Australian Mathematical Society

Australian and New Zealand Industrial and Applied Mathematics

The 60th ANZIAM Conference

11–15 February 2024

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.

We thank the organisers of the ANZIAM 2017 and 2021 conferences for providing their LaTeX templates, and Peter Pudney for his scripting magic.

Editor: Amie Albrecht

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Contents

1 Acknowledgement of Country

We acknowledge the Kaurna and Peramangk people as the Traditional Owners of the Adelaide and Adelaide Hills regions, their Elders past and present, their continued connection with Country, land that was never ceded. We recognise that Aboriginal people have been doing mathematics on this Country for time immemorial, and respect Aboriginal ways of being, doing, and knowing.

2 Conference Code of Conduct

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. A condition of registering to attend the ANZIAM 2024 Conference and/or any associated Satellite Event is agreeing 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, 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; harassing 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.

Conference organisers 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. If a conference participant engages in harassing behaviour, they may be asked by the conference organisers to leave the conference. Any event participant who experiences or witnesses harassment should contact one of the following Code of Conduct representatives:

- Alys Clark
- Michael Dallaston
- Roslyn Hickson
- Matthew Holden
- Mark McGuinness
- Claire Miller
- Mary Myerscough
- Michael Plank

3 Conference Details and History

3.1 Organising committee

- Luke Bennetts (The University of Adelaide)—co-chair
- Bronwyn Hajek (University of South Australia)—co-chair
- Amie Albrecht (University of South Australia)
- Judy Bunder (University of South Australia)
- Mike Chen (The University of Adelaide)
- Alex Tam (University of South Australia)

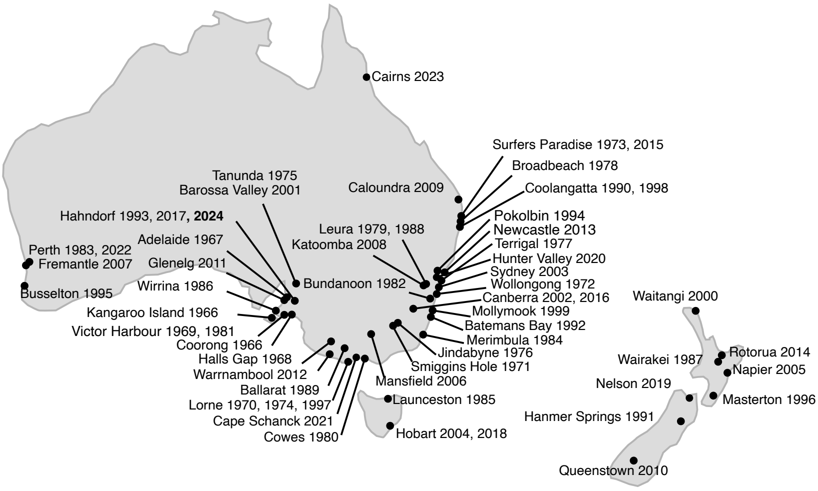
3.2 Invited speakers committee

- Cecilia Gonzalez-Tokman (The University of Queensland)—chair
- Luke Bennetts (The University of Adelaide)
- Kate Helmstedt (QUT)
- Marie Graff (University of Auckland)
- Anja Slim (Monash Univerity)
- Adelle Coster (UNSW)
- Terry O'Kane (CSIRO)
- Mark McGuinness (Victoria University of Wellington)
- Thomas Stemler (The University of Western Australia)
- Bishnu Lamichhane (University of Newcastle)

3.3 Invited speakers

- David Abrahams (University of Cambridge)
- Luke Bennetts (The University of Adelaide)—2023 E. O. Tuck Medallist
- Beth Fulton (CSIRO)
- Adrianne Jenner (Queensland University of Technology)
- Christopher Lustri (University of Sydney)—2023 J. H. Michell Medallist
- Neela Nataraj (Indian Institute of Technology Bombay)
- Tony J. Roberts (The University of Adelaide)—2023 ANZIAM Medallist
- Golbon Zakeri (University of Massachusetts Amherst)

3.4 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	2024	Hahndorf

1

[1] held online due to COVID-19 travel restrictions

3.5 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	U. Sydney
2022	Phil Broadbridge	LaTrobe
2023	Tony Roberts	U. Adelaide

3.6 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 Innov.
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
2023	Luke Bennetts	U. Adelaide

3.7 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
2023	Christopher Lustri	Macquarie U.

