:00 Chenchen Xing (The University of Melbourne)
Estimating Customer Valuation in a Service System with Unobserved Balking
Tully 1 (p. 138)

16:20 Hritika Gupta (The University of Melbourne)
Expected Number of Call Abandonments in a Call Centre
Tully 1 (p. 74)

▷ Wed 8 February

09:40 Radislav Vaisman (The University of Queensland)
Optimal Balanced Chain Decomposition of Partially Ordered Sets with Applications to Operating Cost Minimization in Aircraft Routing Problems
Tully 1 (p. 130)

10:00 Vera Somers (The University of Melbourne)
Optimal Control of Spreading Processes on Dynamic Networked Systems
Tully 1 (p. 121)

10:20 Matthew Tam (The University of Melbourne)
Convergence of Multi-Block ADMM
Tully 1 (p. 125)

Session 13: Statistics and Data Science

Contributed Talks

▷ Mon 6 February

10:20 Zhihao Qiao (The University of Queensland)
An EM Framework for Competing Risks via Multi-Absorbing Phase Type Distributions
Tully 1 (p. 115)

10:40 Jesse Sharp (Queensland University of Technology)
Parameter Estimation and Uncertainty Quantification Using Information Geometry
Tully 1 (p. 118)

11:00 Hui Yao (The University of Queensland)
Estimating Tail Probabilities of Random Sums of Phase-Type Scale Mixture Random Variables
Tully 1 (p. 139)

11:20 Yeming Lei (The University of Queensland)
Multi-Pass Bayesian Estimation: a Robust Bayesian Method
Tully 1 (p. 92)

11:40 Johnathan Adams (QUT)
Person-To-Person Opinion Dynamics: an Empirical Study Using an Online Game
Tully 1 (p. 46)

12:00 Louis Davis (University of Otago)
A Self-Exciting Point Process Model for Earthquakes
Tully 1 (p. 66)

12:20 Grace Robinson (Queensland University of Technology)
Making Land Use Data Useable
Tully 1 (p. 117)

▷ Wed 8 February

11:00 Sarah Vollert (Queensland University of Technology)
Strategic Model Reduction by Analysing Model Sloppiness: Matching Model Complexity to Data Complexity
Tully 1 (p. 133)

11:20 Matthew Adams (Queensland University of Technology)
Using Mechanistic and Statistical Models to Predict Great Barrier Reef Coral Calcification Responses to Cumulative Acidification and Light Stress
Tully 1 (p. 46)

11:40 Shalem Leemaqz (Flinders University)
Predicting Risk of Pregnancy Complications: a Statistical Model
Tully 1 (p. 91)

12:00 Sharon Leemaqz (The University of Queensland)
Phenotyping Cell Populations in Cytometry Data Using a Statistical Model
Tully 1 (p. 91)

12:20 Markus Neuhaeuser (Koblenz University of Applied Sciences)
The Propensity Score for the Analysis of Observational Studies
Tully 1 (p. 107)

12:40 John MacLean (The University of Adelaide)
A New Construction Explains Particle Filter Degeneracy
Tully 1 (p. 93)

Session 14: Mathematical Biology

Contributed Talks

▷ Mon 6 February

10:20 Adrianne Jenner (Queensland University of Technology)
How Partial Differential Equations and MRIs Can Improve Prognosis for Multiple Sclerosis Patients
Ballroom (p. 82)

10:40 Adel Mehrpooya (Queensland University of Technology)
An Advection-Diffusion-Reaction Model for Propagation of Signaling Molecules in Irregular Spatial Networks
Ballroom (p. 101)

11:00 David Morselli (None)
Agent-Based and Continuum Models for Spatial Dynamics of Oncolytic Viruses' Infections
Ballroom (p. 106)

11:20 Mark Flegg (Monash University)
Turing Instabilities in Spatially Heterogeneous Reaction-Diffusion Equations
Ballroom (p. 70)

11:40 Yvonne Stokes (The University of Adelaide)
Chemical Signalling and Tissue Response: a Moving Boundary Problem in Biology
Ballroom (p. 122)

12:00 Keith Li Chambers (The University of Oxford)
LDL vs HDL: a New Lipid-Structured Model for Early Atherosclerosis
Ballroom (p. 62)

12:20 Georgia Weatherley (Queensland University of Technology)
Math, Multiple Sclerosis, and the Mind: Using Agent-Based Modelling to Understand What Causes the Immune System to Attack the Brain
Ballroom (p. 136)

12:40 Anthia Le (The University of Queensland)
The Relationship Between Grandmother Care and the Origin of Menopause
Ballroom (p. 89)

15:00 Robyn Patrice Araujo (Queensland University of Technology)
Cellular Cognition and the Robustness of Life's Networks
Ballroom (p. 52)

15:20 Brock Sherlock (University of New South Wales)
Distance Measures to Compare Stochastic Time Series Data and Stochastic Model Outputs
Ballroom (p. 119)

16:00 Edward Hancock (The University of Sydney)
A Dual-Clock-Driven Model Emulating the Effects of Experimental Knock-Out on Lymphatic Muscle Cell Pace-Making
Ballroom (p. 75)

16:20 Qianqian Yang (Queensland University of Technology)
Using Anomalous Diffusion Models for Mapping Brain Tissue Microstructure
Ballroom (p. 139)

16:40 Karina Arias Calluari (The University of Sydney)
Modelling Daily Weight Variation in Honey Bee Hives
Ballroom (p. 53)

17:00 Alsubaie Faris Saad (The University of Queensland)
Modelling of Tissue Invasion in Epithelial Monolayers
Ballroom (p. 69)

17:20 Zhuang Xu (University of New South Wales)
The Position of the Axon Initial Segment Assembly Site Can Be Predicted from the Shape of the Neuron
Ballroom (p. 138)

▷ Wed 8 February

09:40 Matthew Simpson (Queensland University of Technology)
Computationally Efficient Framework for Diagnosing, Understanding, and Predicting Biphasic Population Growth
Ballroom (p. 120)

10:00 Adriana Zanca (The University of Melbourne)
Comparison of Locally and Globally Acting Wound Closure Mechanisms
Ballroom (p. 141)

10:20 Isabel Cowlishaw (The University of Auckland)
Optimisation of Corneal Tissue Engineering to Facilitate Epithelial Wound Healing
Ballroom (p. 64)

11:00 Pascal R. Buenzli (Queensland University of Technology)
Bone Adaptation with Embedded Mechanical Memory
Ballroom (p. 59)

11:20 Murk Bottema (Flinders University)
Modelling Remodelling in Rat Bones
Ballroom (p. 58)

11:40 Domenic Paul Joe Germano (The University of Melbourne)
Free and Interfacial Boundaries in Individual-Based Models of Multicellular Biological Systems
Ballroom (p. 72)

12:00 Alex Tam (University of South Australia)
Front Stability for a Moving-Boundary Model for Biological Invasion and Recession
Ballroom (p. 125)

12:20 Alistair Falconer (The University of Queensland)
Cell Migration in Sinusoidal Geometries
Ballroom (p. 68)

12:40 Michael Dallaston (Queensland University of Technology)
The Effect of Chemotaxis on T-Cell Regulatory Dynamics
Ballroom (p. 65)

15:00 Stuart Johnston (The University of Melbourne)
Analytic Solutions for Diffusive Processes on Multiple Growing Domains
Ballroom (p. 83)

15:20 Dilan Pathirana (University of Bonn/MPI Bonn)
Faster Model Selection, with Applications in Systems Biology
Ballroom (p. 112)

▷ Thu 9 February

09:40 Matthew Faria (The University of Melbourne)
Quantitative Assessment of Targeted Therapeutics and Cells
Ballroom (p. 69)

10:00 Jiahao Diao (The University of Melbourne)
Modelling Gene Content Across a Phylogeny to Determine When Genes Become Associated
Tully 3 (p. 67)

10:00 Claire Miller (The University of Auckland)
Cell Invasion in Endometriosis
Ballroom (p. 102)

10:20 James Mark Osborne (The University of Melbourne)
An Adaptive Numerical Method for Multicellular Simulations of Organ Development and Disease
Ballroom (p. 109)

11:00 Michael Greg Watson (University of New South Wales)
Investigating Necrotic Core Localisation with a Spatial-Temporal-Structural Model of Early Atherosclerotic Plaque Formation
Ballroom (p. 134)

11:20 Jessica Crawshaw (University of Oxford)
The Role of Hierarchical Bayesian Inference in Understanding Macular Degeneration Treatment Strategies
Ballroom (p. 65)

11:40 Matthew Cody Nitschke (The University of Sydney)
Male-Biased Mating Sex Ratios and the Evolution of Human Pair Bonds
Tully 2 (p. 107)

11:40 Michael Pan (The University of Melbourne)
Computational Modelling of Metabolism Within the Ageing Heart
Ballroom (p. 110)

Session 15: Material Science, Solid Mechanics

Contributed Talks

▷ Tue 7 February

09:40 Zachary James Wegert (Queensland University of Technology)
Constrained Level Set-Based Microstructure Optimisation with a Hilbertian Projection Method
Tully 1 (p. 136)

10:00 Kirsten Louw (University of South Australia)
Two-Dimensional Ferric Ion Diffusion in an Analyte Solution with a MOF Crystal Sink
Tully 1 (p. 93)

10:20 Pierluigi Cesana (Kyushu University)
Mesoscale Modeling of Systems of Disclinations and Dislocations
Tully 1 (p. 61)

▷ Wed 8 February

15:00 Natalie Thamwattana (The University of Newcastle)
A Variational Model for Metal Folding
Tully 1 (p. 128)

15:20 Vivien Challis (Queensland University of Technology)
Understanding Failure with Computational Finite Fracture Mechanics
Tully 1 (p. 62)

Session 16: Stochastic Processes

Contributed Talks

▷ Mon 6 February

12:40 Enrico Valdinoci (The University of Western Australia)
The Lévy Flight Foraging Hypothesis
Tully 1 (p. 132)

Session 17: Other topics

Contributed Talks

▷ Mon 6 February

16:40 Patrick Grant (Queensland University of Technology)
Constructing Virtual Representations of Laminated Timber Products
Tully 1 (p. 73)

17:00 Anthony Vine (Queensland University of Technology)
Mathematical Modelling of the Drying of Fruits and Vegetables
Tully 1 (p. 133)

17:20 Edoardo Fabrini (Kyushu University)
Linear Aeroelastic Stability of Helicopter Rotors in Axial Flight Through BEM Method for Compressible Flows in Frequency Domain
Tully 1 (p. 68)

10 Contributed Abstracts (ordered by surname of presenter)

Why'd You Have to Go and Make Things So Complicated?

Isobel Abell
The University of Melbourne

Tully 3, 16:20 Mon 6 February

It's often said that a model should be "as simple as possible, but no simpler", but how do we know when a model is "as simple as possible"? Modelling for decision-making further complicates this question, as decision-makers may prefer complex models, seeing them as "more trustworthy" or "realistic". How do we balance these complexities to choose the right model for the job? In this work, we emulate the process of modelling for pandemic decision making using a suite of models of varying complexity. Our models focus on two types of complexity:

- *Mathematical complexity*, for example non-linear dynamics, stochasticity, large parameter spaces, and
- *Complexity of communication*, our ability to explain/justify a model and its output to non-mathematicians.

Considering a simulated data set, we pose the question: how many infections and hospitalisations will we see for this epidemic? We fit our models to this data set and then simulate forward to estimate total infections and hospitalisations, allowing us to compare how each of these models answer the questions posed. This simulated decision-making process allows us to investigate how model complexity impacts the mathematical suitability of models to represent a given scenario, as well as suitability for communication to non-mathematicians.

Person-To-Person Opinion Dynamics: an Empirical Study Using an Online Game

Johnathan Adams
QUT

Tully 1, 11:40 Mon 6 February

Opinion's are ubiquitous and motivate people's behaviours. They range from the bien to conspiratorial and the wide adoption of opinions in a society can led to social progress or degradation. Opinion Dynamics, i.e. the study of opinion spreading through society and social networks, is motivated by the fallout of new opinions spread through the populous, potentially tracking the beginnings of new social movements. In this talk we approach this broad topic at the person-to person level by investigating the viability of the extended Martins model, a model which seeks to capture opinion exchange between two individuals, assuming that the individuals update their opinion using limited Bayesian inference. We present the latest research on the Martins model which compares the model's predictions to results from an experiment which measure how much an individual changes their opinion when presented with information that isn't always reliable. Through analysing the results of the experiment, we uncover two phenomena. One that matches the Martins model's predictions and the other fell outside the explanatory scope of the Martins model. The novel phenomenon suggests that individuals are more willing to comprise even when, according to the Martins model, they should reject.

Using Mechanistic and Statistical Models to Predict Great Barrier Reef Coral Calcification Responses to Cumulative Acidification and Light Stress

Matthew Adams, David Suggett, Emma Camp, Mark Baird, Mathieu Mongin, Sarah Vollert, Gloria Monsalve-Bravo, Christopher Drovandi, Robert Mason, Peter Mumby
Queensland University of Technology

Tully 1, 11:20 Wed 8 February

Ocean acidification threatens growth of coral reefs by reducing their net calcification rates. Calcification occurs inside the coral animal, in a compartment that is difficult to measure. Using laboratory data for Great Barrier Reef coral species, we calibrated mechanistic and statistical models of calcification rate responses to seawater conditions, to identify how much information about coral animal biology can be gleaned from this data and make predictions of net calcification rates (including uncertainty) for thousands of reefs within the Great Barrier Reef. The mechanistic model consisted of a set of coupled ordinary differential equations combined with a standard algorithm used to calculate equilibrium kinetics of carbon chemistry (CO2SYS). For both mechanistic and statistical models, calibration to data was undertaken using Bayesian inference, implemented via a robust Sequential Monte Carlo sampling algorithm. Both mechanistic and statistical models plausibly fit the laboratory data and made similar reef-scale predictions. Reef-scale predictions indicated that cumulative acidification and light stress mediate localised reductions of coral reef calcification rate across the Great Barrier Reef, although forecasted uncertainty in predictions was unsurprisingly high.

Parasian Over Parisian, How Much Earlier Should One Exercise?

Lin Ai; Song-ping Zhu
None

Ballroom, 12:40 Tue 7 February

In this paper, an integral equation approach used for pricing American-style Parisian options is extended to pricing Parasian options, after overcoming an additional difficulty of losing the "reset" feature of the latter in addition to still dealing with the highly nonlinearity associated with American-style exercises. More specifically, compared with an American Parisian option, the accumulative feature of the 'tracking clock' time results in a pair of coupled three-dimensional (3-D) Partial Differential Equation (PDE) systems instead of coupled two-dimensional (2-D) and 3-D PDE systems. Upon successfully establishing the couple integral equation systems, we have successfully computed option price and the optimal exercise price and compare the results with those of its Parisian counterpart. Through the comparison, we can directly observe how the accumulativeness of the 'tracking clock' time affects the option and the optimal exercise prices and provide some meaning financial explanations.

A Scenario Modelling Analysis to Anticipate the Impact of COVID-19 Vaccination in Adolescents and Children on Disease Outcomes in the Netherlands, Summer 2021

Kylie EC Ainslie, Jantien A Backer, Pieter T de Boer, Albert Jan van Hoek, Don Klinkenberg, Hester Korthals Altes, Ka Yin Leung, Hester de Melker, Fuminari Miura, Jacco Wallinga
Dutch National Institute of Public Health and the Environment (RIVM)

Tully 1, 10:20 Thu 9 February

Background: Since the roll-out of COVID-19 vaccines in late 2020 and throughout 2021, European governments have relied on mathematical modelling to inform policy decisions about COVID-19 vaccination. Aim: We present a scenario-based modelling analysis in the Netherlands during summer 2021, to inform whether to extend vaccination to adolescents (12–17-year-olds) and children (5–11-year-olds). Methods: We developed a deterministic, age-structured susceptible-exposed-infectious-recovered (SEIR) model and compared modelled incidences of infections, hospital and intensive care admissions, and deaths per 100,000 people across vaccination scenarios, before the emergence of the Omicron variant. Results: Our model projections showed that, on average, upon the release of all non-pharmaceutical control measures on 1 November 2021, a large COVID-19 wave may occur in winter 2021/22, followed by a smaller, second wave in spring 2022, regardless of the vaccination scenario. The model projected reductions in infections/severe disease outcomes when vaccination was extended to adolescents and further reductions when vaccination was extended to all people over 5 years-old. When examining projected disease outcomes by age group, individuals benefitting most from extending vaccination were adolescents and children themselves. We also observed reductions in disease outcomes in older age groups, particularly of parent age (30–49 years), when children and adolescents were vaccinated, suggesting some prevention of onward transmission from younger to older age groups. Conclusions: While our scenarios could not anticipate the emergence/consequences of SARS-CoV-2 Omicron variant, we illustrate how our approach can assist decision making. This could be useful when considering to provide booster doses or intervening against future infection waves.

Determining the Trade-Offs Between Different COVID-19 Control Strategies in the Netherlands: a Counterfactual Analysis

Kylie EC Ainslie, Jantien A Backer, Jacco Wallinga, Pieter T de Boer
Dutch National Institute of Public Health and the Environment (RIVM)

Tully 1, 10:00 Thu 9 February

Background Throughout the COVID-19 pandemic policy makers have been faced with the difficult task of mitigating disease spread and minimizing severe disease outcomes while also limiting the time spent under strict non-pharmaceutical interventions. Here, we present a counterfactual analysis investigating the trade-offs between different intervention strategies in the Netherlands.
Methods Using an age-structured, compartmental susceptible-exposed-infectious-recovered model extended to include severe disease states and vaccination, we simulated disease outcomes (e.g., hospital admissions, intensive care (IC) admissions) over 3 years while implementing five different non-pharmaceutical control strategies: A) no measures, B) partial lockdown, C) early lockdown, D) late lockdown, and E) zero-COVID. We define strategy specific thresholds of IC admissions for entering and exiting lockdown. We perform 200 simulations for each control strategy and determine the number of days spent in lockdown and the number of cumulative hospital and IC admissions for each simulation.
Results With the exception of implementing no control measures (A), we found that under the late lockdown strategy (D), the lowest median percentage of time (44.7% after 1 year, 41.8% after 2 years, and 40.5% after 3 years) was spent in lockdown. Due to a build-up in naturally-acquired immunity, the percentage of time spent in lockdown decreased over time for all intervention strategies, except zero-COVID (E). Under a zero-COVID strategy, the highest median percentage of time was spent in lockdown (92.3% after 1 year, 96.2% after 2 years, and 97.4% after 3 years). We quantified the number of days spent in lockdown per implementation and found that on average the early lockdown strategy (C) had the shortest lockdowns with a median of 26 days per lockdown. The zero-COVID strategy, followed by early lockdown, resulted in the fewest hospital and IC admissions, while no measures, followed by partial lockdown resulted in the most hospital and IC admissions.
Discussion These results highlight and specify the trade-offs that exist for each control strategy and reveal how the ideal control strategy depends on the policy goals (e.g., to limit days in lockdown or limit IC admissions).

Beyond Expected Values: Making Environmental Decisions Using Value of Information Analysis When Measurement Outcome Matters

Morenikeji D. Akinlotan, David J. Warne, Kate J. Helmstedt, Matthew P. Adams
Queensland University of Technology

Tully 3, 10:20 Thu 9 February

In ecological and environmental contexts, management actions must sometimes be chosen urgently. Value of information (VoI) analysis provides a quantitative toolkit for projecting the expected improvement that additional measurements make to the choice of management actions. However, traditional VoI analysis relies strongly on reporting metrics expressing expectations of measurement value, thus hiding uncertainties in projections. If a decision-maker is risk-averse to low-value measurement outcomes, the metrics produced in traditional VoI analysis therefore may not align with their priorities. In the present work, we introduce four new VoI metrics that can together account for risk-aversion of the decision-maker to low-value measurement outcomes. We show application of the new metrics to two ecological case studies for which traditional VoI analysis has been previously applied. In the first case study concerning a test for disease presence at a potential frog translocation site, traditional VoI analysis predicts the test yields an additional expected gain of approximately 10 frogs; however, the new VoI metrics also highlight a 40% risk that the test is valueless. In the second case study concerning the design of a trial release prior to a largescale turtle reintroduction, traditional and new VoI metrics have consistent predictions of which design to choose. However, whilst the best trial release design will increase expected turtle survival in the wild by only 3%, the new VoI metrics find that this trial design has a 93% probability of changing the way the largescale turtle reintroduction is implemented. Using the new metrics, we also demonstrate a clear mathematical link between the often-separated environmental decision-making disciplines of VoI and optimal design. Overall, the introduced VoI metrics complement existing metrics to provide environmental decision-makers with a comprehensive view of the value of, and risks associated with, a proposed monitoring or measurement activity; this is critical for improved environmental outcomes when decisions must be urgently made.

Use of Bayesian Stochastic Hierarchical Models in Epidemiology

Punya Alahakoon, James McCaw, Peter Taylor
The University of Melbourne

Tully 3, 11:20 Mon 6 February

A hierarchical model is a statistical framework where simultaneous estimation can be done at multiple levels. We consider studying multiple outbreak data where the dynamics of each outbreak can be modelled by a stochastic epidemic model. Estimation of the parameters of these models can be done using a hierarchical modelling framework.
In this talk, I present the application of hierarchical models in two contexts. In the first study, we consider multiple outbreak data that display extinctions after the first major outbreak (epidemic fade-outs) and multiple waves: a consequence of the presence of the waning of immunity in closed sub-populations. We illustrate that when a hierarchical modelling framework is used, waning immunity rates are estimated more accurately than when the outbreaks are considered independently.
In the second study, we consider three subsets of multiple outbreak data that display distinct transmission levels: high, medium, and low. In this application, we show that when a hierarchical framework is applied by considering all the subsets together, parameter estimates do not necessarily improve. However, they can be improved when the subsets are recognised prior to a hierarchical analysis.

Effect of Radical Cure Treatment on *P. Vivax* Malaria Transmission via Mass Drug Administration

Md Nurul Anwar,Roslyn I. Hickson,Somya Mehra,James M. McCaw, Mark B. Flegg, Jennifer A. Flegg
The University of Melbourne

Tully 3, 11:00 Mon 6 February

Plasmodium vivax is the most geographically widespread parasite causing malaria resulting in significant associated global morbidity and mortality. One of the factors driving this is the ability of the parasites to remain dormant in the liver, known as ‘hypnozoites’, and activate later to cause further infections, referred to as ‘relapses’. As around 79–96% of infections are attributed to relapses from activating hypnozoites, it is highly impactful to target the hypnozoite reservoir (i.e., the collection of dormant parasites) to eliminate *P. vivax.* Treatment with radical cure, for example tafenoquine or primaquine, to target the hypnozoite reservoir is a potential tool to control and/or eliminate *P. vivax.* We have developed a deterministic multiscale mathematical model as a system of integro-differential equations that capture the complex dynamics of *P. vivax* hypnozoites and the effect of hypnozoite relapse on disease transmission. Here, we use our multiscale model to study the effect of radical cure treatment as a method of mass drug administration (MDA). We implement multiple rounds of MDA with a fixed interval between rounds, starting from different steady-state disease prevalences. We then construct an optimisation model to obtain the optimal MDA interval. We also incorporate mosquito seasonality in our model to study its effect of the optimal treatment regime. We find radical cure alone may not be enough to lead to *P. vivax* elimination under our mathematical model and choice of parameters.

Cellular Cognition and the Robustness of Life’s Networks

Robyn P. Araujo
Queensland University of Technology

Ballroom, 15:00 Mon 6 February

Although all of nature is subject to the laws of physics and chemistry, the notion of ’function’ distinguishes biology from other natural sciences. In particular, evolutionary selection for function has given rise to vast and elaborate networks of interacting molecules within each living cell, comprising mostly proteins, which allow cells to interpret their external environments, make decisions, and orchestrate complex responses. These signalling networks are now recognised to be a rich source of fascinating mathematical problems.

In this talk, I will discuss the search for fundamental design principles in complex cellular networks in the context of a ubiquitously-observed phenomenon known as Robust Perfect Adaptation (RPA). We have recently discovered that all RPA-capable collections of interacting molecules are able to compute integrals by exploiting special structural constraints on their underlying chemical reactions, thereby implementing the well-established engineering strategy known as integral control. This new discovery has important implications for evolutionary biology, embryology and development, cancer research, and drug development.

Modelling Daily Weight Variation in Honey Bee Hives

Karina Arias-Calluari, Theotime Colin, Tanya Latty, Mary Myerscough, Eduardo G Altmann
The University of Sydney

Ballroom, 16:40 Mon 6 February

To understand and prevent honeybee hive collapses it is essential to obtain information about the number of forager bees and their activity in healthy bee colonies. Herein, we model the foraging and food-processing activities of bees as a set of ordinary differential equations, and we show how the parameters of our model can be inferred from data. Our model describes the daily dynamics of the hives and reproduces the main intra-day variations of the weight of the hive. Using weight time series for dozens of hives, we show how our model allows for the estimations of the number of bees collecting food, the amount of food collected, and the time bees spent outside the hive during successful foraging trips just from simple time series of the weight of the hive. Our work's importance relies on understanding why some honeybee hives perform better than others under the same spatial-temporal conditions. Therefore, our model opens the perspective of developing weight-based early-warning indicators of bee colony failure that could lead to new strategies for monitoring and control.

Graph Clustering Problem: Beyond Binary Interactions

Konstantin Avrachenkov
INRIA Sophia Antipolis

Ballroom, 08:20 Wed 8 February

A classical setting of graph clustering consists of partitioning the vertices of a graph into tight-knit clusters. Nowadays, the underlying challenge is frequently called the "community recovery problem" due to its numerous applications in diverse domains such as sociology, neuroscience, bibliography and recommender systems, just to name a few. A benchmark model for graph clustering problem is a Stochastic Block Model (SBM), which is an inhomogeneous version of the Erdos-Renyi random graph. In this talk I discuss several generalizations of SBM that go beyond binary interactions modelled by simple graphs. Specifically, I consider a network, where the observed interactions belong to a general measurable interaction space. This can represent categorical and vector-valued interactions, including time series or spatial point patterns. I present sharp information-theoretic criteria for the strong cluster recovery in terms of data sparsity, the statistical similarity between intra- and inter-block interaction distributions, and the shape and size of the interaction space. This general framework makes it possible to study temporal networks when both the number of nodes and the time horizon go to infinity, and when the temporal interaction patterns are correlated over time. An efficient spectral algorithm to recover clusters will be presented and demonstrated on real-life and synthetic network examples. In some applications, the framework of hypergraphs is more appropriate than the framework of simple graphs or even graphs with weighted edges. The recovery conditions for the hypergraph clustering are also available. Finally, I discuss the case of clustering geometric graphs when the standard Fiedler-vector based algorithms may not be applicable and one needs to look deeper inside the graph spectrum.

Finite Time Analysis of Crises in a Chaotically Forced Ocean Model

Andrew Axelsen
University of Tasmania

Tully 2, 12:40 Mon 6 February

A simple model for the temperature and salinity gradients related to currents in the North Atlantic Ocean was proposed by Stommel in the 1960's. A recent study coupled this model with a famously chaotic model, resulting in chaotic solutions through the introduction of the forcing. With enough forcing applied, we get changes in the stability of the model, known as crises. In this talk, we discuss the dynamical properties and the stability of a variant of this ocean model with and without forcing, before looking closer at the crises that occur through the use of finite time analysis (through the lens of a case study). We comment on the applicability of this analysis to other chaotic systems.

A Resolvent Positive Finite Difference Scheme of Order Alpha for Fractional Derivatives on Bounded Domains

Boris Baeumer, Mihaly Kovacs, Matt Parry
University of Otago

Tully 1, 10:40 Tue 7 February

The solution to

$$\frac{\partial}{\partial t}u(t,x) = c\left(\frac{\partial}{\partial x}\right)^{\alpha} u(t,x); u(0,x) = u_0(x); x \in (0,1)$$

with $u(t,x) = 0$ otherwise, develops a singularity at the boundary, destroying the order convergence of popular approximation schemes. We develop a new approximation scheme based on the polylogarithm function which preserves positivity and is of higher order.

Modelling Species Abundance and Dynamics Using Removal Data

Christopher Baker
The University of Melbourne

Tully 3, 11:00 Thu 9 February

Invasive species cause extensive environmental damage, and, in Australia, introduced predators have been linked to many native species extinctions. While continent-wide eradication of established species is currently infeasible, we can remove species from isolated regions, such as islands and fenced areas. An important aspect of managing these removal projects is estimating species abundance through time, including estimating the probability of eradication once no more individuals are being captured. An important source of information is from the removal data itself, as it shows how removal rates change through time. In this talk I will describe how we model removal data to support evidence-based decision-making in removal projects. I will use a range of case-studies with different target species, including Tasmanian devils, cats and invasive plants to demonstrate a range of model complexity, from estimating only abundance to modelling spatiotemporal population dynamics.

Near-Continuum Oscillatory Gas Flows with Finite Gas-Surface Accommodation

Nitay Ben Shachar, Joseph Johnson, Douglas Brumley, Jason Nassios, John Sader
The University of Melbourne

Tully 3, 12:40 Tue 7 February

Oscillatory gas flows generated by micro- and nano-electromechanical systems are typically in the non-continuum low-Mach-number regime. Asymptotic analyses of the Boltzmann equation for such gas flows predominantly assume diffuse scattering from solid boundaries, despite gas scattering often deviating from this idealized behavior in measurement. Here, a matched asymptotic expansion of the linearized Boltzmann-BGK equation is used to generalize these existing theories to Maxwell-like boundary conditions with finite accommodation at solid surfaces. This is performed for smooth solid boundaries, oscillatory frequencies far smaller than the molecular collision frequency, and to second-order in the Knudsen number. The derived theory is applied to (1) steady Poiseuille flow for a circular pipe and concentric cylinders, and (2) planar oscillatory thermal creep flow. It is found that the second-order slip theory does not universally generate the Knudsen minimum, as implied in the literature, and finite accomodation weakly affects planar oscillatory thermal creep flow.

Efficient Estimation of Epidemic Final Size Probabilities

Andrew Black
The University of Adelaide

Tully 1, 11:40 Thu 9 February

Epidemic final size data is important for the estimation of the transmissibility of a disease. As such the calculation of final size probabilities is the topic of a large literature dating back to the fifties. The best known method, and one of the most general, involves solving sets of linear equations. Despite its elegance this method suffers from numerical instabilities as the population size gets larger. In this talk I will present a new method for the unbiased estimation of epidemic final size probabilities. This is based on a reformulation of some older simulation ideas and the use of sequential importance sampling. The method allows for efficient parameter estimation in larger populations and is easily generalised to more complex multi-type models.

A Computable Characterisation of Model Uncertainty

Liam Blake
The University of Adelaide

Tully 2, 15:00 Mon 6 February

Deterministic continuous-time dynamical systems are vital for prediction in many areas, such as understanding geophysical, biological and socio-economic phenomena. However, uncertainty in such models is unavoidable, arising from observation and discretisation error and other unexplained phenomena. This uncertainty can be accounted for by introducing stochastic components into the deterministic model, but this is both analytically and computationally difficult.
This talk will present a multivariate Gaussian distribution characterising stochastic error in solutions to a best-available deterministic model, by considering an Itô stochastic differential equation formulation. The distribution captures the intrinsic uncertainty in the model, due to both the model dynamics and any specified spatiotemporal dependency in the noise, and is rigorously justified as a small-noise limit. By specifying the Gaussian distribution entirely in terms of the dynamics of the solutions of the deterministic model, uncertainties can be ascribed to *any* such model given only solution data. The computability also means that it can serve as an approximation for the stochastic solutions with small noise, circumventing the need for expensive Monte-Carlo simulations. This practical framework has many applications across oceanography and atmospheric modelling, data assimilation and Lagrangian coherent structure extraction.
This is based on joint work with John MacLean and Sanjeeva Balasuriya.

Modelling Remodelling in Rat Bones

Brianna L Martin, Nicola L Fazzalari, Karen J Reynolds and Murk J Bottema
Flinders University

Ballroom, 11:20 Wed 8 February

Remodelling in bone refers to the process by which bone tissue rejuvenates over time. Cells called osteoclasts remove fatigued bone (resorption) and cells called osteoblasts deposit new bone in replacement (formation). Bone density (bone volume per unit tissue volume) may decrease over time due to ageing or disease. Here, a two-part model is presented to understand, in the context of bone loss, how the remodelling process itself changes, if remodelling alone is responsible for bone loss and how drugs such as bisphosphonates mitigate bone loss.
First, spatio-temporal changes in bone density are modelled by a PDE. This model demonstrates that new bone emerging from the growth plate accounts for the main patterns of bone loss after oestrogen deprivation and subsequent recovery after treatment in growing rat female rats. However, this model does not determine key remodelling parameters such as the sizes of resorption cavities, the balance between resorption and formation or number of remodelling event per unit time. This is addressed by the second part of the model comprising simulations of remodelling events. Structure attributes of actual remodelled bone are compared with structure attributes of bone having undergone simulated remodelling and the difference is minimised over a range of remodelling simulation parameters. The results show that oestrogen deprivation leads to a 30 percent increase in resorption cavity volume and a three fold increase in the number of remodelling events. Subsequent treatment reduces the sizes of resorption cavities to about 10 percent more than the original value and reduces the number of remodelling events to the original value completely. The proportion of the formation volume reduces slightly after ovariectomy and recovers after treatment.

Conditionally Integrable PDE Systems: Applications to Populations and Quantum Measurement.

Philip Broadbridge
La Trobe University

Ballroom, 11:20 Tue 7 February

After combining a conditionally integrable nonlinear PDE with a single constraint, it reduces to a linear PDE with one fewer variables.
There is such a class of n+1-dimensional reaction-diffusion equations that reduces to the linear Helmholtz equation. The nonlinear diffusion may be of any fractional or integer order. Any target reaction function can be assumed. This has many applications, including fisheries modelling. Real fish mobility data from Australia, South Africa and Spain have been incorporated.
Another conditionally integrable system is the forced Madelüng-Burgers fluid velocity field in 3+1 dimensions, which reduces to the linear Schrödinger equation only when the fluid is irrotational. Measurement may introduce vorticity which induces energy dissipation until quantum equilibrium is restored.

The Role of Bacterial Chemotaxis in Microbial Symbiosis

Douglas Brumley
The University of Melbourne

Tully 3, 09:40 Thu 9 February

Bacterial motility, symbioses, and marine nutrient cycling unfold at the scale of individual microorganisms, and are inherently dynamic. Moreover, microorganisms are routinely exposed to microscopic fluid flows, which have the capacity to influence motility and redistribute chemical cues. In this talk, I will outline how combining video-microscopy, image processing and mathematical modelling can resolve dynamic microscale processes which underpin the ecology of microorganisms. I will also demonstrate how the highly-resolved processes at the scale of individual cells can be connected to bulk measurements at the population-level.

Bone Adaptation with Embedded Mechanical Memory

Yves Pauchard, Pascal R. Buenzli
Queensland University of Technology

Ballroom, 11:00 Wed 8 February

The functional adaption of bone to mechanical loads is described in Wolff's law and Frost's mechanostat as a simple response of bone mass to mechanical stimuli. These laws assume a static reference mechanical state and take no account of cellular aspects of how bone tissue senses and responds to mechanics. In this contribution, we develop a mathematical model of bone adaptation that relates the reference mechanical state (setpoint) and the mechanical sensitivity of the tissue to a network of cells that live within bone tissue, called osteocytes. The mechanical setpoint encoded by osteocytes acts as a mechanical memory that can be renewed when bone is replaced during bone resorption and formation. We present how mechanobiological response curves (Wolff's laws) are modulated by setpoint adaptation due to osteocyte replacement, and by disruptions to osteocyte signals, such as due to loss of osteocytes with age. We find that setpoint adaptation may have significant consequences, including long-term irreversibility of mechanical sensitivity, and hysteresis in Wolff's laws, which may be experimentally observable.

Solutions of Delay Differential Equations

Stuart-James Burney
UNSW Sydney

Tully 2, 11:00 Mon 6 February

Delay differential equations are an interesting class of non-local equations that involve a function and its derivatives evaluated at different points in time. These types of equations have had some use in modelling and form interesting cases of dynamical systems. By introducing a new class of functions, we have been able to provide fundamental solutions for autonomous linear integer-order delay differential equations. These functions, referred to as delay functions, relate the power series solutions of ordinary differential and delay differential equations. The functions are also interesting in and of themselves, with analogues of exponentials, trigonometric, and more complicated functions easily obtained. We also show that the delay functions have simple Laplace transforms and show how this allows for the solution of certain delay differential equations via transform methods. The delay function technique is also easily extended to more generalized series solutions. This allows us to obtain closed form solutions to some delay differential equations with periodic coefficients.

Escape Time Statistics in Dissipative Chaotic Scattering

Lachlan Burton
The University of Sydney

Tully 2, 11:20 Mon 6 February

In Hamiltonian systems for which escape of the trajectory from some central region of phase space is a possible outcome (through a hole, leak etc) the decay of the distribution of trajectory lifetimes is well-described by existing transient chaos literature. However, the addition of weak dissipative effects, such a velocity-dependent drag, to such open systems is not well-explored. In this talk I will discuss some observations of dissipative models from dynamical astronomy that are distinct from the usual picture in conservative systems, as well as introducing some theory to explain these observations.

Random Walks with Absorbing Boundaries

Elliot Carr
Queensland University of Technology

Ballroom, 08:40 Tue 7 February

Random walks are fundamental to numerous applications across physics, biology, ecology and medicine. In this talk, I will consider the classical problem of a particle undergoing a random walk until it reaches an absorbing boundary and is removed from the system. In particular, I will describe mathematical techniques for studying two fundamental properties of such problems: (1) probability the particle remains in the system over time and (2) mean time taken for the particle to exit the system. The first half of the talk will show how to construct simple accurate approximations to (1) on radially-symmetric domains. The second half of the talk will show how perturbation theory can be used to calculate (2) on irregular domains. In both cases, results will be compared with averaged data from repeated random walk simulations.

Mesoscale Modeling of Systems of Disclinations and Dislocations

Pierluigi Cesana
Kyushu University

Tully 1, 10:20 Tue 7 February

Planar wedge disclinations are rotational mismatches at the level of the crystal lattice entailing a violation of rotational symmetry. Alongside dislocations, disclinations are observed in classes of Shape-Memory Alloys undergoing the austenite-to-martensite transformation and in crystal plasticity. In this talk, I will describe some recent results on the modeling of planar wedge disclinations and edge dislocations via an energy minimization principle. We model disclinations and dislocations as the solutions to minimum problems for isotropic elastic energies under the constraint of kinematic incompatibility. Our main result is the analysis of the energetic equivalence of systems of disclination dipoles and edge dislocations in the asymptotics of their singular limit regimes. This is based on: https://arxiv.org/abs/2207.02511

Understanding Failure with Computational Finite Fracture Mechanics

Vivien J. Challis, Zachary J. Wegert, Joseph F. Grotowski, Anthony P. Roberts
Queensland University of Technology

Tully 1, 15:20 Wed 8 February

How do we predict the stress at which a perforated plate will fail? While the question is simple, classical approaches are contradictory and don't match experimental data. In this talk I'll discuss our approach to this problem using a more recent paradigm called finite fracture mechanics. Finite fracture mechanics predicts the load at which a sample will fail as the solution of a minimisation problem. We solve this minimisation problem computationally to predict the failure strength of perforated plates with holes of different shapes and sizes. Our computational study elucidates the competition between strength and toughness in determining failure within the finite fracture mechanics paradigm. I will also share our progress validating the computational results with experimental data.

LDL vs HDL: a New Lipid-Structured Model for Early Atherosclerosis

Keith L Chambers, Mary R Myerscough, Helen M Byrne
The University of Oxford

Ballroom, 12:00 Mon 6 February

Atherosclerotic plaques are a major cause of heart attacks and strokes. Plaques form in artery walls due to a chronic inflammatory response driven by lipid accumulation. Lipid enters the plaque from the bloodstream on low-density lipoprotein (LDL) particles. Macrophages ingest extracellular lipid and offload ingested lipid to high-density lipoprotein (HDL) particles. The lipoproteins LDL and HDL (which carry 'good' and 'bad' cholesterol respectively) consequently have opposing effects on macrophage lipid content.
In this paper, we develop a lipid-structured mathematical model for macrophage populations in atherosclerotic plaques to investigate the impact of blood LDL/HDL levels on (i) plaque composition, and (ii) the distribution of lipid in plaque macrophages. The model is novel because it accounts for lipid-dependent rates of ingestion and offloading, which reflect intracellular feedback mechanisms. We show that the model admits a reduced subsystem, derived by summing the equations of the full model. This subsystem expresses the dynamics of various summary quantities (e.g. Total number of macrophages, total amount of intracellular lipid) which facilitate our analysis of plaque composition. We derive a continuum approximation of the model to analyse the macrophage lipid distribution. The results, which include time-dependent numerical solutions and asymptotic analysis of the unique steady state, indicate that plaque lipid content is particularly sensitive to the relative influx of LDL to HDL. The macrophage lipid distribution develops in a wave-like manner towards steady state and may adopt one of several qualitatively distinct equilibrium profiles. The equilibrium profile may be monotone decreasing (which may be concave or convex), a quasi-uniform distribution or a peaked profile.

A Comparison of Weakly Nonlinear Theory to Forced Internal Solitary Waves Using Spectral Methods

Keith Chan
Monash University

Tully 3, 10:40 Tue 7 February

We consider small amplitude solutions to the fully nonlinear solutions of the Dubreil-Jacotin-Long (DJL) equation under the Boussinesq approximation. Solutions for a small amplitude bump topography are modeled by first applying an iterative conformal mapping. Weakly nonlinear theory (WNL) is used to obtain an initial approximation to the forced DJL equation. This requires the solution to the forced Korteweg de-Vries (fKdV) equation. We apply various solitary wave solutions to the fKdV equation as the initial approximation, thereby obtaining various DJL solitary wave solutions. We compare WNL theory with the exact theory based on the DJL equation using spectral multigrid methods. Results show WNL provides a good approximation to the fully nonlinear DJL solutions under optimal parameter choices, but deviate significantly otherwise.

Large Amplitude Non-Spherical Bubbles

Madeleine Cockerill
University of Tasmania

Tully 3, 12:20 Tue 7 February

The stability and morphology of non-spherical bubbles has important applications in the modelling of underwater explosions, cavitation and sonoluminescence, and astrophysical bubble formation. Features of interest include bubble collapse, jet formation, outflows, and toroidal bubbles. Our analysis of this topic begins with a linear approximation, which assumes that the translational or shape deformations to the bubble surface are small. The resulting closed form solution can be used for stability analysis. Then, a fully nonlinear model, allowing for shape-mode interactions and including an arbitrarily high number of modes, is found using spectral methods. Surface tension can be included in both these inviscid models and causes limited mode coupling in the linear model and delays the growth of singularities in the nonlinear model. Viscous effects are introduced with a Boussinesq model, which is also solved using spectral methods and includes a radially inwards gravitational force. A wide range of results is given for a bubble perturbed by an initial disturbance or by source points that are steady, transient or that have oscillating strengths. Results are also given for bubbles in an acoustic field; the behaviour these bubbles is dependent upon the frequency of the pressure oscillations.

Optimisation of Corneal Tissue Engineering to Facilitate Epithelial Wound Healing

Isabel Cowlishaw, Richard Clarke, Laura Domigan, Trevor Sherwin
The University of Auckland

Ballroom, 10:20 Wed 8 February

Development in corneal tissue engineering is critical in aiding donor tissue shortages to treat corneal disease, particularly in developing countries. Cornea epithelial cells provide the protective barrier for the underlying stroma tissue, enabling the tissue to maintain its transparent properties. Central corneal wound healing occurs primarily through the migration of basal epithelial cells derived from limbal stem cells(1). Corneal epithelia have been shown to elongate and align along surface topographical features(2), however, there have been few clinical translations of enhanced epithelial biological structure and function. Post-operative corneal haze has been observed and attributed to incomplete monolayers(3). Thus, optimising the time required for complete coverage of the stroma with an epithelial monolayer is of clinical interest.
In preliminary work, an in-silico cell automata model was developed to study the influence of surface topography and chemotaxis on the monolayer coverage time of a two-dimensional circular wound. The model lacked sufficient representation of the cells' dynamic morphology and mechanical interactions. Open-source tools CompuCell3D(4) and PhysiCell(5) were assessed for their capability in replicating in vitro cell assays. These tools use Cellular Potts and Center-based methods, respectively, to model energy interactions between neighbouring cells. Ring-barrier cell culture assays were used to study the behaviour of cells on wounded and non-wounded edges. Image analysis of monolayer wound healing time-lapse data provided parameters to inform the in-silico model. Each tool presents limitations in accurately representing cell behaviour and interactions. The recommended model for modelling in vitro assays will require the identification of the critical parameters of interest.
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The Role of Hierarchical Bayesian Inference in Understanding Macular Degeneration Treatment Strategies

Jessica Crawshaw
University of Oxford

Ballroom, 11:20 Thu 9 February

Wet age-related macular degeneration (AMD) is a disease which slowly destroys ones' central vision, with a huge impact on quality of life. It is the leading cause of central blindness worldwide. Wet AMD is characterised by neovascularisation, triggered by an unhealthy abundance of vascular endothelial growth factor (VEGF). These newly formed capillaries allow fluids to seep into the retina, damaging the local photoreceptors (critical light sensing cells). Currently, there is no definitive cure for wet AMD. As such, intraocular injections of anti-angiogenic drugs to reduce the abundance of retinal VEGF is the clinical gold standard for disease management, slowing the progression of vision loss. However, injections into the eye are unpleasant, and the fluid dynamics within the eye leads to relatively rapid drug elimination, resulting in the need for regular intraocular injections.

In this talk, we will present and analyse a pharmacokinetic/pharmacodynamic (PK/PD) model of a standard-of-care antibody, Ranibizumab, targeting VEGF. This model has been developed to improve our understanding of the ocular pharmacology of Ranibizumab, and to provide a robust understanding of Ranibizumab retention in the eye. Results from this PK/PD model are compared to published animal (cynomolgus monkey) and human data. We present a hierarchical Bayesian inference strategy to determine relevant parameter distributions. Using this strategy, we provide an insight into the clinically observed inter-patient variability in VEGF suppression and drug retention. Finally, this model establishes the initial basis for a computational framework we are developing to mathematically compare the ocular PK/PD of Ranibizumab with novel therapeutic strategies and other clinical anti-VEGF drugs in the treatment of AMD.

The Effect of Chemotaxis on T-Cell Regulatory Dynamics

Michael Dallaston, Geneva Birtles, Robyn Araujo, Adrianne Jenner
Queensland University of Technology

Ballroom, 12:40 Wed 8 February

Autoimmune diseases are often modelled through the dynamics of T-cell interactions. However, the spatial aspect of such diseases, and how dynamics may result in spatially heterogeneous outcomes, is often overlooked. We consider the effects of diffusion and chemotaxis on T-cell regulatory dynamics using a three-species model of effector and regulator T-cell populations, along with a chemical signalling agent. While diffusion alone cannot lead to instability and spatial patterning, the inclusion of chemotaxis can result in multiple forms of instability that produce highly complicated spatiotemporal behaviour. The parameter regimes in which different instabilities occur are determined through linear stability analysis and the full dynamics is explored through numerical simulation.

A Self-Exciting Point Process Model for Earthquakes

Louis Davis
University of Otago

Tully 1, 12:00 Mon 6 February

Earthquakes are a natural phenomenon that are often modelled stochastically. Self- exciting point process methods have produced the most favourable models to date, but methods to predict magnitude are still unreasonable. To try and remedy this, point process methods are combined with empirical evidence and rheological models to produce the so called 'Fractional Hawkes Process.' The fractional Hawkes process, and the existing ETAS model, are fit to three mainshock sequences in Southern California. It is found the fractional Hawkes process performs well relative to the ETAS model, and the scientific basis for the model appears well founded.

Modelling Gene Content Across a Phylogeny to Determine When Genes Become Associated

Jiahao Diao, Barbara Holland, Malgorzata O' Reilly
The University of Melbourne

Tully 3, 10:00 Thu 9 February

We consider a model for inferring functional gene links. The model aims to detect the instances of independent or correlated gain and loss of pairs of genes from species genomes. We begin with the simple case of two genes whose presence or absence evolves stochastically along a phylogenetic tree. We develop a hidden Markov model that tracks the presence (1) and absence (0) of two genes across an evolutionary tree. The hidden states of the model correspond to whether or not the genes perform a joint function. In the case that two genes do perform a joint function, the rates of gain or loss of each gene depend on the presence or absence of the other gene. Otherwise, those two genes are assumed to be gained and lost independently. Using simulation, we investigate the conditions under which the package corHMM can infer the hidden state correctly, and we also investigate when the Akaike information criterion (AIC) has the power to reject the simpler model when it is incorrect.
We find that to correctly detect shifts in rate class the differences between the rates must be approximately ten-fold and that corHMM is more successful when there are multiple transitions between rate classes.
We show how the two-gene case can be extended to a more general n-gene model with a level-dependent quasi-birth-and-death (LD-QBD) framework. We assume that the level n of the QBD corresponds to the number of genes that are potentially interacting, and the phases within each level record the rates of each gene's gain or loss.

Civil Wars: a New Lotka-Volterra Competitive System

Serena Dipierro
The University of Western Australia

Tully 2, 12:20 Wed 8 February

We consider a model in population dynamics that describes two species sharing the same environmental resources in a situation of open hostility. The interaction among these populations is described not in terms of random encounters but via the strategic decisions of one population that can attack the other according to different levels of aggressiveness. This leads to a non-variational model for the two populations at war, taking into account structural parameters such as the relative fit of the two populations with respect to the available resources and the effectiveness of the attack strikes of the aggressive population. The analysis that we perform is rigorous and focuses on the dynamical properties of the system, by detecting and describing all the possible equilibria and their basins of attraction. Moreover, we analyze the strategies that may lead to the victory of the aggressive population.

Linear Aeroelastic Stability of Helicopter Rotors in Axial Flight Through BEM Method for Compressible Flows in Frequency Domain

Edoardo Fabbrini, G. Bernardini, M. Gennaretti
Kyushu University

Tully 1, 17:20 Mon 6 February

Accurate aeroelastic analysis of helicopter blades is still a challenging topic nowadays. The unsteadiness of the blade's aerodynamic, which easily arises in helicopter dynamics, makes Navier-Stokes solvers, such as DNS, LES or RANS, computationally too expensive and therefore unsuitable for being used in a preliminary stage design. Furthermore, the search for aerodynamic efficiency made the blades extremely slender bodies, making simple linear structural models mostly unsuitable for correctly describing their dynamics. In this work, numerical implementation of an aerodynamic elastic coupled solver for stability analysis of hinge-less axial flight helicopter rotors in the subsonic regime is presented. The equation of motion is obtained considering a flap bending, lead-lag bending, and torsion twisting, rotating cantilever nonlinear beam model. The Galerkin method is proposed as a solving technique. The aerodynamic forces are obtained from a three-dimensional potential unsteady compressible formulation. Viscous corrections are then added. The model is solved adopting a zero order Boundary Element Method in the frequency domain. The linearized stability of the rotor about the equilibrium configuration is presented in terms of the most critical eigenvalue of the problem; the so called "lead-lag damping factor". Numerical and experimental results available in the literature are used to benchmark our solver. We show a sensible improvement of our model with respect to a quasi-steady strip theory aerodynamic formulation. We also show that the agreement between experimental data and numerical results improves by considering the compressibility of the air. Finally, by performing a parametric analysis of different blade tip's Mach numbers, we show that the stability of the blade seems to exhibit a nonlinear behaviour: it increases at moderate speeds to decreases at the limit of the compressible regime. This suggests the rotor is approaching its critical velocity.

Cell Migration in Sinusoidal Geometries

Alistair Falconer
The University of Queensland

Ballroom, 12:20 Wed 8 February

Migrating cells must navigate complex and crowded 3D geometries, requiring them to actively tune both their mechanical and biochemical properties. Recent work identifies the role of shear forces at the cell/wall interface as key to certain modes of this migration which does not rely on external friction. We propose a mathematical model to simulate the dynamics of this migration by coupling a mechanical model of the cell cortex with a boundary element simulation of the cytoplasm dynamics to investigate observed behaviour. We find that consistent with experimental results a cell in a frictionless channel with sinusoidal wall geometry can undergo motility driven by actin treadmilling.

Quantitative Assessment of Targeted Therapeutics and Cells

Matthew Faria
The University of Melbourne

Ballroom, 09:40 Thu 9 February

Imagine a future where we could selectively deliver any molecule – from nucleic acid to fluorescent probe – to specific cell types of our choice. This would revolutionize how we treat and diagnose disease. Delivering on this vision requires us to develop 'targeted carriers' – engineered materials that can protect and deliver a 'cargo' molecule by avoiding the immune system, navigating through biological barriers, and binding to a chosen cell. Substantial effort in nanoengineering and biotechnology has been devoted to developing different forms of targeted carriers; which include lipid nanoparticles [LNPs], viral capsids, and polymeric capsules.
Unfortunately, despite this research effort, experimental assessment of targeting has remained largely qualitative. It is desirable to be able to quantitatively measure targeting (i.e., how well a targeted carrier attaches to a cell) in order to compare different technologies, evaluate progress in the field, and optimize formulations. In this talk, I will introduce a general mathematical framework we have used to developed to accomplish this. It quantifies the kinetics of cell-particle interaction and isolates the biological kinetics within an experiment from variation due to the experimental setup. Crucially, kinetic parameters can be determined from experimental (flow-cytometry) data which is amenable to high-throughput collection. This is analogous to determining R in infectious disease modelling or reaction rate constants in enzyme kinetics. Models are PDE based; with carrier concentration represented as a continuum and cell-carrier interaction represented as a boundary condition. I will additionally discuss biological insight that has been derived from this approach.

Modelling of Tissue Invasion in Epithelial Monolayers

Alsubaie Faris Saad
The University of Queensland

Ballroom, 17:00 Mon 6 February

Mathematical and computational models are used to describe biomechanical processes in multicellular systems. Here, we develop a model to analyse how two types of epithelial cell layers interact during tissue invasion depending on their cellular properties, simulating cancer cells expanding into a region of normal Cells We model the tissue invasion process using the Cellular Potts Model and implement our two-dimensional computational simulations in the software package CompuCell3D. The model predicts that differences in mechanical properties of cells can lead to tissue invasion, even if the division rates and death rates of the two cell types are the same. It is also shown that the invasion speed varies depending on the cell division and death rates and the mechanical properties of the cells.

Simplified Models of Diffusive Transport in Radially-Symmetric Media

Luke Filippini
Queensland University of Technology

Tully 2, 11:20 Wed 8 February

Simple reduced-order mathematical models are commonly proposed in applications such as drug delivery and food drying to approximate PDE models describing the spatial and temporal dynamics of diffusive heat and mass transport. Such reduced-order models are appealing as they bypass solving the PDE model, while also allowing for a simplified analysis and interpretation of results. Recently, a moment-matching approach was proposed and used to develop a simple single-term exponential model for the temporal evolution of the spatial-average of the diffusion equation in homogeneous radially-symmetric geometries. In this talk, I show how this approach can be extended to two-term exponential models that significantly improve on the accuracy of the single-term exponential model, in comparisons with the continuum spatial-average and stochastic simulations.

Turing Instabilities in Spatially Heterogeneous Reaction-Diffusion Equations

Mark Flegg and Jacob Vandenberg
Monash University

Ballroom, 11:20 Mon 6 February

Turing instabilities in reaction-diffusion equations are usually given a definition that contains two conditions that both must be met; (1) when the spatially uniform steady state is stable in the absence of diffusion, and (2) when this steady state is destabilised by the inclusion of diffusion. Whilst these Turing systems are ubiquitous in mathematical biology where they lead to a profusion of patterning outcomes, analytic insight is still largely only possible for spatially homogeneous systems and special cases. This poses a tremendous limitation on the utility of the mathematical theory for real models. For example, what can be said about reaction-diffusion Turing instabilities in the case where reactions are spatially heterogeneous? In this situation there is no uniform steady state to the reaction-diffusion system from which to even define the Turing instability. In this talk, we will take a look at this question.

The Completed Boussinesq Model for Fluid Flow

Larry Forbes
University of Tasmania

Tully 3, 12:20 Wed 8 February

A famously difficult problem in Fluid Mechanics is to compute the flows of multi-fluid interfacial systems. These occur when there are several fluids of different densities present, which meet at interfaces which also move as the fluids flow. The fluids are assumed to be viscous, and governed by the Navier-Stokes equations.
Classical Boussinesq theory is an approximation that ignores the different fluid densities, except when body-force terms are present. In this (crude) approximation, the only effect that the different fluid densities can have is on the buoyancy of each fluid, relative to the others. This simple theory has the enormous computational advantage that it allows the multi-fluid system to be treated as if it were a single fluid with spatially-varying density; and the interfaces are approximated by narrow regions in which the density changes smoothly from one region to the next.
Unsurprisingly, Boussinesq theory works well when the fluid densities are all nearly equal. But when there are large density differences, Boussinesq theory can predict interfaces with elaborate over-turning regions and spirals, when the true interface shape is nowhere near so flamboyant. We have developed a “Completed Boussinesq Theory” that keeps the key simplifying approximation of Classical Boussinesq theory, but also retains the exact Navier Stokes momentum equation. This can be extremely accurate, and the talk will show some examples and comparisons.

Bathymetry Imposes a Global Pattern of Cross-Front Transport in the Southern Ocean

Michael Denes, Gary Froyland, Shane Keating
University of New South Wales

Tully 2, 10:20 Mon 6 February

The Southern Ocean plays an integral role in the global climate system, exchanging heat, salt, and carbon throughout the three major ocean basins via the deep, fast-flowing Antarctic Circumpolar Current. The Antarctic Circumpolar Current is bounded by spatially and temporally varying fronts that partition distinct water masses. Locating and quantifying cross-front transport is crucial for understanding global patterns of inter-basin exchange; however, this is challenging because fronts are typically defined by hydrographic properties (subject to external sources and sinks), rather than as properties of the flow itself. We show that, when characterized by material contours that minimize deformation and cross-contour mixing, Southern Ocean fronts exhibit a global pattern of alternating poleward and equatorward transport caused by frontal meandering, which, in turn is influenced by prominent sea-floor obstacles. These results highlight the importance of bathymetric features in controlling Southern Ocean dynamics and inter-basin exchange.

Free and Interfacial Boundaries in Individual-Based Models of Multicellular Biological Systems

Domenic Germano
The University of Melbourne

Ballroom, 11:40 Wed 8 February

How a cellular boundary is modelled in an individual-based model of a tissue is not well understood. With multiple modelling choices to be made, such as how to incorporate the boundary of a tissue, there is a need to identify and understand how the choices may affect the tissue evolution, structure and even interface between two tissues. Within this talk, we present three popular individual-based models of epithelial tissues; Overlapping Spheres (OS), Voronoi Tessellation (VT) and Vertex Models (VM). We will present three cellular boundary descriptions for each of the aforementioned models, and investigate how this choice affects tissue dynamics. We investigate these models in the context of bold closure, tissue growth, and tissue collision. We will show how the VT model is most sensitive, the time scale within an OS model depends on the boundary description, while VM is comparatively the least sensitive to boundary description.

A Journey Into Random Dynamical Systems and Multiplicative Ergodic Theory

Cecilia Gonzalez-Tokman
The University of Queensland

Ballroom, 14:00 Wed 8 February

Random (or non-autonomous) dynamical systems are flexible mathematical models for the study of complicated systems whose evolution is affected by external factors, such as seasonal influences and random effects. Multiplicative ergodic theory provides fundamental information for the study of transport phenomena in such systems, including long-term behaviour, mixing rates and coherent structures. In this talk, we will take a journey into random dynamical systems and multiplicative ergodic theory, guided in part by questions arising from the investigation of oceanic and atmospheric flows.

Constructing Virtual Representations of Laminated Timber Products

Patrick Grant, Dr Steven Psaltis, Professor Ian Turner, Dr Maryam Shirmohammadi
Queensland University of Technology

Tully 1, 16:40 Mon 6 February

The complex structure of timber has traditionally been difficult to model as it is a highly heterogeneous material. In structural timber species, such as Radiata Pine, the density can vary by up to a factor of four times within the span of a few millimetres over the growth rings. Numerical simulation methods are becoming more prevalent as a method of predicting moisture migration, stress & strain distributions, and fungal/rot intrusion in timber. A computational mesh that captures heterogeneities present within structural timbers is required. In this work, a low-cost algorithmic method is developed that utilises image analysis techniques and spectral segmentation to produce a three-dimensional computational mesh of a laminated timber product. Starting with a photograph or a scan of the end grain of a timber board, an image mask is produced by employing thresholding and image smoothing techniques. This mask highlights the darker, latewood sections of the board providing a binary image of the growth ring locations. The growth rings are then identified using a spectral clustering algorithm, which performs exceptionally well on the three test images (quartersawn, plainsawn and back sawn boards). Next, the centre of the tree (pith) is located by using an iterative constrained least-squares algorithm. We assume the growth rings to be circular and compute a least-squares fit for each growth ring, fitting for the centre location and the radius, constraining the pith location at each iteration. The density can be determined by first computing the non-dimensionalised intra-growth ring radial length and feeding this into a fitted five-point logistic (5PL) function. Using the 5PL function allows for the density to be determined as a proportional length through the growth ring, where the coefficients are calculated from image analysis on an anatomical image of the cellular structure spanning over a growth ring. Lastly, a density can be assigned for each mesh element resulting in the virtual reconstruction of a singular board. Meshes of multiple timber boards can then be combined to produce the final mesh of a laminated timber product.

Expected Number of Call Abandonments in a Call Centre

Hritika Gupta
The University of Melbourne

Tully 1, 16:20 Mon 6 February

Assessing call abandonments is crucial for a call centre as they reflect an unsatisfactory customer experience and poor performance possibly due to understaffing or inefficient call allocation. Also, when a caller abandons the queue of a sales-based call centre, it could mean a loss in revenue. We aim to find the expected number of call abandonments during a future time interval given the current number of callers in the system. We consider a call centre with one type of customer, a fixed number of agents and a limited number of telephone trunk lines. The first method uses Laplace transforms to find the expected number of call abandonments during the time period $(0, t)$ given the number of callers at time 0. The second method uses backward induction for solving the Bellman equation for the expected number of call abandonments during the next $n-i$ events, given the number of callers at event number i.

Time-Dependent Solutions of a Fisher-KPP-Like Equation

Bronwyn Hajek
University of South Australia

Tully 2, 10:00 Thu 9 February

Nonlinear reaction-diffusion equations are used widely to model many different systems and processes, particularly in biology. While exact analytic solutions are often extremely useful, they can be particularly difficult and sometimes impossible to construct for nonlinear PDEs. I'll talk about a family of exact solutions to a nonlinear reaction-diffusion model that is analogous to the well-known Fisher-KPP model in a particular limit. The exact solution is interesting since exact solutions of the Fisher-KPP model are rare, and often restricted to long-time travelling wave solutions for special values of the travelling wave speed.

A Dual-Clock-Driven Model Emulating the Effects of Experimental Knock-Out on Lymphatic Muscle Cell Pace-Making

Edward Hancock
The University of Sydney

Ballroom, 16:00 Mon 6 February

Lymphoedema is a common dysfunction of the lymphatic system that results in fluid accumulating between cells. Fluid return through the lymphatic vascular system is primarily provided by contractions of muscle cells in the walls of lymphatic vessels, driven by oscillations in membrane potentials (action potentials) and calcium ion concentrations. However, there is incomplete understanding of the mechanisms involved in these oscillations, restricting the development of pharmacological treatments for dysfunction. Previously, we proposed a model where autonomous oscillations in the membrane potential (M-clock) drove passive oscillations in the calcium concentration (C-clock). In this paper, we extend this model to the case where the M-clock and the C-clock oscillators are both active and coupled together, and thus both driving the action potentials. The synchronized dual-driving clock behaviour enables the model to match experimental knock-out data, resolving an issue with previous models. We also use phase-plane analysis to explain the mechanisms for the dual-clock coupling. The model has the potential to help determine mechanisms and find targets for pharmacological treatment of lymphoedema.

Inertial Migration of Spherical Particles in Curved Ducts at Moderate Dean Numbers

Brendan Harding
Victoria University of Wellington

Tully 3, 11:00 Wed 8 February

Finite size particles suspended in flow through micro-scale ducts are known to migrate across streamlines and focus towards stable equilibria. In curved ducts the migration of particles is further complicated by the cross-sectional vortices present in Dean flow. For a fixed cross-section geometry the location of equilibria depends primarily on particle size, duct bend radius and the flow rate. To date we have had some success in modelling particle focusing through curved rectangular cross-sections at low flow rates, but extending this to moderate flow rates is challenging. I will discuss some of the difficulties and illustrate what happens when changes to the Dean flow are incorporated into our existing model.

Correlation of Viral Loads in Disease Transmission Chains Could Bias Early Estimates of the Reproduction Number

Thomas Harris, Nicholas Geard, Cameron Zachreson
The University of Melbourne

Tully 3, 16:40 Mon 6 February

Early estimates of the transmission properties of a newly emerged pathogen are critical to an effective public health response, and are often based on limited outbreak data. Here, we use simulations to investigate a potential source of bias in such estimates, arising from correlations between the viral load of cases in transmission chains. We show that this mechanism can affect estimates of fundamental transmission properties characterising the spread of a virus. Our computational model simulates a disease transmission mechanism in which the viral load of the infector at the time of transmission influences the infectiousness of the infectee. These correlations in transmission pairs produce a population-level decoherence process during which the distributions of initial viral loads in each subsequent generation converge to a steady state. We find that outbreaks arising from index cases with low initial viral loads give rise to early estimates of transmission properties that are subject to large biases. These findings demonstrate the potential for bias arising from transmission mechanics to affect estimates of the transmission properties of newly emerged viruses.

Modelling the Environmental Niche of Japanese Encephalitis Virus in Australia

Lucinda Harrison
The University of Melbourne

Tully 3, 12:00 Mon 6 February

Japanese encephalitis virus is a leading cause of viral encephalitis worldwide, causing life-changing disability and death in humans. Historically, the disease has only been recognised in Australia in small outbreaks in the Torres Strait and Far North Queensland, fuelled by independent introductions. However, since early 2022, the disease has been identified in 32 people and 85 piggeries across central and eastern Australia, as far south as central Victoria. The transmission cycle of the mosquito-borne virus is complex, with many reservoir species. In Australia, some species that drive transmission in other endemic areas are absent. In this work, we model the geographic distributions of wildlife host and vector species using environmental data. We use the predictions of these models to visualise the spatial extent of disease transmission during the outbreak of early 2022. We also estimate the potential spatial distribution of disease risk, given the modelled environmental niches of host and vector species. We consider how these outputs and their associated uncertainties, within a structured decision-making framework, might inform the spatial allocation of surveillance resources. This framework will support decision-makers to best respond to future outbreaks of Japanese encephalitis virus in Australia.

Modelling Spread of SARS-CoV-2 to Household Contacts and the Impact of Household Quarantine and Testing

Joel Trent, Emily Harvey, Joshua Looker, Dion O'Neale
The University of Auckland

Tully 1, 11:00 Thu 9 February

When aiming to limit onwards transmission of an airbourne infectious disease, one of the best places to look for new potential cases is the household contacts of confirmed cases. During much of the first two years of the SARS-CoV-2 pandemic, household contacts were required to quarantine in many countries. However, with the arrival of the Omicron variant, the sheer number of cases meant that a substantial proportion of the population was either isolating (as a confirmed case) or quarantining (as a household contact of a confirmed case).
In order to assess the effectiveness of different quarantine and testing policies for household contacts, a number of factors need to be considered:

- The first confirmed case in a household may not be the first infection in the household.
- There may be chains of transmission in larger households.
- The first case detected in a household could be detected many days through their infection (not on Day 0).
- Rapid Antigen Tests do not have perfect sensitivity and have a lag at the beginning of the infectious period.
- People may not follow the requirements/guidelines related to testing an quarantine.

We have built a stochastic model of household transmission and detection (as a Julia package) that includes consideration of all of these factors, and have combined this model with data from reported cases and household contacts during the Omicron wave(s) in March-July 2022 in Aotearoa NZ to investigate the spread of SARS-CoV-2 to household contacts and the real world effectiveness of household contact testing and quarantine.
This work produces a number of insights into testing behaviour of household contacts, the spread dynamics within households, and the real world effectiveness of RATs that are important to consider when developing household testing and quarantine policies.

A Mean-Field Version of Bank-El Karoui'S Representation of Stochastic Processes

Xihao He, Xiaolu Tan, Jun Zou
The Chinese University of Hong Kong

Ballroom, 10:20 Tue 7 February

We study a mean-field version of Bank-El Karoui's representation theorem of stochastic processes. Under different technical conditions, we establish some existence and uniqueness results. In particular, we derive a stability result on the classical representation result, which would have its own interests. Finally, as motivation and applications, our meanfield representation results provide a unified approach to study different Mean-Field Games (MFGs) in the setting with common noise and multiple populations, including the MFG of timing, the MFG with singular control, etc.

The Mathematics of Protecting Antarctic Biodiversity

Kate Helmstedt
Queensland University of Technology

Tully 3, 17:20 Mon 6 February

Antarctica is a massive continent which has largely been unexplored. We have very little data about the species that are there, yet nations around the world agree that their protection are critical. This is a perfect opportunity for optimal ecological management planning to create a real environmental impact. However, the complex political context for Antarctic management is a uniquely complex, opaque, and dynamic social network. As a result, optimal management for Antarctic biodiversity protection requires stitching together models and mathematical tools to understand a complicated decision pathway. Here I'll introduce these complexities, give an overview for how we're tackling them in the ARC Special Research Initiative 'Securing Antarctica's Environmental Future', and provide some exciting emerging directions. These will touch upon spatial optimisation, Value of Information analyses, Bayesian network modelling, and political network modelling.

Exploring the Interactions Between Policy and Human Mobility Patterns During the COVID Pandemic Through Flight Data: an Australian Case Study

Christine Little, Jess Liebig, Maryam Golchin, Emma Allnutt, Dean Paini, Morgan Furlong, Piper Rains, Roslyn Hickson
CSIRO and James Cook University

Tully 3, 15:20 Wed 8 February

Human mobility is a known driver of infectious disease spread. The covid pandemic provides an opportunity to explore the interactions between policy and human movement patterns during a pandemic. We created a flight passenger network model based on OAG Traffic Analyser data. This model was used to explore the interactions between flight passengers, notified covid cases and policy through the analysis of key weighted network properties. Given the complexities of differing policy decisions globally and federally, we have chosen Australia as a case study to explore the relationship between properties of the network and differences between local and inter-jurisdiction travel policies.
We depict how policy changed by jurisdiction in Australia through time, show how the corresponding passenger and covid-weighted node degree changed through time, and how the number and spatial configurations of detected network-communities changed through time. We show that, as expected the covid-weighted node degree was highly correlated to the number of reported covid cases in the airport catchment area, with a notable variation during Sep-Nov of 2020. On the other hand, we show quite a varied correlation of number of reported covid cases and passenger-weighted node degree.

Mechanisms by Which Buoyancy Segregation Can Suppress Viscous Fingering

Edward Hinton and Apoorv Jyoti
The University of Melbourne

Tully 2, 11:20 Thu 9 February

‘Viscous fingers’ can arise when a low viscosity fluid displaces a more viscous fluid. The fingers occur due to the discontinuity in the pressure gradient across the fluid-fluid interface. This classical instability is ubiquitous in flows in porous media and other confined geometries. In the case that the two fluids have different densities and gravity acts perpendicular to the direction of the displacement flow, the fluids can become segregated by the buoyancy force. It has been observed that this segregation may suppress viscous fingers. Through numerical simulations and stability analysis, we show that buoyancy-segregated horizontal displacements are stable for any viscosity ratio provided that the fluids have different densities. We analyse the physical mechanisms that eliminate the pressure discontinuity associated with the classical instability.
This is talk is based on the following paper: E.M. Hinton and A. Jyoti (2022). ‘Buoyancy segregation suppresses viscous fingering in horizontal displacements in a porous layer’. Journal of Fluid Mechanics, 946, A48.

Tractable Online POMDP Planning: Challenges and Methods

Marcus Hoerger
The University of Queensland

Ballroom, 17:00 Wed 8 February

Planning under partial observability is an essential capability of autonomous robots to complete a given task robustly. The Partially Observable Markov Decision Processes (POMDP) is a principled framework that enable autonomous robots to make good decisions in the presence of various uncertainties. While POMDPs are notoriously difficult to solve exactly for all but the simplest problems, the past two decades have brought tremendous advances in developing approximately optimal online solvers, making them viable tools for realistic planning problems under partial observability. Despite this progress, large POMDPs with continuous action and observation spaces remain a fundamental challenge in online POMDP planning.
In this talk I will present methods and and techniques to make online POMDP solving more tractable for large POMDPS. In particular I will discuss how Monte-Carlo-Tree-Search (MCTS) – a popular algorithm in POMDP planning – can be combined with continuum-armed bandit techniques to handle POMDPs with continuous-action POMDPs more efficiently. To handle handle continuous observation spaces, I will present a lazy sampling method called LABECOP, which enables us to scale to POMDP problems with high-dimensional observation spaces more effectively compared to state-of-the-art methods.

Value of Model Complexity for Fisheries Management

Matthew Holden
The University of Queensland

Tully 2, 10:20 Tue 7 February

Both simple and complex models provide major benefits to society. They allow us to make more objective, less biased decisions, which often produce better outcomes than decisions based solely on human judgment. However, despite their benefits, both simple and complex models carry serious costs. On the one hand, simple models are often unable to predict unexpected perverse outcomes caused by human action. On the other hand, large, complex models can be challenging to implement, fit, and interpret. While they are capable of foreshadowing perverse outcomes, their predictions can be inaccurate due to both overfitting and sensitivity to small perturbations in parameter values, model structure, and initial conditions. So how complex should our models be? In this talk, I will walk through some examples and rant about the need to publish cost-benefit data on all aspects of the modelling process.

Stochastic Spatial Random Forest for Detecting Remotely Sensed Forest Cover Change Despite Missing Data

Jacinta Holloway-Brown
None

Tully 2, 17:20 Mon 6 February

Forest cover is an indicator of species habitat and biodiversity that can be monitored effectively using satellite images. The benefits of using satellite images for large scale forest monitoring are that they are freely available globally and frequently updated, which reduces the need for extensive field data collection. Field data collection to monitor forest change can be prohibitively costly in many places around the world. A challenge of working with these images is missing data due to clouds, particularly in tropical regions where forest monitoring is essential. Existing methods for interpolating missing data based on only past observations, such as compositing, are effective for stable land cover but inaccurate for dynamic and substantially changing landscapes. In this talk I present joint work with Dr Kate Helmstedt and Distinguished Professor Kerrie Mengersen: our new machine learning method Spatial Stochastic Random Forest (SS-RF). Our method accurately interpolates missing forest and land cover under simulated forest clearing scenarios by taking spatial relationships in the landscape and past and current data into account to produce probabilities of land cover classifications. This is necessary because monitoring changing landscapes and modelling missing data are highly uncertain problems.
We found our SS-RF method detected different land clearing scenarios accurately, and importantly offers more accurate and robust estimates with associated uncertainty measurements not possible with traditional compositing approaches. This method has promise for use for other remotely sensed environmental monitoring cases, and has been presented to a UN expert group as a potential method to inform adaptive ground truth sampling plans.

How Partial Differential Equations and MRIs Can Improve Prognosis for Multiple Sclerosis Patients

Adrianne Jenner
Queensland University of Technology

Ballroom, 10:20 Mon 6 February

Multiple sclerosis (MS) is a life-long disease arising from the immune system mistakenly attacking the protective insulation of nerve cells causing irreversible damage in the brain and impairment in physical and mental activity. This damage results in lesions (scarring) in the brain which are visible on MRIs. Currently, these MRIs are only used for diagnosis and little-to-no information about patient disease prognosis can be extracted from an MRI. Fortunately, mathematical modelling lends itself to be able to capture this disease. We developed a system of partial differential equations (PDEs) capturing the immunology of MS and validated this model against experimental data, solving it using a Finite Volume Method (FVM) discretisation. Using our system of PDEs, we predicted the expansion of lesions from 10 patient MRIs. From this, we hope to provide information to patients about their disease course and in the future help to aid clinicians in improving prognosis and treatment for MS and other MRI based diseases.

Adaptation in Ecosystems: Lessons from Cellular Signalling Networks

Cailan Jeynes-Smith
Queensland University of Technology

Tully 2, 12:40 Tue 7 February

In cellular signalling networks, adaptation is the ability for a protein to consistently return to the same abundance following some perturbation, and can be observed unanimously across many forms of life. Several pivotal studies use a mathematical idealisation of this behaviour, robust perfect adaptation, to identify the core mechanisms which enable this behaviour in any sized network. In my work, I ask the question if this behaviour could also be observed in an ecological context, which would have huge consequences in agriculture, conservation, and ecosystem management. By using mathematical methods from algebraic geometry, developed for studying cellular systems, I analytically determine the capability of ecological networks to have the robust perfect adaptation property. I found the conditions required for robust perfect adaptation in ecological networks are significantly more constraining on ecological applications than in cellular systems.

Analytic Solutions for Diffusive Processes on Multiple Growing Domains

Stuart Johnston
The University of Melbourne

Ballroom, 15:00 Wed 8 February

The behaviour of cells that reside on a growing domain is of key interest in developmental biology. For certain developmental processes, such as the colonisation of the enteric nervous system during embryogenesis, there are distinct regions of the domain that exhibit different growth rates. A critical biological question is whether the cells reach the far end of the growing domain. The cell migration process can be described by an advection-diffusion equation on multiple growing domains. The advective component represents cell motion due to domain growth while the diffusive component represents random cell motion. Here we derive analytic solutions to this problem, which allows us to explicitly calculate relevant metrics such as the time-varying splitting probabilities and the survival probability.

The Establishment of Japanese Encephalitis Virus in Australia

Daniel Longmuir, Stephen Davis, Peter Durr, Simon Johnstone-Robertson
RMIT University

Tully 3, 11:40 Mon 6 February

Japanese encephalitis virus (JEV) is the cause of a zoonotic vector-borne disease (JE) and is transmitted when mosquitoes bite reservoir vertebrate hosts, including pigs and ardeid birds (e.g. herons). Whilst occasionally detected over the last two decades in far northern Queensland, infections and illness in humans and domestic pigs have only been documented in southeastern Australia (QLD, NSW, SA, and VIC) for the first time in 2022. This extensive spatial spread of JEV is thought to be the result of higher-than-normal mosquito densities resulting from unseasonably wet conditions. However, there are complex host and geographic factors to consider, especially that whereas domestic pigs kept at high densities were the primary host in the southern outbreaks, in the north it is likely that feral pigs—which occur at lower densities—were the amplifying host. The contribution of nomadic waterbirds to the emergence of JEV is unclear and may also vary by region. In this talk a next generation matrix model for the establishment and spread of JEV in Australia will be presented for estimating the basic reproduction number, R_0, a threshold quantity describing whether a disease can become established in a new population and/or geographic region ($R_0 > 1$). The relationship between R_0 and key biological factors such as mosquito density will be described. The results of a sensitivity and loop analysis will identify the parameters and transmission pathways (bird, domestic or feral pig) respectively that are key to understanding the spatial spread of JEV in Australia. The presentation will conclude by discussing the potential for extending the model to produce a time- and spatially-dependent R_0 that incorporates seasonal and environmental factors.

Model-Based Offline Reinforcement Learning for Sustainable Fishery Management

Jun Ju
The University of Queensland

Tully 2, 10:00 Tue 7 February

Fisheries, as indispensable natural resources for human, need to be managed with both short-term economical benefits and long-term sustainability in consideration. This has remained a challenge, because the population and catch dynamics of the fisheries are complex and noisy, while the data available is often scarce and only provides partial information on the dynamics. To address these challenges, we formulate the population and catch dynamics as a Partially Observable Markov Decision Process (POMDP), and propose a model-based offline reinforcement learning approach to learn an optimal management policy. Our approach allows learning fishery management policies from possibly incomplete fishery data generated by a stochastic fishery system, with the learned fishery dynamics model providing explainability for the resulting policy. The reuslts show that when the effort levels are sufficiently variable, our method can produce competitive policies, even for the hardest case of noisy incomplete data and a misspecified model. Additionally, the learned policies seem to be robust in the presence of model learning errors.

Modelling Rainfall Induced Landslides with Smoothed Particle Hydrodynamics

Laura Karantgis
La Trobe University

Tully 3, 12:00 Wed 8 February

Landslide events have a devastating impact on communities and industries. Modelling these complex systems is valuable for predictive and preventative measures to reduce the impact of these events. Landslides are often caused by heavy rainfall, hence, changes in soil water content are important to consider when modelling slope stability, as it alters the soil strength. We can consider a rainfall induced landslide model in two main parts. Firstly, the rainfall, or infiltration phase. This phase has a long timescale, often occurring over hours or days. Then we have the failure phase of the landslide that occurs over a much shorter time, occurring over a few minutes or even seconds. We have constructed an approach to modelling both, the infiltration phase and failure phase with the computational method Smoothed Particle Hydrodynamics. We will model the infiltration phase using Darcy's law and the Richards equation. And model the failure phase using a Drücker-Prager model, where soil properties such as cohesion, friction angle, pore water pressure, and density are defined as a function of the water content calculated from the infiltration phase. We will compare our results with analytical solutions and experimental data to validate the accuracy of our methods.

Extreme Precipitation Events in the East Coast of Australia

Ruethaichanok Kardkasem
The University of Queensland

Tully 2, 12:00 Mon 6 February

Climate change has influenced more precipitation extremes that cause many devastating events. This study presents generalized Pareto distribution (GPD) to fit the daily precipitation extremes of data observed in stations on the east coast of Australia from 1995 to 2022. We use nonstationary modeling to control for extreme precipitation dependency on El NiñoSouthern Oscillation (ENSO) and investigate clusters of extreme by estimating the extremal index. The results reveal low extremal index values in the northern and along the coastal areas, showing consecutive extremes of precipitation highly occur.

Two-Echelon Location Routing Problem with Delivery Options Under a Stochastic Environment

Amin Karimi
None

Tully 1, 15:00 Mon 6 February

Distribution systems are currently facing an increasing number of challenges in delivering and distributing products in crowded urban areas because of urbanisation and growing e-commerce. To address these challenges, decision-makers can use an optimisation model. This research investigates a two-echelon location routing problem with multiple delivery options, sustainability issues, and uncertainty in parameters. As part of this model, we consider multiple delivery options, including home delivery using drones or vans, and click-and-collect from local shops or parcel lockers, to increase customer satisfaction. Additionally, the model analyses the impact of keeping inventory in stores on customer satisfaction and the cost of logistics. Stochastic models will be developed to cope with the uncertain nature of parameters.

Self-Similarity and Fractalisation in Interfacial Hydrodynamics

Steven Kedda
None

Tully 3, 10:20 Tue 7 February

Thin film equations are classes of nonlinear partial differential equations, which are applied in industrial and scientific modelling to describe the dynamics of viscous liquid flow on solid surfaces. Our work investigates the self-similar dewetting behaviour of thin film models, particularly for the case of Marangoni-driven rupture, where iterated patterns form and create an intriguing hierarchical structure. This phenomenon leads us to search for an unstable periodic orbit in a rescaled similarity space. This talk will discuss a series of challenges in modelling the interplay of these highly nonlinear effects and include numerical results of thin film evolution in the original coordinate system and rescaled similarity space. An extension of considering non-Newtonian thin film flow will be explored, with some preliminary numerical results of thin film evolution for different values of the non-Newtonian parameter.

Which Lockdowns Are the Best Lockdowns?

Pratyush Kumar Kollepara
La Trobe University

Tully 3, 10:40 Mon 6 February

Interventions to mitigate the spread of infectious disease epidemics, while succeeding in their goal, have economic and social costs associated with them. This limits the duration and intensity of the interventions. We study a strategy of weak but long-duration interventions which minimise the number of infections by eliminating the overshoot part of an epidemic, and prevent a second-wave of infections after the intervention is removed. We numerically show that it is an optimal strategy and find the optimal strength of the intervention analytically. Due to the non-linearities in the dynamics of infectious disease spread, the optimal intervention can possibly require increasing the transmission in certain groups of the population, leading to an ethical dilemma. Finally, we take cues from coarse-graining concepts to explore the limitations of our strategy, in relation with the information one has about the population structure.

Mathematical Modelling and Approximation for Optimizing Intervention Strategies for Malaria Elimination

Maame Akua Korsah, Jennifer Flegg, Stuart Johnston, Camellia Walker, Kathryn Tiedje
The University of Melbourne

Tully 3, 12:20 Mon 6 February

Malaria remains a major health problem in endemic areas since its emergence. There have been several intervention programs like the Indoor Residual Spraying (IRS), Insecticide Treated Nets (ITNs), and Seasonal Malaria Chemoprevention (SMC) with antimalarials created and employed to control and perhaps even eradicate malaria. Yet current global statistics suggest there is not a steady decline in malaria infection and mortality cases even amidst these interventions. There is an urgent need to understand the current transmission dynamics of malaria in response to interventions. This is underscored by the established initiative of the WHO and the Lancet Commission to eradicate malaria from the world by 2050. The required level of intervention programs to make this possible however, is unknown. We seek to develop a fit-for-purpose model to optimize the levels of intervention needed to eliminate malaria in a geographic setting. The model analyses the impact of preventive practices on the spread of malaria parasites by incorporating human behavior in modelling the disease prevalence which is dependent on contact between the host and vector populations. We examine the model's equilibrium state and identify conditions that result in the global asymptomatic stability of the system. A sensitivity analysis of the model is performed to determine the relative significance of model parameters to initial disease transmission. We also explore how existing variations in the recruitment and management of intervention strategies affect malaria transmission. Our results imply that the mismanagement of existing interventions has a significant effect on malaria prevalence.

Slow Migration of Brine Inclusions in First-Year Sea Ice

Noa Kraitzman
Macquarie University

Tully 2, 15:00 Wed 8 February

We derive a thermodynamically consistent model for the formation and evolution of brine inclusions in sea ice. Taking the salt entropy relative to the liquid water molar fraction provides a transparent mechanism for salt rejection under ice formation. We identify slow varying coordinates, including salt density relative to liquid water molarity weighted by latent heat, and use multiscale analysis to derive a quasi-equilibrium Stefan-type problem via a sharp interface scaling. The singular limit is under-determined and the leading order system is closed by imposing local conservation of salt under interface perturbation. The quasi-steady system determines interface motion as balance of curvature, temperature gradient, and salt density. We resolve this numerically for axisymmetric surfaces and show that the thermal gradients typical of arctic sea ice can have a decisive impact on the mode of pinch-off of cylindrical brine inclusions and on the size distribution of the resultant spherical shapes. The density and distribution of inclusion sizes is a key component of sea ice albedo which factors into global climate models.

The Structure of Accumulating Global Bifurcations of Two Coupled Phase-Amplitude Oscillators

Bernd Krauskopf
University of Auckland

Tully 3, 10:20 Wed 8 February

We consider a four-dimensional vector field that arises as the semiclassical approximation of two coupled, driven and lossy photonic crystal nanocavities — optical devices that operate with only a few hundred photons. Mathematically, this system describes the dynamics of two coupled phase-amplitude oscillators that are driven with strength f and frequency detuning δ. We employ advanced tools from bifurcation theory, in combination with the computation of kneading invariants and of maximum Lyapunov exponents, to determine the bifurcation diagram in the plane of (f, δ)-plane. Its complicated structure of accumulating global bifurcations is organised by a number of codimension-two bifurcations, including a homoclinic flip, a Bykov T-point and new types of degenerate singular heteroclinic cycles. In particular, we identify in this way regions with different types of chaotic switching between the two oscillators.
This is joint work with Andrus Giraldo (KIAS) and Neil Broderick (Auckland)

A Geometric Analysis of Biochemical Reaction Networks

Timothy Earl Figueroa Lapuz
The University of Sydney

Tully 2, 15:20 Mon 6 February

Biochemical reaction networks (BRNs) describing, for example, enzyme kinetics or ligand-receptor kinetics, often consist of processes evolving on multiple timescales. From an application point-of-view, transient fast dynamics can be often ignored if the main dynamics evolve on slow(er) time scales. In such cases, a primary goal is to find model reductions that approximate the long-term behaviour of a given BRN. This makes high-dimensional problems more amenable for mathematical analysis. Our focus is on using the tools from geometric singular perturbation theory (GSPT), which provide rigorous geometric methods for model reductions.
In this talk, we focus on a mathematical algorithm one can follow to achieve the previously mentioned goal. This process begins with some preliminary steps, including identifying suitable small parameters in BRN models resulting in singular perturbation problems. Here, GSPT tools can be employed for the model reductions. We will demonstrate this algorithm for the Michaelis-Menten model, highlighting that the same steps work for many different singular perturbation cases with different combinations of small parameters. We then demonstrate the algorithm for a larger BRN: the Goldbeter-Koshland model describing ultrasensitivity, highlighting the general applicability of our algorithm.

The Relationship Between Grandmother Care and the Origin of Menopause

Anthia Le
The University of Queensland

Ballroom, 12:40 Mon 6 February

Previously, we proposed a system of ordinary differential equations (ODE), analogous to Morton et al.'s agent-based model, to investigate the evolution of menopause in women. Their work was based on the hypothesis that ancestral male's preference to forgo mating with older females was the driving force behind the evolution of menopause. However, our results contradict that of Morton et al. in that a slight deviation from mating with only young females is sufficient to maintain lifelong fertility as the dominant trait in a population. Here we propose that the Grandmother Hypothesis is the more likely cause for old-age infertility in females. As environmental changes caused root vegetables to become the primary food source rather than soft berries, it encouraged postmenopausal females to aid in caring for dependants. This ensures the survival of their kin hence, over time, the old-age infertility trait accumulates across the population.
Our system of ordinary differential equations (ODE) examines whether the Grandmother Hypothesis is the drive behind the evolution of menopause and investigates whether a population with a chimp-like lifespan and a human-like lifespan can co-exist, connecting to real world results where great apes and humans have co-existed.

Modelling the Impact of Hybrid Immunity on Future COVID-19 Epidemic Waves

Thao P. Le, Isobel Abell, Eamon Conway, Patricia T. Campbell, Alexandra B. Hogan, Michael J. Lydeamore, Jodie McVernon, Ivo Mueller, Camelia R. Walker, and Christopher M. Baker
The University of Melbourne

Tully 3, 09:40 Tue 7 February

Since the emergence of SARS-CoV-2 (COVID-19), there have been multiple waves of infection and multiple rounds of vaccination rollouts. This has led to complex immune landscapes with individuals and populations having "hybrid immunity", i.e. with immune protection from a mixture of prior infection and vaccination. We explore how different configurations of hybrid immunity affect the size and severity of near-future Omicron waves. To investigate the role of hybrid immunity, we use an agent-based model with waning immunity to simulate outbreaks in populations with varied past attack rates and past vaccine coverages. The simulated populations have demographics and past histories based on the World Health Organization (WHO) Western Pacific Region (WPR). We find that if the past infection rate is high, but vaccination levels are low, then the secondary outbreak with the same variant can occur within a few months after the first outbreak. In contrast, high vaccination levels can suppress near-term outbreaks and delay the second wave. Meanwhile, hybrid immunity has limited impact against immune-escape variants. This work can aid the anticipation of future epidemic activity due to current and emergent variants, including the likely impact of responsive vaccine interventions.

Predicting Risk of Pregnancy Complications: a Statistical Model

Shalem Leemaqz, Gus Dekker, Claire Roberts
Flinders University

Tully 1, 11:40 Wed 8 February

Regression models are widely popular in clinical studies. However, direct applications of these models sometimes do not achieve an acceptable level of prediction performance required at a clinical level. This is the case for modelling pregnancy complication risks. We therefore propose a hierarchical or tiered approach for regression that can vastly improve the prediction accuracy of these models. In Australia, 25% of first pregnancies are affected by Preeclampsia (PE), preterm birth (PTB), intrauterine growth restriction (IUGR) and/or gestational diabetes mellitus (GDM), with mothers and babies at risk of short-term or long-term morbidity and even death. Early identification of individuals at risk is crucial in providing intervention strategies to reduce the severity of adverse outcomes. However, the modelling of these risks is challenging due to the large number of variables (or potential risk factors) involved and the complex relationships between these factors. Traditional (single-tiered) regression models typically fail to achieve a reasonable balance between predictive accuracy (i.e. sensitivity and specificity) and predictive values (PPV and NPV). We developed a tiered prediction strategy using penalised regression to estimate the probability of each of the three pregnancy complications – PE, PTB, and GDM. Each model comprises two tiers, the first tier provides classification into two groups (low-risk and at-risk), while the second tier targets the at-risk group to provide further classification into moderate and high-risk groups. Our model is applied to the Screening for Pregnancy Endpoints (SCOPE) data and validated on the Screening Tests to identify poor Outcomes in Pregnancy (STOP) data. The proposed model performs favourably compared to existing methods, achieving remarkedly higher sensitivity for tier 1, while retaining a clinically acceptable PPV for tier 2.

Phenotyping Cell Populations in Cytometry Data Using a Statistical Model

Sharon Lee
The University of Queensland

Tully 1, 12:00 Wed 8 February

Cytometry is a powerful technology for measuring physical and molecular characteristics of single cells, allowing comprehensive studies on complex biological systems. In both research and clinical settings, a major focus is to understand cellular heterogeneity and to identify biomarkers of diseases. Conventional analysis involves manual identification (or 'gating') of cell populations, a process that is highly inefficient and error prone. We present an automated approach to identity and characterize cell populations in cytometry data based on a statistical model. Furthermore, our approach can build a parametric template to describe each disease group of interest, facilitating the phenotyping of cell populations to discriminate between the disease groups.

Multi-Pass Bayesian Estimation: a Robust Bayesian Method

Yeming Lei
The University of Queensland

Tully 1, 11:20 Mon 6 February

The prior plays a central role in Bayesian inference, but specifying a prior is often difficult, and a prior considered appropriate by a modeller may be significantly biased. To address this, we propose multi-pass Bayesian estimation (MBE), a robust Bayesian method capable of adjusting the prior's influence on the inference result based on the prior's quality. MBE adjusts the relative importance of the prior and the data by iteratively performing approximate Bayesian updates on the given data, with the number of updates determined using a cross-validation method. Our method provides robust inference results as compared to standard Bayesian inference and maximum likelihood estimations on several simulated and real-world datasets.

Little Red Flying Foxes Under the Hood: Using Metapopulation Models to Investigate Population Dynamics

Daniel Longmuir, Roslyn Hickson, and Andrew Hoskins
CSIRO

Tully 2, 10:20 Wed 8 February

The Little Red Flying Fox (*Pteropus scapulatus*) is native to large coastal areas of northern and eastern Australia. A primary food source for this species is the nectar from *Eucalyptus* and *Corymbia* blossoms. There is only partial understanding of their roosting locations (known as "camps") and movement, being semi-nomadic in nature to move between flowering events and camps. This creates a complexity in modelling the Little Red Flying Fox population. However, through satellite imaging data giving monthly estimates of blossom availability, we can begin to understand how the bats move with these events. To investigate the population dynamics, we use a metapopulation model, coupling the spatial data of average monthly nectar availability through a radiation model for movement between camps. We couple the $\approx 1 \times 1$km spatial nectar data using Voronoi diagrams based on known camp locations. We compare our modelled population based on caloric needs with historic camp survey data of population estimates.
This metapopulation model based on nectar availability will form the basis of further work exploring infectious diseases risks, such as Hendra and/or Leptospirosis. Our model can be extended to consider other resource availability, such as fresh water, vegetation coverage, and other environmental factors (temperature, humidity, aridity, etc.).

Two-Dimensional Ferric Ion Diffusion in an Analyte Solution with a MOF Crystal Sink

Kirsten Louw
University of South Australia

Tully 1, 10:00 Tue 7 February

Knowing the concentration of ferric ions during chemical leaching processes leads to making decisions that can optimise copper extraction. This project studies a new purpose-built sensor that will measure ferric ion concentrations. This sensor contains a thin film of polymer imbedded with metal-organic framework (MOF) crystals. Using numerical methods, we study how the ferric ions diffuse through the chemical solution and the polymer to associate with the MOF crystals. Using this knowledge, we can provide advice about what sensor properties could be altered to reduce the amount of time the sensor should be exposed to the solution.

A New Construction Explains Particle Filter Degeneracy

John MacLean
The University of Adelaide

Tully 1, 12:40 Wed 8 February

An interesting problem, often encountered, is that of *sequential filtering.* In this problem one must somehow fuse noisy, incomplete data together with forecasts from a predictive model in order to track the movement of some object and/or set of parameters over time.
I will open the talk by giving a mathematics-free introduction to Particle Filters and Gaussian Mixture Filters, explaining their theoretical relevance in sequential filtering. The main part of the talk will derive a novel theoretical result for the performance of these filters in any dimension. Together, we will study the transformation of uncertainty from a dynamical concept to a statistical one, and discover a new type of Particle Filter degeneracy.
Given time, I will conclude by explaining how this result suggests the development of some new filters—after all, "there's nothing as practical as a good theory."

Staff Shift Scheduling for a Blood Donor Centre

Achini Wellalage
The University of Melbourne

Tully 1, 15:20 Mon 6 February

Australian Red Cross Lifeblood collects blood from non-remunerated voluntary donors. Thus, it is important to encourage donors to return to donate frequently by offering a satisfying service. Donor experience is adversely influenced by prolonged waiting times, but they may be reduced by determining the non-stationary staffing demand over the day. In addition, an optimal staff shift schedule, that fulfills labour standards, may improve staff satisfaction and also reduce staff non-utilised time. Hence, our objective is to implement a two-phase method that determines the optimal shift schedule for a typical day based on the predicted staffing demand. First, we establish minimum staffing requirements to ensure that the system's predicted average waiting time does not exceed a certain limit. In the second phase, we find the optimal staff shift schedule that meets the minimum staffing requirements. In this talk, an integer linear programming model to determine the optimal staff shift schedule in the second phase will be presented. The optimal shift schedule minimises staff non-utilised time, satisfies the minimum staffing requirement determined by Phase 1, and maintains staff satisfaction by allocating breaks to shifts and fulfilling all labour standards.

Exponential Integrators for the Investigation of the Stability of Nonlinear Waves.

Kholod Mandoora
Monash University

Tully 2, 16:20 Mon 6 February

In order to numerically investigate the stability of nonlinear internal waves, the pseudospectral method for spatial discretisation and fourth-order semi-implicit time integration are implemented for a range of equations with various initial conditions. Fourth-order semi-implicit integration, such as exponential time differencing, linearly implicit Runge–Kutta, and splitting methods, are used for time integration. Three different models of nonlinear internal waves are discussed: the Korteweg-de Vries equation, extended Korteweg-de Vries equation, and forced Korteweg-de Vries equation. We aim to develop an efficient variable step-size approach for the proposed numerical methods using the conservation of energy (Hamiltonian) to monitor the accuracy of these methods and to determine the optimal step-size. A comparison between fixed step-size and variable step-size approaches was carried out to investigate the robustness of these numerical methods. Our numerical experiments show that the variable step-size approach is more efficient than the fixed step-size approach and allows the user to specify the desired accuracy.

Bayesian Belief Network Modelling for the Great Barrier Reef

Brianna Martin, Tania Kenyon, David Callaghan, Tom Baldock, and Peter Mumby
The University of Queensland

Tully 3, 11:40 Thu 9 February

Corals on the Great Barrier Reef can be damaged or killed by disturbances including cyclones, coral bleaching and outbreaks of coral-eating starfish. When corals die or degrade coral rubble is formed, which is a natural cycle on coral reefs. Typically coral rubble settles and new corals are subsequently recruited to restore local reef health. In some locations coral rubble movement persists and rubble stabilisation is required to promote reef recovery and new coral growth. These coral rubble dynamics comprise complex interactions across multiple scales in space and time and are not yet well understood.

A framework for spatial Bayesian network modelling is in development to characterise probabilistic dependencies between coral rubble outcomes and variables that affect rubble generation and rubble movement, within the local climate and the hydrodynamic and biological environment. Here, for any given location on the Great Barrier Reef, at any given time following a disturbance, the Bayesian model will provide estimates for the likelihood that rubble will naturally consolidate, and estimates for the associated time frame required for natural consolidation. In the event that rubble is not likely to consolidate, the Bayesian model will provide estimates for the likelihood of success for a number of standard rubble stabilisation intervention methods. The Bayesian model will be trained with empirical and modelling data contributions from a large multidisciplinary team supported within the Rubble Stabilisation subprogram of the longterm nationwide Reef Restoration and Adaptation Program.

Dynamics of Hydrodynamically Unstable Premixed Flames in a Gravitational Field

Kaname Matsue
Kyushu University

Tully 3, 12:40 Wed 8 February

Dynamics of hydrodynamically unstable premixed flames are studied. Our main focus is the effect of gravity on flame dynamics. In addition to well-known Darrieus-Landau instability in premixed flame dynamics, Rayleigh-Taylor effect is included to determine the asymptotic flame morphology. We study a variant of nonlinear Michelson–Sivashinsky (MS) equation describing time evolution of flame fronts under the small gas expansion assumption and apply the bifurcation theory to extracting a global picture of physically (and nonlinearly) stable flame morphology in various properties of combustible mixture and gravitational environment. This talk is based on the work collaborated with Prof. Moshe Matalon (University of Illinois at Urbana-Champaign).

Infectious Disease Dynamics

James McCaw
The University of Melbourne

Ballroom, 12:00 Thu 9 February

Infectious disease dynamics is the study of how pathogens replicate within a host and of how they spread from host to host. The foundational mathematical descriptions of both of these processes are similar. In virus dynamics, the Target cell–Infectious cell–Virus (TIV) model describes the non-linear dynamics of viral infection, in which exponential growth of an invading pathogen is limited by the availability of the host's susceptible target cells. In epidemiology, the Susceptible–Infectious–Removed (SIR) model describes an invading pathogen, with the size of an epidemic wave limited by susceptible depletion. At both scales additional factors, such as the immune response or behavioural changes, drive changes in the dynamics of infection. Modelling at both these scales has driven biological and epidemiological discovery and supported clinical and public health research for numerous infectious diseases of global importance.
In this talk I will cover three broad topics: 1) how both the rigorous mathematical analysis of simple abstracted models and the computationally intensive study of highly complex more realistic models contribute to infectious disease dynamics research; 2) Bayesian statistical inference as an approach to model-based data analysis; 3) the use of mathematical models in policy development and decision-making.

Interpreting Burgers' Equation in the Complex Plane

Scott McCue, Daniel VandenHeuvel
Queensland University of Technology

Tully 2, 11:00 Wed 8 February

Burgers' equation $u_t+uu_x = \mu u_{xx}$ is a very well-studied parabolic pde which sets up a competition between nonlinear advection that tends to steepen the solution profile and linear diffusion that tends to smooth it out. A simpler version is the inviscid Burgers' equation, which is a first-order nonlinear pde that can be solved exactly by an undergraduate using the method of characteristics. For this version of Burgers' equation, there is no diffusion and so nonlinear advection drives the solution to continue to steepen until the derivative blows up somewhere in finite time. We shall revisit these models, but instead of restricting ourselves to the real line, we shall continue the solution out to the complex plane. In this way, we observe directly the culprit for the finite-time blow-up in the inviscid Burgers' equation, which is a branch point that moves towards the real axis and touches it at the blow-up time. In the viscous Burgers case, the singularity structure in the complex plane is much more complicated, but with some investigative tools we can track the motion of the singularities and show why blow-up does not occur.

Compensating Model Error Using Koopman Operator Theory

Sean McGowan, William Robertson, Sanjeeva Balasuriya
The University of Adelaide

Tully 2, 10:40 Mon 6 February

Modeling real spatiotemporal systems is a powerful tool in the analysis of physical processes such as in oceanography and meteorology, however, modeling alone cannot represent dynamics on all spatial and temporal scales due to a lack of knowledge. Data assimilation allows observations to be incorporated into models by optimally setting model parameters. The resulting model, despite being more accurate, will still neglect some fundamental dynamics of the observed system. Data-driven methods instead use only the observations and have shown great success in reconstructing and predicting spatiotemporal data, however, are not as interpretable as models derived from first principles (i.e., via conservation laws). Using a combination of domain knowledge models and data-driven techniques avoids these issues, by studying the dynamics of the discrepancy between the model and the true system, enabling interpretable and accurate forecasting. In this talk, the dynamics of the discrepancy between the true system and model will be analysed through the perspective of Koopman operator theory.

Reflections at the Interface

Mark McGuinness, Lata Paea, and Sione Paea
Victoria University of Wellington

Tully 2, 09:40 Thu 9 February

In this talk we will reflect upon water, air, bauxite, money, mathematical models, microwaves, and Maxwell's equations.

One alumina factory in Ireland uses nearly four million tonnes of bauxite each year, at \$50 per tonne (USD). The water component is typically 5–10% by weight, and accurate measurement of the water content is worth serious money to the alumina company and to the bauxite shipper. Inaccuracies of just ± 1 % are worth $\pm$ \$2 million p.a.

Microwaves have been used to probe bauxite ore on a conveyor belt and continuously measure the moisture content during offload from ship to factory. Since water is a strong polariser, it has significant effects on microwave transmission, so it seems like a good idea to try to detect water content by using a microwave analyser.

Discrepancies between microwave analyser results and laboratory measurements prompted the alumina company to bring their problem to a European Study Group with Industry in Limerick in 2017. This meant that we got our hands on some very useful data with some very puzzling features. We also got to play with linear second-order differential equations with constant coefficients.

Simple models fail to explain data behaviour, prompting us to cook up more sophisticated mathematical models that provide very good matches to data behaviour. We will see that warnings in the microwave literature have been ignored, and multiple internal reflections at interfaces in the path of the microwaves give interference effects that dominate signal strength, masking moisture effects.

Mindful of John C. Maxwell's quote that *Reflective thinking turns experience into insight*, we use our model to suggest some simple ways to improve microwave analyser accuracy.

Replicating Superspreader Dynamics with Simple Epidemic Models

Michael Meehan
James Cook University

Tully 1, 09:40 Thu 9 February

Infectious disease outbreaks often exhibit superspreader dynamics, where most infected individuals generate no, or few secondary cases; with only a small fraction of individuals responsible for a large proportion of transmission. Although capturing this heterogeneity is critical for estimating outbreak risk and the effectiveness of group-specific interventions, it is typically neglected in the most commonly used compartmental modelling framework. In this project we propose different classes of simple compartmental epidemic models, fit them to a number of real transmission datasets, and compare model performance with canonical superspreader models (i.e., Negative Binomial). We find that with even a small number of free parameters, properly constructed compartmental models can capably reproduce observed superspreader dynamics and, in many instances, outperform canonical models.

A Strategy for Constructing Tractable Epidemic Models of Malarial Superinfection

Somya Mehra, James McCaw, Jennifer Flegg, Peter Taylor
The University of Melbourne

Tully 3, 12:40 Mon 6 February

Superinfection — that is, the concurrent presentation of separately-acquired infections — is an important feature of several infectious diseases. A particularly pertinent example is malaria: a parasitic, mosquito-borne disease that poses a significant burden in the Global South. Population-level compartment models allowing for (unlimited) malarial superinfection may take the form of countably infinite systems of ordinary differential equations (ODEs), posing complications for simulation and analysis.

Here, we present, to the best of our knowledge, a novel strategy for deriving tractable systems of integrodifferential equations (IDEs) for epidemic models of malarial superinfection. Our approach is predicated on the analytic characterisation of within-host dynamics as a function of the intensity of mosquito-to-human transmission, referred to hereafter as the force of reinfection (FORI).

We illustrate our approach in the context of the classical model of superinfection for *Plasmodium falciparum* malaria, whereby the functional dependence of within-host superinfection dynamics on the FORI is modelled using an infinite server queue. By observing that the classical (deterministic) compartment model — comprising a countably infinite system of ODEs — encompasses the Kolmogorov forward differential equations for the infinite server queue, we recover a reduced IDE governing the FORI. As a function of the FORI satisfying this IDE, we can obtain quantities of epidemiological interest on the population-level using (analytic) results derived at the within-host level.

Our approach generalises to additional biological complexity, granted within-host analyticity is preserved. The imposition of a catastrophe process, for instance, yields a simple framework for modelling demography, in addition to drug treatment, as implemented previously in the literature. Extension to a network of infinite server queues allows for the concurrent characterisation of immunity under an intuitive shot-noise model. Relaxing the assumption of single arrivals to account for batch inoculation allows us to capture the accrual of the "hypnozoite reservoir" — a bank of dormant liver-stage parasites that can activate to yield repeated relapses of *Plasmodium vivax* malaria.

The resultant systems of IDEs are amenable to numerical solution, allowing us to explore the transient, population-level dynamics of superinfection without resorting to approximation. The derivation of bifurcation parameters governing the existence of non-trivial (endemic) equilibria enables the characterisation of threshold phenomena, while sensitivity analyses follow directly from identified stationary solutions.

An Advection-Diffusion-Reaction Model for Propagation of Signaling Molecules in Irregular Spatial Networks

Adel Mehrpooya, Vivien Challis, Pascal Buenzli
Queensland University of Technology

Ballroom, 10:40 Mon 6 February

The osteocyte network is a living network of cells embedded in bone tissue that plays a significant role in the mechanical regulation of bone. When osteocytes are stimulated mechanically, they emit signaling molecules propagating throughout the osteocyte network to the bone surface, where they induce new bone formation or bone resorption. These processes adapt the bone structure to mechanical loads, and they enable the detection and repair of micro-damage which modifies the bone structure. It remains poorly understood how osteocyte network properties such as the spatial density of osteocytes and the number of connections between them influence how and when bone formation or bone resorption occur. In this work, we study the propagation of signaling molecules reacting and diffusing in spatial networks. We use random walk models, and discrete, compartmental models on irregular 1D networks with near and far connections and jump probabilities that may be space dependent. The continuum limit of these models is an advection-diffusion-reaction equation where diffusivity and drift velocity explicitly depend on network structure such as node density and node connectivity. Numerical simulations of the discrete model, the stochastic model and the corresponding advection-diffusion-reaction equation match well when the number of nodes is large and when network properties are sufficiently regular. On more irregular networks with sharp changes or discontinuities in drift $u(x)$ and diffusion $D(x)$, the discrete model is a robust discretization method for the advection-diffusion-reaction equation. Our simulation results also indicate that connections with far nodes increase the noise in signaling. This increase occurs due to a concurrent increase in diffusivity.

Balanced Harvest in an Age-Structured Fishery Model

Manuela Mendiolar
The University of Queensland

Tully 2, 10:40 Tue 7 February

In Queensland, like in many other developed countries, sustainability targets for managed fisheries are usually expressed in terms of ratio rules such as maintaining a population size equal to 60% of carrying capacity. Despite the obvious appeal of such a simple quantitative target, it is clear that an unintended consequence may be a significant tilting of the proportions of biomass across different ages, from what they would have been under harvest free conditions. In this presentation, we focus on various notions of "Balanced Harvest" across age-cohorts of a single harvested species whose population can be well captured by an age-structured model. Fortunately, the generic age-structured model, widely used in Queensland, possesses some desirable mathematical properties. Despite being nonlinear, it can be shown to be asymptotically stable under weak conditions. This allows us to formulate a bi-objective optimization problem which captures the trade-offs between the desire to maximize sustainable yield and minimize a deviation function representing the degree to which the harvest is balanced. Since the latter function is non standard we consider several alternatives such as simple distance from the virgin biomass equilibrium, cross-entropy and an interior point barrier function.

Cell Invasion in Endometriosis

Claire Miller
The University of Auckland

Ballroom, 10:00 Thu 9 February

Endometriosis is a chronic gynaecological condition that is estimated to affect 1 in 9 people with a uterus. Cells similar to those that line the uterus (endometrial cells) grow outside the uterus, such as in the lining of the pelvis. Very little is understood about this disease and the conditions required for its onset. It is hypothesised that endometriosis originates from menstrual debris entering the pelvic region via the fallopian tubes, rather than being shed through the vagina as normal. The endometrial cells in this menstrual debris then breach the epithelial layer lining the pelvis or afflicted organ and form lesions that intrude into the lower layers of the tissue. Endometriosis is particularly difficult to study as menstruation (the shedding of the endometrium) does not occur naturally in non-primates, limiting the use of *in vivo* studies, and diagnosis usually occurs several years after lesion onset, limiting the availability of clinical data.

How the cells invade the epithelial layer is not known. This behaviour could be a result of dysfunctions of the immune system, the inflammatory system, the invading cells or invaded cells, or any combination of these. We are interested in using agent-based modelling to investigate hypotheses related to the onset of endometriosis lesions. In this presentation I explore how changes to different mechanistic aspects, such as adhesion and proliferation dynamics, affect the success of cell invasion.

The Impact of a Single Individual in an Epidemic

Joel Miller
La Trobe University

Tully 1, 11:20 Thu 9 February

Many policy responses to the COVID-19 pandemic involved behaviour restrictions. Often these have been associated with penalties/rewards to induce compliance. When
designing a policy, ethical considerations suggest that the penalties/rewards for an action should be proportional to the harm/benefit caused by that action.
In this talk, I will explore the expected impact on the final size of an epidemic of a single individual changing behaviour as well as the combined impact of a group.
Due to the convexity of the final size relation, the marginal benefit of an individual changing behaviour to prevent transmission is increased if others are also taking actions to prevent
transmission. This benefit is largest when the reproduction number is close to 1.

Properties of a Non-Classical Symmetry Solution to a Reaction Diffusion Equation with a Region of Negative Diffusivity

Thomas Miller
University of South Australia

Tully 2, 12:00 Wed 8 February

Reaction diffusion equations describe how the density or concentration of something varies in space and time and have many applications including chemical physics, population dynamics and biomedical processes. Usually the diffusion is positive which causes the concentration to disperse, but in practice there are some cases where we would prefer the concentration to aggregate. We can model aggregation by including a nonlinear diffusion term that is negative for some values of the concentration. While numerical solutions cannot be obtained without regularization, by using a non-classical symmetry we can construct an implicit multivalued solution that can be made single valued by inserting a shock. In this talk I will show some example solutions and discuss some of their properties (such as a Stefan-like boundary condition).

A Generalised Sigmoid Population Growth Model with Energy Dependence: Application to Quantify a Tipping Point for Antarctic Shallow Seabed Algae

Elise Mills, Graeme F. Clark, Matthew J. Simpson, Mark E. Baird, Matthew P. Adams
Queensland University of Technology

Tully 2, 10:00 Wed 8 February

Sigmoid growth models are widely used to study population dynamics. The size of a population at equilibrium commonly depends implicitly on the availability of resources, such as an energy or nutrient source. We introduce a simple generalised extension of sigmoid growth models that can explicitly account for this resource-dependence; models that belong to this extended family of models we call 'energy-dependent sigmoid growth models'. We show three examples of this family of models, of increasing mathematical complexity. The first model example is equivalent to a classic sigmoid growth model with an energy-dependent growth rate. The second model example is a simple extension of the first that permits a continuous relationship between steady state population size and energy availability. The third model retains the advantages of the second model, has less parameters but a more complex mathematical form, and is derived from geometric arguments for plant cover as a function of light availability, so is directly applicable to modelling plant growth. We calibrate and compare each model to observed data for algae cover (a measure of algae population) under sea-ice in the coastal waters of Antarctica. We show that these models can estimate key properties of a sea-ice melt controlled tipping point for the algae, including minimum light requirements (from all three models) and the rapid variation in steady state algae cover in the vicinity of the tipping point. Neither of these ecologically relevant quantities can be estimated by calibration of standard sigmoid growth models. We also found that the best model of the three we tested, according to formal model selection approaches, is the third model based on geometric arguments. The broader family of energy-dependent sigmoid growth models that we propose likely has usage in many population growth contexts where resources limit population size.

The Effect of Combination of Two Periodically Driving Force Due to Solar Radiation and Sea Surface Temperature in the Bloom Dynamics

Milton Mondal, Tonghua Zhang and Chidella Srinivasa Rao
Swinburne University of Technology

Tully 2, 12:20 Mon 6 February

Phytoplankton bloom received considerable attention for many decades. There are different types of model, different types of approaches have been used to study the dynamics of the model and explain the bloom phenomena. I have incorporated two periodically driving force in the growth rate term of the phytoplankton due to solar radiation and sea surface temperature (SST) effect in an existing ODE NPZ model. Temperature dependency of maximum growth rate has been modelled by well-known Q_{10} formulation : $\mu_{max} = \mu_0 * (Q_{10})^{T/10}$. All the stability conditions for all three equilibrium points has been expressed in terms of the new parameter ρ_2 (which appears due to the incorporation of periodically driving forces). Bloom phenomenon has been explained by saddle point bloom mechanism even when the co-existing equilibrium point doesn't exist for some value of ρ_2. Solar radiation and SST has been modelled by using sinusoidal function which are constructed by comparing with satellite data. Model simulated result describes the phytoplankton bloom in region 25-35° W, 40-45° N of North Atlantic with better timing than the results of an existing model. An approximately 14 days improvement has been observed in the bloom initiation date. Rate of change method (ROC) has been applied to predict when the bloom initiates.

Agent-Based and Continuum Models for Spatial Dynamics of Oncolytic Viruses' Infections

David Morselli
None

Ballroom, 11:00 Mon 6 February

The ability of viruses to infect cancer cells while sparing healthy tissues has been known for a long time. Despite increasing research on the subject in recent years, it has not been possible to sufficiently characterise the spatial spread of the infection in solid tumours and effective therapeutic protocols remain elusive. In order to investigate such dynamics, we present here a stochastic agent-based model describing infected and uninfected cells: uninfected cells undergo movement, proliferation and infection, while infected cells undergo movement and death. Since local cell pressure may influence reproduction and movement in crowded environments with a cell density close to the carrying capacity, we compare different expressions for the probabilities that these processes take place (i.e., unlimited growth vs. logistic growth and undirected random movement vs. pressure-driven movement). We formally derive the continuum limit of the models and carry out a systematic quantitative comparison between this system of PDEs and the individual-based model, both in one and two spatial dimensions. Furthermore, we study the one-dimensional travelling waves of the two populations, with the uninfected proliferative cells trying to escape from the infected cells.
Our simulations show a good agreement between agent-based simulations with a sufficently large cell number and the numerical and analytical results for the continuum model. Nevertheless, in some situations the stochasticity originates asymmetric or disperse patterns in the discrete model that cannot be described by the continuum model. Some of these situations allow us to qualitatively reproduce patterns observed in *in vitro* experiments: this suggests that stochastic events may play a central role in the use of oncolytic virotherapy.

Propagating Fronts for a Fisher-KPP-Type Moving Boundary Problem

Gene Nakauchi
Queensland University of Technology

Tully 2, 11:40 Wed 8 February

The Fisher-KPP equation is used regularly in mathematical biology, for example to model collective cell motion. Here we consider an alternative model that has the advantage of including a propagating front explicitly via a moving boundary. For a cell-spreading geometry (like in a barrier assay), solutions to the moving boundary problem approach travelling wave profiles for large time. We describe these time-dependent solutions numerically and travelling wave solutions exactly. For a hole-closing geometry (like in a scratch assay or sticker assay), the near-extinction limit is described by either a similarity solution or rather complicated asymptotics, depending on the value of the single dimensionless parameter in the model. Again, we show numerical and analytical results for this geometry. While this is a theoretical study, in the future this model could be calibrated to experimental data from real assays.

The Propensity Score for the Analysis of Observational Studies

Markus Neuhaeuser
Koblenz University of Applied Sciences

Tully 1, 12:20 Wed 8 February

In observational, non-randomized studies, groups usually differ in some baseline covariates. Propensity scores are increasingly being used in the statistical analysis to adjust for those between-group variation. There is great flexibility in how the propensity score can be appropriately used. One possible strategy is stratification, also called subclassification. We present examples, mainly from medical applications, and discuss the question how many strata are useful. Moreover, the flexibility might encourage p-value hacking, where several alternative uses of propensity scores are explored and the one yielding the lowest p-value is selectively reported. Although such an approach is scientifically not acceptable, it might occur and therefore we simulate the extent of type I error inflation.

Male-Biased Mating Sex Ratios and the Evolution of Human Pair Bonds

Matthew Cody Nitschke
The University of Sydney

Tully 2, 11:40 Thu 9 February

We present a mathematical model to simulate how stable male-female breeding bonds may have formed in humans. Compared to our closest living primate relatives, human life history involves a greater longevity, which includes a distinctive postmenopausal life stage. The extension of the human lifespan (and of the male fertility period) without lengthening female fertility to later ages, directly changes the ratio of fertile males to fertile females currently able to conceive, called the operational sex ratio (OSR). Our model is an agent-based model (ABM), in which males compete for paternities using either a multiple-mating or mate-guarding strategy. The model is formulated according to the Gillespie algorithm of determining the times to next events where individuals go through several distinct life stages: dependant, juvenile, fertile, and post-fertile. We will show preliminary results that suggest the OSR is a good indicator for predicting which strategy males will adopt.

Multiple Criteria Decision Making for Technology Value Index and Technology Commercial Index in Patent Selection

Syarifah Z Nordin, Hafizah Farhah Saipan Saipol, Zulhasni Abd Rahim, Amir Syafiq Syamin Syah Amir Hamzah and Naoki Ohshima
Universiti Teknologi Malaysia

Tully 1, 12:20 Tue 7 February

A patent is an intellectual property (IP) right granted for an invention. The patent can help to increase the technology and hence higher the economic value. Our focus is on the sustainability of the industrial revolution and the innovation strategic planning. Our objective is to find the most valuable patent that meet both technology value index (TVI) and technology commercial index (TCI). In order to rate the patent according to the index, a comparative performance of the five methods of multi-criteria decision making (MCDM) is investigated. We conduct a computational testing on Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS), Weighted Product Model (WPM), Analytical Hierarchy Process (AHP), Weighted Product Model (WPM) and Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) to analyze the comparison among the MCDM methods for priorities in selecting patent. We discuss on the similarities and the contrast of the ranking results for the patents.

A Framework for Regime Dependent Causal Graphs for Assessing Climate Risk

Terence O'Kane, Dylan Harries, Mark Collier, Jana de Wiljes
CSIRO

Tully 2, 17:00 Wed 8 February

Our current understanding of the future climate relies on general circulation models coupling the ocean, atmosphere, land and sea ice domains. Ideally, if these models can be shown to reasonably reproduce the observed climate modes of variability and the relationships between them, then systematic changes in their networks and graphical structure in response to anthropogenic changes in the boundary conditions (radiative forcing) would enable a deep understanding of the potential future climate risks for a given emissions scenario. Here, we describe a framework to combine Homogeneous dynamic Bayesian network models (DBNs) with regularized optimisation of a cost functional whose parameters are the regime dependent parents and link coefficients of direct acyclic graphs (DAGs) conditioned on a given regime. The DAGs are to be constructed from time series of the major modes of climate variability to determine probabilistic Granger causal graphical models. Reversible jump Markov Chain Monte Carlo is employed to provide a quantification of the uncertainty associated with the selection of a single network structure. The aim is to extend Bayesian inference via DBNs to nonstationary flow problems via embedding within an optimal regime learning process.

How Can We Choose Suitable Case Isolation Settings to Reduce Spread of Infectious Disease?

Dion O'Neale; Joel Trent; Emily Harvey
The University of Auckland

Tully 3, 16:00 Mon 6 February

Stay home if you're sick is classic public health advice for infectious diseases. When diseases are of particular concern, such as COVID-19, we even mandate this behaviour via public health orders. I will describe a piece of work that used stochastic simulations to quantify the effect of different possible case isolation scenarios, specific to COVID-19 in Aotearoa. This work quantified the competing issues of unnecessary hours spent in isolation (when isolation periods are too long) with hours spent in the community while still infectious (when isolation periods are too short). A key result was that almost any case isolation scenario can be improved by using rapid antigen tests and a test-to-release approach to make isolation policies either less burdensome and/or less risky. In short, we show that having more information about infectivity means it's possible to make better choices about isolation.

An Adaptive Numerical Method for Multicellular Simulations of Organ Development and Disease

James Mark Osborne
The University of Melbourne

Ballroom, 10:20 Thu 9 February

In recent years, there has been a significant advancement in both experimental and mathematical studies of tissue and organ development. With the increasing availability of powerful computational tools, mathematical models have become ever more sophisticated, leading to an increased use of multicellular approaches for understanding the self-organization of cells within tissues.
Traditionally, these models have relied on simple numerical methods such as Forward Euler with small time steps to avoid numerical instability. Here we propose a more efficient approach by introducing an adaptive numerical scheme that utilizes higher order Runge Kutta methods. This adaptivity can either increase the numerical accuracy of the simulation or maintain the same level of accuracy with greatly reduced computational time allowing more realistic simulations.

Heterodimensional Cycles as Organising Centres of Complicated Dynamics

Hinke Osinga
The University of Auckland

Tully 3, 09:40 Wed 8 February

A heterodimensional cycle consists of a pair of heteroclinic connections between two saddle periodic orbits with unstable manifolds of different dimensions. We study heterodimensional cycles in a four-dimensional vector field, where such cycles are characterised by a connecting orbit that lies in the intersection of two two-dimensional manifolds; the return connection is given by a family of connecting orbits in the structurally stable two-dimensional intersection of two three-dimensional manifolds. Heterodimensional cycles are known to organise highly complicated dynamics, which persist under C^1-perturbations of the vector field. We employ continuation techniques on a two-point boundary value problem set-up of Lin's method to compute heterodimensional cycles and associated nearby global bifurcations. We find that our four-dimensional vector field exhibits cycles of four different types that are distinguished by the orientability properties of the tangent bundles associated with the periodic orbits. In this talk, we present transitions from one cycle type to another and the effect such changes in orientability have geometrically. We explore how heterodimensional cycles contribute to the organisation of the overall bifurcation structure, which in turn, elucidates mechanisms behind the generation of C^1-robust chaotic dynamics.
This is joint work with Nelson Wong and Bernd Krauskopf (University of Auckland), and Andy Hammerlindl (Monash University)

Computational Modelling of Metabolism Within the Ageing Heart

Michael Pan, Giovanni Guglielmi, Peter Gawthrop, Sean Lal, Fabian Spill, Vijay Rajagopal
The University of Melbourne

Ballroom, 11:40 Thu 9 February

Age is one of the most significant risk factors for cardiovascular disease. Understanding the biochemical mechanisms underlying ageing, particularly in humans, may facilitate the discovery of new interventions to help us stay healthy as we grow older. To better understand the biochemistry of ageing, we developed a computational model of a key metabolic pathway (oxidative phosphorylation) within heart cells to compare the function of old hearts compared to young hearts. Our model development was informed by human omics data collected by the Sydney Heart Bank.
Modelling oxidative phosphorylation is challenging because it involves both biochemical and electrical components, and therefore requires a modelling approach that allows different physical domains to communicate. The bond graph approach can address these challenges by accounting for energy as the universal currency of all physical systems. In this talk, I will outline how bond graphs can be used to model oxidative phosphorylation.
Using our mathematical model of oxidative phosphorylation, we were able to study the functional implications of the biochemical adaptations observed in young and old hearts. Our results suggest that some of the changes to substrate availability may in fact be protective against heart failure in older hearts, which may compensate for other inefficiencies that arise as the heart ages.

Technology Development for Conservation Purposes as an Adaptive Management Problem

Luz Pascal
Queensland University of Technology

Tully 2, 09:40 Wed 8 February

Adaptive management is a common practice in conservation to manage systems under uncertainty. Here we formulate the selection, schedule and deployment of R&D for conservation as an adaptive management problem using hidden model Markov Decision Process (hmMDP). We applied our approach to a case study inspired from the management of the Great Barrier Reef.
Our case study shows that a hmMDP policy is more robust to uncertainty, and therefore in average produces better outcomes than naive policies, especially when the feasibility of technologies is unknown.
Our formulation provides a prototype of adaptive management framework for R&D for conservation purposes. We hope our formulation will promote the uptake of adaptive management and artificial intelligence planning tools in R&D.

Faster Model Selection, with Applications in Systems Biology

Jakob Vanhoefer[1], Antonia Körner[1], Domagoj Doresic[1], Vincent Wieland[1], Jan Hasenauer[1,2,3], Dilan Pathirana[1]
University of Bonn/MPI Bonn

Ballroom, 15:20 Wed 8 February

Model-based results depend on a reasonable choice of model components. When competing hypotheses about model components exist, model selection methods can be used to identify useful sets of hypotheses, hereby referred to as models. For example, models are selected as a balancing act between their parsimony and their ability to fit data, when using the Akaike (AIC), the corrected Akaike (AICc), or the Bayesian (BIC) information criterion to compare models. In this work, we consider a single superset model that combines all model components, such that the model space is generated by taking subsets of the components in the superset model.
A complete comparison would require testing every model in the model space, in a brute-force manner. This is generally infeasible because the model space grows exponentially with the number of hypotheses. Hence, heuristic methods are often employed, for example, stepwise methods like forward and backward selection. However, such methods cannot guarantee that the globally-best model is found.
We propose a branch-and-bound algorithm that exploits the balancing act to reduce the space of plausible models. We demonstrate this algorithm on model selection problems taken from the systems biology literature, and show a reduction in computation time by orders of magnitude, compared to the standard brute-force, while guaranteeing that the globally-best model is found.

The Reduction in Wave Energy in Ice Covered Oceans

Jordan Pitt, Luke Bennets
The University of Adelaide

Tully 2, 15:20 Wed 8 February

At the Earth's poles, temperatures are so low that the surface of the ocean freezes, forming a layer of floating sea ice. The floating sea ice cover is subject to incoming surface waves from the open ocean which propagate through it and determine its evolution. In turn the ice cover produces a reduction of the energy of the surface waves over distance, limiting the impact of surface waves deeper into the ice cover. The feedback between wave energy reduction and ice evolution is critical to the annual growth and retreat of the Earth's sea ice and thus the climate. Recent laboratory experiments investigated the reduction of wave energy through broken and unbroken ice covers. The experiments showed large reflection and slight attenuation of wave energy when the ice cover is unbroken and low reflection and larger attenuation of wave energy when the ice cover is broken. I present a mathematical model to explain these laboratory experiments, demonstrating the effect of broken ice covers on the reduction in wave energy, showing the homogenized limit as the size of the chunks of sea ice approaches zero.

Simulation-Based Inference and Communicating Uncertainty in Epidemiological Models

Michael Plank
University of Canterbury

Tully 3, 15:00 Wed 8 February

Mathematical models have been a key input into government decision making during the Covid-19 pandemic in countries around the world. Models come in a wide variety of types and used for a range of different purposes. However, they all make some assumptions about the epidemic dynamics and these assumptions create uncertainty in the results. Quantifying and effectively communicating the uncertainty associated with model outputs is essential to ensuring results are interpreted and acted on appropriately.
Often, model outputs are fitted to epidemiological data in real time by a parameter inference procedure. This procedure will typically yield an ensemble of model trajectories, which can be used to construct prediction intervals for key epidemiological observables such as daily cases or hospital occupancy.
In this presentation, I will talk about parameter inference in mechanistic epidemiological models. I will also talk about different approaches to quantifying and visualising the uncertainty associated with an ensemble of model outputs. This will include a comparison of approach of fixed-time descriptive statistics, which is one common approach, with using curve-based metrics. I will reflect on strengths and weaknesses of these when used for epidemiological modelling for policy advice in real time.

The Role of Cultural Innovation in the Emergence of New Diseases

Pantea Pooladvand (Presenting), Prof Mark Tanaka, A/Prof Jeremy Kendal
UNSW Sydney

Tully 3, 17:20 Wed 8 February

The emergence of new diseases is often triggered by a change in our microbial environment. This change is usually promoted by alterations in human behaviour, such as the adoption of new cultural practices or innovations. Deforestation for farming and settlement has given rise to Nipah and Ebola virus. The development of cooling towers for air-conditioning systems created a suitable environment for legionnaires disease. Changes in our behaviour modify microbial populations and create environments in which pathogens can arise. In this project we construct a model to investigate how a new cultural practice can trigger the emergence of a pathogen. We consider a scenario in which a new practice appears in a human population, and spreads through social learning. As a result, the population begins to interact closely with a microbe. Microbes can mutate to become pathogens through a stochastic process. We look for conditions that promote or dampen the emergence of the pathogen. Our model suggests that certain conditions lead to less predictable behaviour in the dynamics of the pathogen population. Lower mutation rates lead to larger variation in the emergence of the pathogen. The unpredictability in pathogen dynamics also occurs when the fitness benefit in adopting the cultural practice is high. Importantly, the model highlights the strong relationship between changes in human behaviour and the emergence of new diseases.

Nonlinear Periodic and Solitary Rolling Waves in Falling Two-Layer Viscous Liquid Films

Andrey Pototsky and Ivan S. Maksymov
Swinburne University of Technology

Tully 3, 11:20 Wed 8 February

We investigate nonlinear periodic and solitary two-dimensional rolling waves in a falling two-layer liquid film in the regime of non-zero Reynolds numbers. At any flow rate, a falling two-layer liquid film is known to be linearly unstable with respect to long-wave deformations of the liquid-air surface and liquid-liquid interface. Two different types of zero-amplitude neutrally stable waves propagate downstream without growing or shrinking: a zig-zag surface mode and a thinning varicose interface mode. Using a boundary-layer reduction of the Navier-Stokes equation, we investigate the onset, possible bifurcations and interactions of nonlinear periodic travelling waves. Periodic waves are obtained by continuation as stationary periodic solutions in the co-moving reference frame starting from small-amplitude neutrally stable waves. We find a variety of solitary waves that appear when a periodic solution approaches a homoclinic loop. Wave interactions are studied using direct numerical simulations of the boundary-layer model. We reveal that in the early stages of temporal evolution coarsening is dominated by an inelastic collision and merging of waves that travel at different speeds. Eventually, coarsening becomes arrested when the waves have reached the largest admissible amplitude. Bifurcation analysis confirms the existence of an upper bound of possible solitary wave amplitudes, thus explaining the arrest of coarsening. In the mixed regime, when both mode types are unstable, the temporal dynamics becomes highly irregular due to the competition between a faster-travelling zig-zag mode and a slower-travelling varicose mode. A quintessentially two-layer dynamical regime is found, which corresponds to a ruptured second layer. In this regime, the first layer adjacent to the solid wall acts as a conveyer belt, transporting isolated rolling droplets made of the second fluid downstream.

An EM Framework for Competing Risks via Multi-Absorbing Phase Type Distributions

Zhihao Qiao, Budhi Surya, Azam Asanjarani, Benoit Liquet and Yoni Nazarathy
The University of Queensland

Tully 1, 10:20 Mon 6 February

Phase-Type (PH) distributions are versatile semi-parametric models for life-time duration and can be used in survival analysis and reliability analysis. In this paper, we put forward methods for using PH distributions in the competing risk model. In this case, the distribution records both the time until absorption and the reason for absorption and is thus a bi-variate random variable with a continuous non-negative component and a discrete component. After formulating the basic properties of such PH variants, which we call multi-absorbing phase type ($\mathrm{MAPH}_{p,q}$), we adapt the EM algorithm for parameter inference and illustrate applications and numerical properties.

Finite-Time Dynamics, Hyperbolicity, and Regime Behaviour

Courtney Quinn, Terry O'Kane, Andrew Axelsen
University of Tasmania

Tully 2, 12:40 Wed 8 February

In many applications, particularly those of weather and climate, there is a greater interest in "local" behaviour as opposed to asymptotic. For instance, if a chaotic attractor has imbedded regimes, a transition between regimes could have drastic impacts on the tangible effects in the physical system. In order to understand such transitions, we consider various local dynamical measures such as finite-time Lyapunov exponents, alignment of covariant Lyapunov vectors, and dimension measures based on the former two. We explore these in a paradigm example of a chaotic attractor with regime behaviour and show how the finite-time measures connect to localisation along the attractor. Such measures are perhaps not only useful in regime transitions, as a recent study shows they may also indicate crises in systems of multiple chaotic attractors.

Introducing HARP - a New Metric to Describe Hysteresis

Melanie Roberts, Donghwan Kim, Jing Lu, David Hamilton
None

Tully 3, 11:20 Thu 9 February

Hysteresis occurs in ecological systems where internal dynamics produce variable responses to an external stimulus. For example, a high sediment load being flushed out of a stream during the rising limb of the storm (first flush effects). Understanding and quantifying hysteresis is important to inform understanding of system behaviour, support water quality modelling, and to provide comparisons between and within systems. This talk introduces a new way to describe and quantify hysteresis that is suitable for complex discharge-concentration curves and for use within summary statistics for comparison within and between systems. HARP is introduced in the context of water quality hysteresis, however the metric is general and can be applied to all systems.

Making Land Use Data Useable

Grace Robinson
Queensland University of Technology

Tully 1, 12:20 Mon 6 February

Earth's land is finite and with an ever growing population this scarcity needs to become more efficiently utilised to allow us to meet not only environmental sustainability goals but human development goals also. Data on land uses are reported based on artificial boundaries, at both national and subnational levels. Models of the impacts of land use changes are largely dependent on boundaries that differ greatly from those that this data is reported, namely unique climate and habitat areas. I have developed a method, using a linear program, that uses spatial fractional land cover data to map land use data spatially. This method was used to develop fractional 100m resolution land use maps globally for the year 2019. Highlighting an example of the need for these maps, I predicted expected species losses and due to the level of detail they contain I was able to then link these losses with specific crops.

A Nonsmooth Optimizer's Perspective of Splitting Methods

Claudia Sagastizábal
IMECC-Unicamp and CEMEAI, Brazil

Ballroom, 08:40 Thu 9 February

For large-scale optimization, popular approaches such as the ADMM and the Progressive Hedging algorithm exploit separable structures by solving in parallel individual sub-problems which are then coordinated by performing a simple algebraic step (typically, a projection onto a linear subspace).
While parallelism is the strength of all Douglas-Rachford-like splitting methods, their weak points are the adjustment of certain proximal parameter and the lack of a fully implementable stopping test. These difficulties, which date back to Spingarn's method of partial inverses, stem from the very design of these approaches, which were created to find zeroes of operators.
We discuss how to endow some splitting methods with an optimization perspective that introduces knowledge about the objective function throughout the iterative process. The resulting new family of methods à la bundle incorporates a projective step to coordinate parallel information while allowing the variation of the proximal parameters and the construction of a reliable stopping test. A Bundle Progressive Hedging algorithm, derived from the general theory, illustrates the interest of the proposal.
Credit to co-authors will be given during the talk.

Prevalence and Observability in Dynamical (and Nondynamical) Systems

Timothy Sauer
George Mason University

Ballroom, 09:00 Mon 6 February

The concept of prevalence, as a means of giving mathematical precision to informal instances of "almost every", has been useful over the last few decades in dynamical systems theory. We survey a number of prototypical applications, including more recent examples, some of them non-dynamical. In particular, connections to ecological models, dynamical networks and their observability will be discussed.

Parameter Estimation and Uncertainty Quantification Using Information Geometry

Jesse A. Sharp, Alexander P. Browning, Kevin Burrage, Matthew J. Simpson
Queensland University of Technology

Tully 1, 10:40 Mon 6 February

Information geometry is a branch of mathematics connecting aspects of information theory including probability theory and statistics with concepts and techniques in differential geometry. Central to information geometry is the concept of a statistical manifold; an abstract geometric representation of a distribution space, or a Riemannian manifold consisting of points that correspond to probability distributions. In this talk I will introduce and discuss the application of techniques from information geometry, including geodesic curves and Riemann scalar curvature, to supplement typical techniques for uncertainty quantification. These techniques provide data-independent insights into uncertainty and identifiability, and can be used to inform data collection decisions.

Distance Measures to Compare Stochastic Time Series Data and Stochastic Model Outputs

Brock Sherlock, Adelle Coster
University of New South Wales

Ballroom, 15:20 Mon 6 February

Many real-world dynamical systems are inherently stochastic. Data is often in the form of a series of repeated samples at discrete time points. Stochastic models can be used to describe these time evolving distributions, leading to the need for a comparison mechanism between the stochastic model outputs and the stochastic data.

To drive parameter inference, a distance measure between model and data is needed that has a directed decrease as parameter values approach their true values. The comparison needs to be made not only at each sample time, but also across the evolving system. In the case of small sample sizes, such as those found in biological experiments, some traditional comparators of distributions become ineffective. The Kolmogorov-Smirnov distance, for example, is highly sensitive to outliers and is highly bimodal, limiting its use for inference.

Here, a closed queuing network is used to model the recycling of proteins in a cellular system. Synthetic data was created using the model at set parameter values. Different measures of distance between the model outputs and the synthetic data were explored, focussing on those that do not assume specific functional forms for the underlying distributions. The implications of the measure choice for inference are discussed.

Computationally Efficient Framework for Diagnosing, Understanding, and Predicting Biphasic Population Growth

Matthew Simpson
Queensland University of Technology

Ballroom, 09:40 Wed 8 February

Throughout the life sciences, biological populations undergo multiple phases of growth, often referred to as biphasic growth for the commonly-encountered situation involving two phases. Biphasic population growth occurs over a massive range of spatial and temporal scales, ranging from microscopic growth of tumours over several days, to decades-long re-growth of corals in coral reefs that can extend for hundreds of kilometres. Different mathematical models and statistical methods are used to diagnose, understand, and predict biphasic growth. Common approaches can lead to inaccurate predictions of future growth that may result in inappropriate management and intervention strategies being implemented. Here we develop a very general computationally efficient framework, based on profile likelihood analysis, for diagnosing, understanding, and predicting biphasic population growth. The two key components of the framework are: (i) an efficient method to form approximate confidence intervals for the change point of the growth dynamics and model parameters; and, (ii) parameter-wise profile predictions that systematically reveal the influence of individual model parameters on predictions. To illustrate our framework we explore several real-world case studies including coral reef re-growth after a disturbance as well as tumour growth in the laboratory.

Data Assimilation for Networks of Coupled Oscillators

Lauren Smith and Georg Gottwald
The University of Auckland

Tully 1, 17:00 Wed 8 February

Many natural phenomena and engineering applications can be described as networks of coupled oscillators, for example, neurons in the brain and the dynamics of the power grid. Here we discuss the adaptation of data assimilation methods (commonly used for weather forecasting) to networks of coupled oscillators. In particular we show that data assimilation can be used to estimate unknown model parameters in the case where not all oscillators are observed. We also discuss the challenges of data assimilation, and data-based techniques generally, for parameter estimation in networks of coupled oscillators. For instance, convergence to a synchronised state leads to data degeneracy.

Optimal Control of Spreading Processes on Dynamic Networked Systems

Vera Somers
The University of Melbourne

Tully 1, 10:00 Wed 8 February

Misinformation, epidemics, and bushfires are all examples of significant real-world problems that can be interpreted and modeled as a spreading process on an underlying contact or geographic network. The temporal and large-scale nature of the networks these processes typically evolve on, however, pose an interesting challenge in formulating any straightforward optimal intervention methods to reliably control them and reduce their impact. In this talk, I will, therefore, present an optimisation framework to reduce and bound the risk of an outbreak of such spreading processes on temporal networks by use of sparse resource allocation. The presented framework utilizes convex optimisation, in particular exponential cone programming, and dynamic programming techniques to allocate budgeted resources each time step. In particular, I will discuss how the framework can be modified based on the application and underlying process and network structure.

Efficacy of Monoclonal Antibody Therapy for COVID-19

Eva Stadler, Khai Li Chai, Martin T Burgess, Timothy E Schlub, Deborah Cromer, Mark N Polizzotto, Stephen J Kent, Nicole Skoetz, Lise Estcourt, Zoe K McQuilten, Erica M Wood, David S Khoury, Miles P Davenport
UNSW Sydney

Tully 3, 15:00 Mon 6 February

Some patients cannot mount an immune response to COVID-19 protecting them from re-infection or severe disease. These patients may be treated with passive antibody therapies such as monoclonal antibodies (mAbs). However, it is not clear if a similar level of protection can be achieved by passive antibody treatment compared to vaccination. Moreover, mAbs which were developed to protect against earlier COVID-19 variants may have no or reduced efficacy against currently circulating variants.
In this work, we combined data from randomized controlled trials that assess the efficacy of passive antibody therapies to estimate the efficacy of mAbs at different doses for both prophylactic and therapeutic treatment. We used model fitting, model comparisons and generalized linear mixed models to find a dose-response curve, compare vaccination and mAb treatment efficacies and study the impact of treatment time on the efficacy. Using this dose-response relationship and *in vitro* data for the potency of different mAbs against COVID-19 variants also allows us to predict the efficacy of mAb treatment against variants.
We find that prophylactic mAb therapy can achieve similar levels of protection as vaccination. However, the efficacy of mAbs is greatly reduced against variants and we predict that none of the considered mAbs could give 30 days of 50% prophylactic protection against the Omicron BA.4 and 5 variants.

Conservation Planning in the Presence of Cumulative Disasters

Tace Stewart
Queensland University of Technology

Tully 2, 12:20 Tue 7 February

Coral cover of reefs has declined globally over the past 30 years. Some of the pressures on coral cover include cyclones, bleaching, and crown-of-thorns starfish. Planning conservation with these events in mind is necessary to ensure optimal species preservation continues during and after they occur.
Our research investigates the likelihood and impact of disturbances compounding in time or space, as they can result in disasters. The aims of this study are to analyse the history of compounding disturbances in the Great Barrier Reef, including its impact on coral and the expected recovery time given the combined disturbances. This study also proposes a marine protection plan that considers the impact of compounding disturbances, and increases coral resilience against such events.

Chemical Signalling and Tissue Response: a Moving Boundary Problem in Biology

Yvonne Stokes
The University of Adelaide

Ballroom, 11:40 Mon 6 February

Prior to fertilisation a mammalian oocyte (egg) is surrounded by cumulus cells. Upon fertilisation the cumulus tissue expands and the cells die; imaging during this process reveals a moving boundary problem. This behaviour is thought to be a response to a calcium signal which is, likely, amplified by the cumulus cells. I will discuss mathematical modelling, being done to investigate this hypothesis.

Modular Modelling of Hurricanes: the Role of Ocean Spray Polidispersity

Sergey A. Suslov and Yevgenii Rastigejev
Swinburne University of Technology

Tully 2, 11:40 Mon 6 February

Tropical cyclones and hurricanes with wind speeds exceeding 250 km/h cause enormous damage worldwide that on average costs around $19 billion per event (around 7 events per year). Yet their studies and forecast are severely hindered by several objective factors including the danger of field observation, wide diversity of the acting physical mechanisms and a huge range of spatial scales covering 9 orders of magnitude. In this talk I will discuss the modular modelling approach based on a rigorous (asymptotic and numerical) solution of physical conservation equations describing individual physical effects. Specifically, I will focus on the influence of polydisperse sea spray in the global sea-air momentum exchange in strong-wind conditions of a hurricane.

Rare-Event Simulation Techniques for Structured Fisheries Models

Hermanus M. Jansen, Michel Mandjes, Thomas Taimre
The University of Queensland

Tully 2, 09:40 Tue 7 February

One of the main goals in fisheries management is to prevent the collapse of fish stocks. A key consideration therefore is the impact of different harvest strategies and environmental noise on the likelihood of future stock collapse, or quasi-extinction. Motivated by this problem, we consider several rare-event simulation techniques to increase the speed and accuracy of projections of stock collapse. We consider both a one-dimensional structured fisheries model and a multidimensional age-structured fisheries model in applying our techniques. We observe that the way in which catch is modelled has a substantial impact on the likelihood of quasi-extinction. We reach the overall conclusion that the use of rare-event simulation techniques for structured fisheries models is worthwhile when the probability of quasi-extinction is on the order of 10^{-2} or smaller.

Inverse Problems for First-Order Hyperbolic Equations

Hiroshi Takase
Kyushu University

Tully 2, 10:20 Thu 9 February

Let $d \in \mathbb{N}$ and $\Omega \subset \mathbb{R}^d$ be a bounded domain with Lipschitz boundary $\partial\Omega$. Set $Q := \Omega \times (0,T)$ for $T > 0$. We consider the first-order partial differential operator P such that $Pu := A^0(x,t)\partial_t u + A(x,t)\cdot\nabla u$, where $A^0 \in C^1(\overline{Q}) \cap L^\infty(\Omega \times (0,\infty))$ is a positive function and $A = (A^1,\dots,A^d) \in C^2(\overline{Q};\mathbb{R}^d)$ is a vector-valued function. Define an outgoing boundary $\Sigma_+ := \{(x,t) \in \partial\Omega \times (0,T) \mid A(x,t)\cdot\nu(x) > 0\}$ and incoming boundary $\Sigma_- := \big(\partial\Omega \times (0,T)\big) \setminus \Sigma_+$, where ν denotes the outer unit normal to $\partial\Omega$. We consider the following two kinds of inverse problems.

Inverse source problem

Let u be a function satisfying

$$\begin{cases} Pu + p(x,t)u = R(x,t)f(x) & \text{in } Q, \\ u = 0 & \text{on } \Sigma_-, \\ u(\cdot,0) = 0 & \text{on } \Omega, \end{cases}$$

where $p \in W^{1,\infty}(0,T;L^\infty(\Omega))$, $R \in H^1(0,T;L^\infty(\Omega))$, and $f \in L^2(\Omega)$. We will see global Lipschitz stability to determine f in Ω from observation data on Σ_+.

Inverse coefficient problem

For $m = 1,\dots,d+1$, let u_m be a function satisfying

$$\begin{cases} Pu_m + p(x,t)u_m = 0 & \text{in } Q, \\ u_m = g_m & \text{on } \Sigma_-, \\ u_m(\cdot,0) = \alpha_m & \text{on } \Omega, \end{cases}$$

where $p \in W^{1,\infty}(0,T;L^\infty(\Omega))$, $g_m \in L^2(\Sigma_-)$, and $\alpha_m \in W^{1,\infty}(\Omega)$. We will see global Lipschitz stability to determine $\{A^\mu\}_{\mu=0}^d$ from finitely many observation data on Σ_+.
This is a joint work with G. Floridia in Sapienza Università di Roma.

References

[1] G. Floridia and H. Takase. Inverse problems for first-order hyperbolic equations with time-dependent coefficients. *J. Differential Equations* 305 (2021), 45–71.

Front Stability for a Moving-Boundary Model for Biological Invasion and Recession

Alex Tam, Mat Simpson
University of South Australia

Ballroom, 12:00 Wed 8 February

The Fisher–Stefan model is a modification to the Fisher–KPP equation, a common prototype model in mathematical biology. The Fisher–Stefan model involves solving the Fisher–KPP equation on a compactly-supported region with a moving boundary that evolves analogously to the classical one-phase Stefan condition. Unlike the Fisher–KPP equation, the Fisher–Stefan model admits solutions with compact support, and has travelling wave solutions with non-negative density for any wave speed. Despite these advantages, there remains much to study about the Fisher–Stefan and related moving-boundary models. In this work, we use linear stability analysis and numerical solutions using the level-set method to investigate whether planar Fisher–Stefan fronts are stable to transverse perturbations. We found that invading planar fronts are linearly stable (like solutions to the Fisher–KPP equation), but receding planar fronts are unstable. Instability in receding fronts suggests a mechanism for pattern formation in receding biological populations.

Convergence of Multi-Block ADMM

Matthew K. Tam
The University of Melbourne

Tully 1, 10:20 Wed 8 February

The *alternating direction method of multipliers (ADMM)* is an iterative algorithm for solving structured convex optimisations problems. In recent times, it has found applications in many areas including robust principle component analysis, statistical estimation, and energy management. The basic idea of the method is to decompose the original optimisation problem into two simpler subproblems (called "blocks") and exploit their relative simplicity. The good performance of ADMM on large-scale problems motivates the development of an extension which can handle a decomposition involve three or more blocks, rather than just two. However, a explicit counter-example in the literature shows that this is not possible for the "direct extension" of ADMM. In this talk, we remedy this shortcoming but providing different approach to multi-block ADMM which yields provably convergent alternative.

Selecting Embedding Delays: a New Method Using Persistent Homology

Eugene Tan, Shannon Algar, Debora Correa, Michael Small, Thomas Stemler, David Walker
The University of Western Australia

Tully 3, 10:00 Wed 8 February

Delay embedding methods are a staple tool in the field of time series analysis and prediction. However, the selection of embedding parameters can have a big impact on the resulting analysis. This has led to the creation of a large number of methods to optimise the selection of parameters such as embedding lag, as well as non-uniform embedding lags for greater flexibility. However, the latter efforts often yield lags with no clear dynamical explainability. We provide an alternative method of selecting embedding lags that includes a mixture of both dynamical and topological arguments. The proposed method, Significant Times on Persistent Strands (SToPS), uses persistent homology to construct a characteristic time spectrum that quantifies the relative dynamical significance of each time lag. We test our method on periodic, chaotic and fast-slow time series and find that our method performs similar to existing automated non-uniform embedding methods. Additionally, n-step predictors trained on embeddings constructed with SToPS was found to outperform other embedding methods when predicting fast-slow time series

Evaluation of the Effectiveness of Mass Drug Administration Strategies for Reducing Scabies Burden in Monrovia, Liberia: an Agent-Based Modelling Approach

Nefel Tellioglu, Rebecca H. Chisholm, Patricia Therese Campbell, Shelui Collinson, Joseph Timothy, Karsor Kollie, Samuel Zayzay, Angela Devine, Jodie McVernon, Michael Marks, Nicholas Geard
The University of Melbourne

Tully 3, 17:00 Mon 6 February

Background
Scabies is a parasitic infestation with high global burden. Mass drug administrations (MDAs) are recommended for communities with a scabies prevalence of >10%. Quantitative analyses are needed to demonstrate the likely effectiveness of MDA recommendations. In this study, we compare the effectiveness of differing MDA strategies, supported by improved treatment access, on scabies prevalence in Monrovia, Liberia.

Methods
We developed an agent-based model of scabies transmission calibrated to demographic and epidemiological data from Monrovia using Bayesian inference. We used this model to compare the effectiveness of MDA scenarios for achieving scabies elimination and reducing scabies burden, as measured by time until recrudescence following delivery of an MDA and disability-adjusted-life-years (DALYs) averted. We also investigated the additional impact of improving access to scabies treatment following delivery of an MDA.

Results
Our model showed that 3 rounds of MDA delivered at 6-month intervals and reaching 80% of the population could reduce prevalence below 2% for 3 years following the final round, before recrudescence. When MDAs were followed by increased treatment uptake, prevalence was maintained below 2% indefinitely. Increasing the number of and coverage of MDA rounds increased the probability of achieving elimination and the DALYs averted.

Conclusions
Our results suggest that acute reduction of scabies prevalence by MDA can support a transition to improved treatment access. This study demonstrates how modelling can be used to estimate the expected impact of MDAs by projecting future epidemiological dynamics and health gains under alternative scenarios.

A Variational Model for Metal Folding

Natalie Thamwattana
The University of Newcastle

Tully 1, 15:00 Wed 8 February

This talk is motivated by the project ‘Tools to measure the carbon content of soil’ from a company, ‘CarbonPump’, at the MISG 2022.
Soil has been used to capture and store significant carbon from the atmosphere. To collect a soil sample for measuring its carbon content, CarbonPump uses a metal tube to drill roughly 1.5m into the ground to obtain a vertically profiled sample. Inserted inside this metal tube is a reusable folded metal sheet for collecting the sample. The folded metal sheet as an insertion enables its re-usability since it is designed to fit and have enough strength to stay intact inside the outer metal tube to withstand high pressure during the drilling process. A critical feature of the inner metal sheet is its flexibility to insert into the outer metal tube and unroll to reveal a column of soil sample after being removed from the outer tube. To achieve this flexibility, a series of kerf cutting and cold pressing are introduced to the metal sheet. While flexibility may be achieved, kerf patterns generally compromise the strength of the material. As such, investigation into the effect of kerf cutting and cold pressing on the metal sheet is required. This talk is part of the investigation done at the MISG 2022, where a variational model is used to study the folding of metal sheets with kerf patterns.

The Retirement Income Market in Australia

Yu Tian
Monash University

Ballroom, 10:40 Tue 7 February

The retirement income system in Australia is ranked as one of the top retirement income systems in the world and is becoming a crucial part of the long-term investment industry that affects the economy and millions of population towards retirement. I’d like to discuss the challenges and opportunities for researchers in financial maths and actuarial science from a practical perspective.

A Room Inventory Model for Operating Room Planning and Scheduling

Liam Timms, Michael Forbes
The University of Queensland

Tully 1, 12:40 Tue 7 February

Operating rooms (OR) and surgeries are integral to hospital function, however, efficiently creating a surgery timetable that maximises productivity and minimises cost is a complex problem. This paper presents a novel room inventory formulation for operating room planning and scheduling (ORPS). We create an inventory of available ORs instead of directly tracking individual ORs with a room index on variables. This removes symmetry in the model arising from permutations of the room indices. The computational results demonstrate that this formulation is superior to existing methods for solving both integrated ORPS (IORPS) and collaborative ORPS (CORPS).

Forecasting the Impact of COVID-19 on Australian Hospitals

Ruarai Tobin
The University of Melbourne

Tully 3, 15:20 Mon 6 February

Assessing the potential impact of COVID-19 on the Australian healthcare system has been of vital importance since the beginning of the pandemic. Across Australia, alongside the daily counts of new COVID-19 cases, the number of COVID-19 cases in hospital each day has been tracked closely. In this work, we demonstrate a model for forecasting this quantity across both ward and intensive care unit beds which has been used to provide situational awareness to public health authorities on a weekly basis since December 2021. Our model assumes that COVID-19 cases progress via a simplified compartmental model, with information on severity being informed by epidemiological data sources in near-real-time. The model is paired with an approximate-Bayesian inference method and utilises an efficient algorithm for simulation of the compartmental model, allowing for forecasts to be produced with short turnaround.

Topological Transforms for Use in Statistical Shape Analysis

Katharine Turner
Australian National University

Ballroom, 14:00 Mon 6 February

Persistent homology and other topological summaries like Euler curves provides quantitative methods to characterise geometric shape. One common filtration, inspired by Morse theory in pure mathematics, is via increasing sublevel sets of a height function with respect to some direction. By calculating the evolution of topology under a height filtration we capture information about geometry of a shape with respect to this specific direction. The Persistent Homology Transform (and its variants) basically expand on this idea by considering the height functions in all directions. These topological transforms have nice theoretical properties, in particular they completely describe compact nice subsets of Euclidean space, and can provide new metrics for quantitatively measuring the difference between geometric objects.
This talk will assume no prior familiarity with persistent homology, and will introduce these topological transforms, outline some related theory and briefly mention some applications in the literature.

Optimal Balanced Chain Decomposition of Partially Ordered Sets with Applications to Operating Cost Minimization in Aircraft Routing Problems

Radislav Vaisman and Ilya B. Gertsbakh
The University of Queensland

Tully 1, 09:40 Wed 8 February

We consider the task of constructing a cost-effective daily flight schedule with minimum number of required aircrafts and maximum numberof balanced flight routes, namely, routes with the same start and end spatial location. We suggest a solution strategy which is able to determine the problem's hardness by estimating the number of all flight plans with minimum number of required aircrafts. Provided that this number is not too large, the same algorithm is utilized for fully enumerating and detecting the set of solutions that have the maximum number of balanced routes. Our experimental study implies that the method is both effective and scalable in practice. For example, when applied to the Australian domestic flights timetable which is serviced by a total of eighty-eight aircrafts, our method manages to increase the number of balanced flight routes from nine to forty-two, while using only several minutes of computational time.

Inertial Particle Focusing in Curved Ducts: Bifurcations and Dynamics

Rahil Valani, Brendan Harding, Yvonne Stokes
The University of Adelaide

Tully 2, 11:00 Thu 9 February

Particles suspended in fluid flow through a curved duct can focus to stable equilibrium positions in the duct cross-section due to the balance of two dominant forces - inertial lift force from axial flow and secondary drag force from cross-sectional vortices. Such particle focusing is exploited in various medical and industrial technologies aimed at separating particles by size. In this talk, I will present results of our numerical investigation of the dynamics of neutrally buoyant particles in fluid flow through curved ducts with rectangular cross-sections. I will show that rich bifurcations take place in the particle equilibria as a function of the duct bend radius. I will also offer insights on how these bifurcations in combination with particle dynamics can be exploited to separate particles of different sizes in circular and spiral ducts.

Attractor-driven Matter

Rahil Valani, David Paganin
The University of Adelaide

Tully 1, 17:20 Wed 8 February

Attractors such as fixed points, limit cycles and strange attractors arise in nonlinear dynamical systems, however, such attractors may also be used to drive complex dynamics. By using a low-dimensional chaotic dynamical system to model each particle's internal state space, we present a new class of matter coined "attractor-driven matter". Through illustrative examples, I will show how attractor-driven particles when combined with particle-particle interactions and environment can give rise to complex dynamical and emergent behaviors reminiscent of active matter. The formalism may be applicable more broadly, to model complex dynamical and emergent behaviors in a variety of contexts.

The Lévy Flight Foraging Hypothesis

Enrico Valdinoci
The University of Western Australia

Tully 1, 12:40 Mon 6 February

Foraging theory tries to identify the most efficient strategy of a predator in different environments. In the last years, more and more attention has been devoted to the analysis of Lévy-type patterns in animal searches.
We will present several efficiency functionals whose optimality is discussed in relation to the Lévy exponent of the corresponding evolution equation for the forager. We will also discuss whether or not the optimal Lévy exponent corresponds to a viable strategy and detect high-gain/high-risk foraging patterns.

The Making of New Zealand's COVID-19 Frankenstein's Monster Model

Giorgia Vattiato
University of Auckland

Tully 3, 17:00 Wed 8 February

Since the start of the COVID-19 pandemic, Covid Modelling Aotearoa (New Zealand's COVID-19 modelling group) has been developing epidemiological models to model the spread of COVID-19, to forecast the number of infections, cases, hospitalisations, and deaths in New Zealand. As time has progressed, these models have undergone numerous updates to reflect the increasingly complex population immunity profile and the rising number of observed COVID variants, behavioural changes, and policy changes.
In this talk, I will present our Ordinary Differential Equation transmission model and the Approximate Bayesian Computation method we use to estimate unknown parameters, as well as describing some of the major model features which have been added over time, used to simulate the different moving parts in Aotearoa New Zealand's ever-evolving COVID transmission landscape.

Mathematical Modelling of the Drying of Fruits and Vegetables

Anthony Vine
Queensland University of Technology

Tully 1, 17:00 Mon 6 February

Fruits and vegetables contain over 80% water making them highly perishable commodities. Removal of this water by way of convective drying has become the most common method of preserving fruits and vegetables, however, this is an energy intensive and time consuming process. Mathematical modelling is an ideal way to optimize the drying parameters in order to reduce the overall operational costs. Fruits are comprised of a complex structure of cells consisting of vacuoles, cytoplasm, membranes, cell wall, and gaseous pores. Water is found within the cell interstices, bound to the cell wall, and in the porous space between cells. The location of water within the cellular matrix determines its rate of transport. Accurate modelling of mass transport in food materials requires knowledge of how water transport properties depend on this material structure. In this work different mathematical models of drying are compared to identify the moisture migration mechanisms within each of the domains of the cellular matrix and the mass transfer rates between these domains. Experimental results for the convective drying of apples are used to analyse the accuracy of the simulated moisture content and temperature distributions computed by the various models.

Strategic Model Reduction by Analysing Model Sloppiness: Matching Model Complexity to Data Complexity

Sarah Vollert
Queensland University of Technology

Tully 1, 11:00 Wed 8 February

Large models can be challenging to simplify while retaining predictive ability, particularly when there are hidden parameter interdependencies. We demonstrate that an analysis of model sloppiness – a data-informed sensitivity analysis – is a new and invaluable tool for strategically simplifying models. Such an analysis identifies parameter combinations that strongly and/or weakly inform model behaviours through data. For a physiological coral model calibrated to experimental data, the approach reduces the number of model parameters from 20 to 12 without loss of predictive power.

Bayesian Uncertainty Quantification to Identify Vaccine Hesitancy Behaviours

David J. Warne, Abhishek Varghese, Alexander P. Browning, Mario M. Krell, Christopher Drovandi, Wenbiao Hu, Antonietta Mira, Kerrie Mengersen, Adrianne L. Jenner
Queensland University of Technology

Tully 3, 10:20 Mon 6 February

By January 2021, two COVID-19 vaccines with greater than 90% efficacy to reduce symptomatic infection risk were approved by many therapeutic regulators globally. As a result, the COVID-19 pandemic response around the world began to complement non-pharmaceutical interventions (NPIs), such as lock-downs and travel restrictions, with vaccination programs. The success of such programs crucially depended on a sufficient proportion of the population accepting a vaccine. Vaccine hesitancy, that is, a delay in acceptance or refusal of vaccines despite availability, was a major concern in many jurisdictions, including Australia. Therefore the ability to detect different vaccine hesitancy behaviours in a population is important to adjust vaccine information campaigns. In this work, we perform a simulation study to explore the potential for vaccine hesitancy patterns to be identified from population level reported case, death, and vaccination counts. We develop a stochastic epidemiological model incorporating both NPI and vaccination effects on virus transmission, vaccination effects on disease severity, and changes in the probability of individuals to get vaccinated in response to observed data. Using Bayesian analysis, we are able to identify when a vaccine hesitancy effect is present and provide some insight into the dominant reasons for this hesitancy.

Investigating Necrotic Core Localisation with a Spatial-Temporal-Structural Model of Early Atherosclerotic Plaque Formation

Michael Greg Watson
University of New South Wales

Ballroom, 11:00 Thu 9 February

Atherosclerotic plaques are fatty, cellular lesions that form in major arteries. Plaque growth begins when blood-derived lipids accumulate in the artery wall and trigger the recruitment of specialised immune cells called macrophages. Macrophages ingest these lipids and seek to remove them from the wall. However, when lipid-loaded macrophages die in the wall, a dangerous necrotic core of lipid and cellular debris is formed. In human and murine plaques, the necrotic core typically emerges in the centre of the plaque. This phenomenon is poorly understood because core placement reflects the outcome of a complex interplay between macrophage lipid accumulation, macrophage death, and the relative movement of macrophages and lipids in the plaque. In this talk, I will investigate necrotic core localisation using a novel spatio-temporal model of plaque formation in which macrophages are structured by their ingested lipid load. Using steady state analysis and numerical simulations, I will demonstrate the formation of a necrotic core in the model and discuss the factors that determine its spatial profile and position in the model plaque.

Modelling of a Five Reactor Activated Sludge Cascade Process

Simon Watt
UNSW Canberra

Tully 2, 17:20 Wed 8 February

The activated sludge process is the most widely used process for the biological treatment of domestic and industrial wastewaters. Wastewater treatment plants using the activated sludge process are in widely used in developed and developing countries.
The activated sludge model number 1 (ASM 1) is an internationally accepted standard for activated sludge modelling. It describes nitrogen and chemical oxygen demand within suspended-growth treatment processes, including mechanisms for nitrification and denitrification.
We analysed the biological treatment of a wastewater when a cascade of five reactors were used. Operating conditions were investigated in which the first reactor was not aerated. The second reactor could be either be aerated or not aerated. The remaining reactors were aerated. The process configuration included one settling tank and one recycle step. Both of these were placed after the final reactor in the cascade.

Towards Optimal Space-Time Discretizations of Reachable Sets of Control Systems

Janosch Rieger and Kyria Wawryk
Monash University

Tully 2, 16:00 Mon 6 February

The reachable sets of control systems can in general only be approximated numerically, and these approximations are typically very expensive to calculate. Since the sets evolve in time, numerical approximations require discretization in both space and time.

Attempts to increase the order of convergence of the corresponding Runge-Kutta-type methods have only been moderately successful. One key obstacle is the nature of the reachable set itself: even for linear control systems with box constraints, the reachable set is not a smooth object. Another key obstacle is the exponential relationship between the number of evaluations of the multivalued vector field in a time step and the computational cost of that time step.

On the other hand, very little thought has been given to whether the degrees of freedom of the space-time discretization of basic Runge-Kutta-type methods can be used to improve their performance. We explore this option and introduce three new approaches to reduce the computational cost of a numerical approximation of the reachable set induced by Euler's scheme by choosing the temporal and spatial grids in a nonuniform way. In addition, we show that a reachable set approximation that satisfies a user-provided error tolerance can be produced by any of these approaches.

Math, Multiple Sclerosis, and the Mind: Using Agent-Based Modelling to Understand What Causes the Immune System to Attack the Brain

Georgia Weatherley
Queensland University of Technology

Ballroom, 12:20 Mon 6 February

Every day, we use our bodies to move, think, talk and eat but for people with multiple sclerosis (MS) these tasks can be virtually impossible. MS is a chronic disease which develops because the immune system attacks the insulation (myelin sheath) around the nerve cells in the brain. Despite considerable technological advances in the last 20 years, the immune cells and their kinetics that drive this disease are largely unknown. The local degradation of myelin and the resulting patient symptoms are extremely heterogeneous and result in stochastic disease fluctuations. Agent-based models (ABMs) are a stochastic modelling technique that allow us to capture each individual immune cell agent and investigate it's resulting actions. In this work, we develop an on-lattice ABM that captures the involvement of three immune cells in the degradation of myelin. We validate our model by comparing bias and undirected random walks from the model with their continuum known solutions. Using the model, we investigate the impact of the chosen neighbourhood assumptions on the model predictions and what situations give rise to diseased brain regions and what give rise to recovered brain regions. Our work hopes to form the basis for future works in this area, as there is a significant lack of mathematical modelling being done in MS.

Constrained Level Set-Based Microstructure Optimisation with a Hilbertian Projection Method

Zachary J. Wegert, Vivien J. Challis, Anthony P. Roberts
Queensland University of Technology

Tully 1, 09:40 Tue 7 February

Computational topology optimisation is a powerful tool for designing structures and microstructures with improved physical properties. We will describe classical level set-based topology optimisation including Hilbertian velocity extension-regularisation. Following this, we will present our Hilbertian extension of the projection method for constrained level set optimisation. Using several benchmark microstructure optimisation problems we show that our new approach is effective for constrained microstructure optimisation. Furthermore, we find that little-to-no parameter tuning is required for the different benchmark problems. Modern additive manufacturing technology enables the construction of materials with architected microstructures, and topology optimisation enables exploitation of this new geometric freedom.

Positive-Unlabeled Learning Using Random Forests via Recursive Greedy Risk Minimization

Jonathan Wilton
The University of Queensland

Tully 2, 16:40 Mon 6 February

The need to learn from positive and unlabeled data, or PU learning, arises in many applications and has attracted increasing interest. While random forests are known to perform well on many tasks with positive and negative data, recent PU algorithms are generally based on deep neural networks, and the potential of tree-based PU learning is under-explored. We propose new random forest algorithms for PU-learning. Key to our approach is a new interpretation of decision tree algorithms for positive and negative data as recursive greedy risk minimization algorithms. We extend this perspective to the PU setting to develop new decision tree learning algorithms that directly minimizes PU-data based estimators for the expected risk. This allows us to develop an efficient PU random forest algorithm, PU extra trees. Our approach features three desirable properties: it is robust to the choice of the loss function in the sense that various loss functions lead to the same decision trees; it requires little hyperparameter tuning as compared to neural network based PU learning; it supports a feature importance that directly measures a feature's contribution to risk minimization. Our algorithms demonstrate strong performance on several datasets.

An Operator Analysis Approach to the Stochastic Differential Equation Diffusion Generative Model

Yunpei Wu
Kyushu University

Tully 2, 17:00 Mon 6 February

The diffusion generation model, also known as the diffusion model, has received a lot of attention in recent years. Many papers have shown that it surpasses the generative adversarial network in its ability to generate high-precision images. The main idea of the diffusion model is to continuously apply noise interference to the original dataset so that it eventually becomes noisy data, and then reverse the process so that we can use the noisy data to generate new data that approximates the original dataset. If the process of disturbing the dataset is continuous and can be described by stochastic differential equations (SDE), we call it the SDE diffusion model. When applying the SDE diffusion model, if we solve the SDE with a traditional one, such as the Fokker-Plank equation, it will be computationally intensive due to its nonlinear computational characteristics. We propose an operator analysis method to convert the SDE solution process into a computationally convenient linear operation, which can greatly reduce the computational complexity of the SDE diffusion model.

Estimating Customer Valuation in a Service System with Unobserved Balking

Chenchen Xing
The University of Melbourne

Tully 1, 16:00 Mon 6 February

We consider a service system selling goods to strategic customers. Customers are inhomogeneous on the valuation of goods. At their arrival times, customers are informed about the information of the current system. Customers probably arrive and then immediately balk if the waiting cost is above the valuation. Those balking customers are not observed by the system manager. The aim of the system manager is to estimate customers' valuation distribution as well as the arrival rate of customers including balking customers.
The modelling framework that we will be working with is a double sided queue with Poisson streams of goods and customers on both sides. We find the maximum likelihood estimators for the customer's valuation and the arrival rate. Consistency of MLEs holds based on simulation results.

The Position of the Axon Initial Segment Assembly Site Can Be Predicted from the Shape of the Neuron

Zhuang Xu
University of New South Wales

Ballroom, 17:20 Mon 6 February

Neurons are highly polarized cells with segregated domains specialized for either receiving (soma/dendrites) or transmitting (axons) cellular signals. The two major domains are distinct in terms of their structure and molecular composition. A unique compartment called the axon initial segment (AIS) is found critical for the proper segregation of the two domains. Experimental evidence suggests that the establishment of neuronal polarity is both intrinsic and dynamic in early neuronal development. However, how the AIS is assembled near the proximal end of the axon during this stage remains unclear. In this work, we observe that the position of the AIS assembly site is correlated with the nodal plane of the 1st harmonic of the Laplace-Beltrami operator solved over the geometry of the neuron. To carry out the analysis, the mouse hippocampal neurons were cultured on the glass coverslips, from which their geometries were extracted and reconstructed via image analysis. We then developed a numerical method to efficiently approximate the harmonics of the Laplace-Beltrami operator over the geometry of the neuron samples. The results here suggest that neurons can self-detect an optimal region for AIS assembly by coupling to their shape such that mixing between the two distinct domains is minimized. We identify the reaction-diffusion system as a potential mechanism for AIS assembly and neuronal polarity establishment.

Using Anomalous Diffusion Models for Mapping Brain Tissue Microstructure

Qianqian Yang (QUT), David C. Reutens (UQ), Viktor Vegh (UQ)
Queensland University of Technology

Ballroom, 16:20 Mon 6 February

Diffusion magnetic resonance imaging (MRI), which measures the random motion of water molecules in biological tissues, has become a pillar of modern neuroimaging. One major challenge in the field of diffusion MRI is that the measurement is at millimetre scale while the tissue microstructure, providing key insight into diagnosis and treatment of central nervous system diseases and disorders, is at microscale. Many models have been proposed to link millimetre measurements with microscale tissue properties. In this talk, we focus on the continuous time random walk (CTRW) modelling framework, which considers the diffusion of water molecules in brain tissue as an anomalous (Non-Gaussian) transport process and infers microstructure information through different anomalous diffusion parameters. We also show that CTRW modelling framework is able to unify several established non-Gaussian models, including the prevalent diffusional kurtosis imaging (DKI) model. This link between the DKI and sub-diffusion (a special case of CTRW) models led to a new robust and accurate technique for generating maps of kurtosis and diffusivity using the sub-diffusion parameters. Superior tissue contrast is achieved in kurtosis maps based on the sub-diffusion model. Overall, our results suggest that anomalous diffusion models under the CTRW framework play an important role in mapping tissue microstructure and deriving tissue specific micro-parameters.

Estimating Tail Probabilities of Random Sums of Phase-Type Scale Mixture Random Variables

Hui Yao, Thomas Taimre
The University of Queensland

Tully 1, 11:00 Mon 6 February

We consider the problem of estimating tail probabilities of random sums of scale mixture of phase-type distributions — a class of distributions corresponding to random variables which can be represented as a product of a non-negative but otherwise arbitrary random variable with a phase-type random variable. Our motivation arises from applications in risk, queueing problems for estimating ruin probabilities, and waiting time distributions respectively. Classical rare-event simulation algorithms cannot be implemented in this setting because these methods typically rely on the availability of the cumulative distribution function or the moment generating function, but these are difficult to compute or not even available for the class of scale mixture of phase-type distributions. We propose alternative simulation methods for estimating tail probabilities of random sums of scale mixture of phase-type distributions; our algorithms combine importance sampling and conditional Monte Carlo methods. We show the efficiency of proposed estimators for a wide class of scaling distributions. The empirical performance of the suggested methods are validated via numerical experimentation. Keywords: Subexponential Distribution; Rare Event Simulation; Conditional Monte Carlo; Importance Sampling

Machine Learning as a New Tool for Applied Mathematicians: a Tutorial

Nan Ye
None

Ballroom, 16:00 Wed 8 February

Machine learning is gaining more popularity among applied mathematicians as a valuable tool. This talk aims to provide an overview of the capability of this important tool and a roadmap for mastering it. I will begin with an overview of machine learning's roles in mathematical modelling, including its ability to provide highly flexible approximation models and methods for solving mathematical models. Next, I will introduce the general approach and concepts of machine learning by drawing connections to classical mathematical concepts such as approximation and interpolation/extrapolation. Much emphasis will be given to the revolutionary sub-field of deep learning. Lastly, I will cover several important applications of machine learning in mathematical modeling, including multiphysics problems, fluid modelling, inverse problems, combinatorial optimization problems, time series modelling.

Mathematical Modelling of Heat Conduction in Extrusion

Eunice B. Yuwono
The University of Adelaide

Tully 3, 11:40 Wed 8 February

Fibre fabrication is a two-step process: preform extrusion and fibre drawing. The extrusion process, where the inclusion of the second-order conduction term is necessary, is a boundary-value problem with a far-field boundary condition. In extrusion, the fibre is pulled with a pulling tension or gravitational force. The gravitational force problem is more complex, due to the varying pulling force, where each cross-section of fibre has different force. We will explore the difficulties of the gravitational force problem and our approach to solve it.

Agent-Based Modelling of SARS-CoV-2 Transmission in Quarantine Facilities

Cameron Zachreson, Freya M. Shearer, David J. Price, Michael J. Lydeamore, Jodie McVernon, James McCaw, Nicholas Geard
The University of Melbourne

Tully 3, 10:00 Tue 7 February

In Australia, international travel restrictions combined with border quarantine acted as a front-line defense against the introduction of SARS-CoV-2 from March 2020 through December 2021. We developed a computational simulation model to help understand the dynamics of COVID-19 transmission in managed quarantine systems and the risk of infected individuals entering the community.
The border quarantine context provides an exemplar use case for agent-based models of disease transmission for four main reasons: (1) The high consequences of rare breach events; (2) The structured nature of the facilities; (3) The explicit time delays associated with quarantine, screening, and discharge, and; (4) The highly heterogeneous transmission properties of SARS-CoV-2.
This talk will describe the model and briefly discuss its application in assessing the effectiveness of different quarantine policies. Several aspects of the modelling framework will be described in detail, with an emphasis on the sub-models used for disease progression, transmission, and detectability. Scenario comparisons will illustrate the flexibility of the model using infection screening and vaccination policies as case studies.

Comparison of Locally and Globally Acting Wound Closure Mechanisms

Adriana Zanca
The University of Melbourne

Ballroom, 10:00 Wed 8 February

Epithelial wound closure is a complex process involving the coordination of many mechanisms across multiple spatial and temporal scales. In this work we use cell-based modelling to investigate a subset of wound closure mechanisms acting on whole-wound and localised spatial scales. We begin by exploring spatial effects on wound closure - specifically tissue compression due to cell division events and individual cell growth. We then explore two key wound healing mechanisms: purse-string closure and cell crawling. The purse-string mechanism involves contraction of the actomyosin cables in cells adjacent to the wound edge whereas the cell crawling mechanism describes active cellular migration due to lamellipodial protrusions. Previous cell-based models of wound healing have attempted to describe each of these mechanisms on different spatial scales and with different descriptions, however, to the best of our knowledge, a comparison of these methods has not been undertaken. In this work we develop and compare whole-wound and localised models for the purse-string and cell crawling mechanisms and discuss the relative benefits of each. We conclude by summarising the overall differences between globally and locally acting mechanisms and propose more realistic extensions of each model.

A Generalized Approach for Pricing American Options Under Regime-Switching Model

Yawen Zheng and Song-Ping Zhu
University of Wollongong

Ballroom, 10:00 Tue 7 February

In this paper, we present a new approach with which American option price under a general regime-switching model with an arbitrary finite number of economic states can be efficiently computed without solving a system of n differential equations simultaneously. Comparing with all the existing approaches, this approach has a distinguishing feature: a set of completely decoupled integral equations is numerically integrated for each economical state within a finite n-state economy. Such a high efficiency is achieved through a pre-analysis of the associated matrices and their eigenvalues without worrying if the duplicated roots of the these matrices are misidentified as simple roots due to round-off errors or there are actually two extremely closed simple roots inherently in the original system. Numerical examples are provided to demonstrate the implementation of the new approach and its efficiency.

Large Ranking Games with Diffusion Control

Stefan Ankirchner, Nabil Kazi-Tani, Julian Wendt, Chao Zhou
National University of Singapore

Ballroom, 12:20 Tue 7 February

We consider a symmetric stochastic differential game where each player can control the diffusion intensity of an individual dynamic state process, and the players whose states at a deterministic finite time horizon are among the best of all states receive a fixed prize. Within the mean field limit version of the game we compute an explicit equilibrium, a threshold strategy that consists in choosing the maximal fluctuation intensity when the state is below a given threshold, and the minimal intensity otherwise. We show that for large n the symmetric n-tuple of the threshold strategy provides an approximate Nash equilibrium of the n-player game. We also derive the rate at which the approximate equilibrium reward and the best response reward converge to each other, as the number of players n tends to infinity. Finally, we compare the approximate equilibrium for large games with the equilibrium of the two-player case. This talk is based on the joint work with Stefan Ankirchner, Nabil Kazi-Tani and Julian Wendt.

Time Inconsistency, Precommitment and Equilibrium Strategies for a Stackelberg Game

Zhou Zhou
The University of Sydney

Ballroom, 09:40 Tue 7 February

We consider a Stackelberg game in discrete time where a manager (leader) hires an agent (follower) for the completion of a project. The project has two states: either uncompleted or completed. The manager gets a fixed reward upon the completion of the project. At the beginning of each stage given the project has not been completed, the manager proposes an amount that will be paid to the agent if the project is completed in the next period. The agent controls the level of effort which is equivalent to the probability of the project being completed in the next period. Both the manager and agent aim to maximize their own expected payoffs subject to exponential discounting. It turns out that the manager's problem is time-inconsistent, albeit with exponential discounting. We provide the manager's optimal Markov, optimal precommitment, and equilibrium strategies.
Next, we extend our results to the problem where the project has two milestones, i.e., three states. Moreover, we show that if the manager is weakly less patient then the agent, then under optimal Markov and precommitment strategies there is no need for the manager to pay the agent upon the completion of the intermediate milestone, while that may not be the case for the equilibrium strategy.

Conference Delegates (as of the 30th of January 2023)

Ms Isobel Abell

Mr Johnathan Adams

Dr Matthew Adams

Mrs Lin Ai

Dr Kylie Ainslie

Dr Morenikeji Deborah Akinlotan

Miss Punya Alahakoon

Miss Tiria Andersen

Dr Christopher Angstmann

Mr Md Nurul Anwar

Dr Rosemary Aogo

Dr Robyn Patrice Araujo

Dr Karina Arias Calluari

Dr Konstantin Avrachenkov

Mr Andrew Axelsen

Prof Boris Baeumer

Dr Christopher Baker

Mr Nitay Ben Shachar

Mr Edward Bissaker

Dr Andrew Black

Mr Liam Blake

Assoc Prof Murk Bottema

Prof Philip Broadbridge

Dr Douglas Brumley

Dr Pascal R. Buenzli

Mr Stuart-James Burney

Mr Lachlan Burton

Dr Jim Byrnes

Dr Meagan Carney

Dr Elliot J. Carr

Prof Pierluigi Cesana

Dr Vivien Challis

Mr Keith Li Chambers

Mr Keith Chan

Dr Simon Clarke

Ms Madeleine Cockerill

Prof Adelle Coster

Miss Isabel Cowlishaw

Dr Jessica Crawshaw

Dr Michael Dallaston

Dr Duy-Minh Dang

Mr Louis Davis

Dr Jiahao Diao

Prof Serena Dipierro

Dr Mareike Dressler

Mrs Maud El-Hachem

Dr Edoardo Fabrini

Mr Alistair Falconer

Dr Matthew Faria

Mr Alsubaie Faris Saad

Prof Lilia Ferrario

Prof Jerzy Filar

Mr Luke Filippini

Prof Jennifer Flegg

Dr Mark Flegg

Prof Larry Forbes

Prof Gary Froyland

Mr Domenic Paul Joe Germano

Dr Maryam Golchin

Assoc Prof Cecilia Gonzalez-Tokman

Mr Patrick Grant

Ms Hritika Gupta

Assoc Prof Bronwyn Hajek

Dr Edward Hancock

Dr Brendan Harding

Mr Thomas Harris

Ms Lucinda Harrison

Dr Emily Harvey

Mr Xihao He

Dr Kate Helmstedt

Assoc Prof Roslyn Hickson

Dr Edward Hinton

Prof Graeme Hocking

Dr Marcus Hoerger

Dr Matthew Holden

Dr Jacinta Holloway-Brown

Ms Elizabeth Ivory

Mrs Chathranee Jayathilake

Dr Roxanne Jemison

Ms Adrianne Jenner

Mr Cailan Jeynes-Smith

Dr Stuart Johnston

Dr Simon Johnstone-Robertson

Prof Nalini Joshi

Miss Jun Ju

Ms Laura Karantgis

Miss Ruethaichanok Kardkasem

Mr Amin Karimi

Mr Steven Kedda

Mr Pratyush Kumar Kollepara

Ms Maame Akua Korsah

Dr Noa Kraitzman

Prof Bernd Krauskopf

Mr Shahak Kuba

Mr Timothy Earl Figueroa Lapuz

Miss Anthia Le

Dr Thao Phuong Le

Dr Shalem Leemaqz

Dr Sharon Leemaqz

Mr Yeming Lei

Mr Kai Li

Mr Ryu Lippmann

Dr Ian Lizarraga

Mr Daniel Longmuir

Miss Kirsten Louw

Dr Michael Lydeamore

Dr John MacLean

Mrs Achini Erandi Madduma Wellalage

Ms Kholod Mandoora

Mrs Philipps Maren

Dr Bree Martin

Assoc Prof Kaname Matsue

Mr Harry Ros Mcarthur

Prof James Mccaw

Prof Scott Mccue

Mr Sean McGowan

Prof Mark Joseph Mcguinness

Dr Michael Meehan

Miss Somya Mehra

Mr Adel Mehrpooya

Ms Manuela Mendiolar

Assoc Prof Mike Meylan

Dr Claire Miller

Dr Joel Miller

Mr Thomas Miller

Ms Elise Mills

Mr Milton Mondal

Mr David Morselli

Prof Mary Myerscough

Mr Gene Nakauchi

Prof Markus Neuhaeuser

Dr Matthew Cody Nitschke

Dr Syarifah Nordin

Dr Terence O'Kane

Dr Dietmar Oelz

Dr Dion O'Neale

Dr James Mark Osborne

Prof Hinke Osinga

Dr Michael Pan

Miss Luz Pascal

Dr Dilan Pathirana

Dr Jordan Pitt

Prof Michael Plank

Dr Pantea Pooladvand

Dr Andrey Pototsky

Mr Zhihao Qiao

Mr Cheng Qu

Dr Courtney Rose Quinn

Dr Melanie Roberts

Prof Tony Roberts

Ms Grace Robinson

Mrs Efat Rostami Khosroabadi

Dr Claudia Sagastizábal

Dr Hafizah Farhah Saipol

Prof Timothy Sauer

Dr Jesse Sharp

Mr Brock Sherlock

Prof Matthew Simpson

Dr Lauren Smith

Dr Vera Somers

Dr Eva Stadler

Mrs Tace Stewart

Prof Yvonne Stokes

Prof Sergey A. Suslov

Assoc Prof Daisuke Tagami

Dr Thomas Taimre

Dr Hiroshi Takase

Dr Alex Tam

Dr Matthew Tam

Mr Eugene Tan

Prof Peter Gerrard Taylor

Ms Nefel Tellioglu

Prof Natalie Thamwattana

Mr Yu Tian

Mr Liam Timms

Mr Ruarai Tobin

Dr Katharine Turner

Dr Radislav Vaisman

Dr Rahil Valani

Prof Enrico Valdinoci

Dr Giorgia Vattiato

Mr Anthony Vine

Ms Sarah Vollert

Dr Camelia Walker

Dr David James Warne

Dr Michael Greg Watson

Dr Simon Watt

Ms Kyria Wawryk

Ms Georgia Weatherley

Mr Zachary James Wegert

Mr Jonathan Wilton

Mr Yunpei Wu

Mr Chenchen Xing

Miss Huansang Xu

Mr Zhuang Xu

Dr Kazutoshi Yamazaki

Dr Qianqian Yang

Ms Hui Yao

Dr Nan Ye

Miss Eunice Blessica Yuwono

Dr Cameron Zachreson

Ms Adriana Zanca

Miss Yawen Zheng

Assoc Prof Chao Zhou

Dr Zhou Zhou