3.8 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	Hayden Tronnolone	U. Adelaide
2016	David Arnold	U. Adelaide
	Adrianne Jenner	U. Sydney
2017	Claire Miller	U Melbourne
	Eric Hester	U. Sydney
2018	Nabil Fadai	U. Oxford
	Eloise Tredenick	QUT
2019	Elle Musoke	U. Auckland
	Conway Li	UWA
2020	Rose Crocker	U. Adelaide
2021	Alex Browning	QUT
	Rahil Valani	Monash U.
2022	Adriana Zanca	U. Melbourne
	Michael Denes	UNSW
2023	Sarah Vollert	QUT
	Kyria Wawryk	Monash U.

3.9 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
2023	Adrianne Jenner	QUT

3.10 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
2021		
2022	Eugene Tan	UWA
2023	Noa Levi	QUT

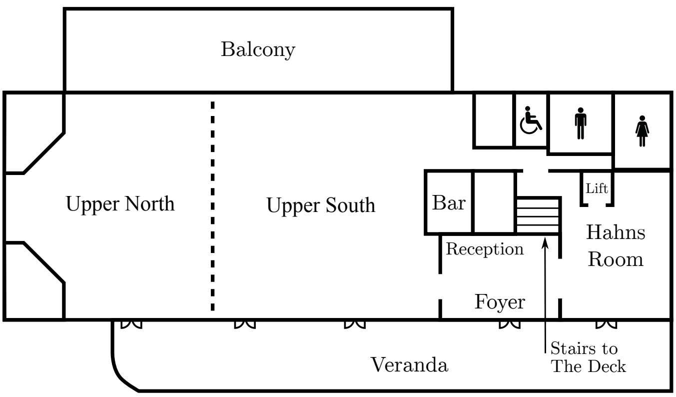
3.11 Acknowledgements

The Organising Committee gratefully acknowledges John Banks (The University of Melbourne) for his help with developing and maintaining the online conference registration system. The Committee is also immensely thankful for the support of the following organisations.

4 Conference Venue

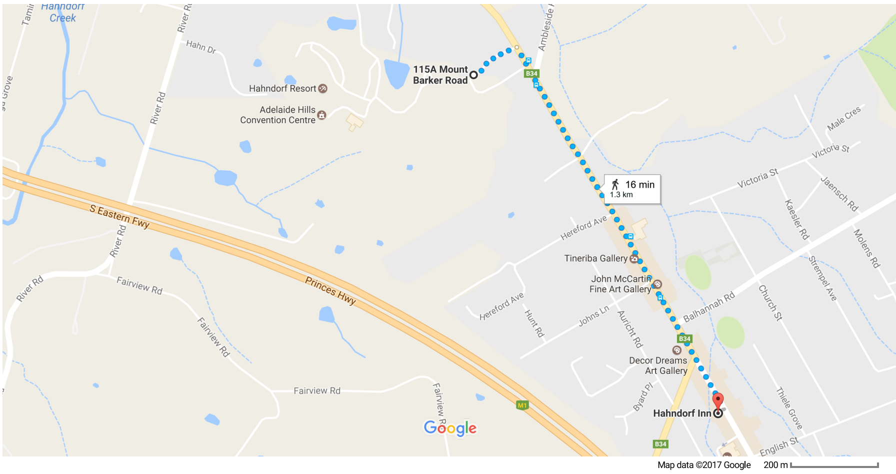
The conference is being held at the Adelaide Hills Convention Centre (AHCC) in Hahndorf, South Australia. The AHCC is located within the Hahndorf Resort Tourist Park, shown on the map below. This map shows the Convention Centre as well as **Lakeview**, **Business Centre** and **Summit Centre** — all of which will be used for the conference. Gender neutral toilets are available downstairs.

The floor plan for the main building (the Convention Centre) is shown below. The Deck may be reached by the stairs as indicated.



Adelaide Hills Convention Centre

For those wishing to walk between the venue and Hahndorf town centre, see the map below.



4.1 Conference Reception

The welcome reception will be held from 6.30 pm on Sunday 11 February on The Deck at the Adelaide Hills Convention Centre. All conference delegates and registered guests are invited.

4.2 Conference Dinner

The conference dinner will be held at the Adelaide Hills Convention Centre in the plenary room (Upper North and Upper South), on Wednesday 14 February beginning with pre-dinner drinks from 6:30 pm.

4.3 Refreshment Breaks and Lunches

Morning and afternoon tea and light refreshments will be available on The Deck. Lunches are included in the registration fee for delegates and their registered guests and will be available on The Deck after the last presentations of the morning sessions.

4.4 Internet Access

Delegates will be provided with WiFi internet access throughout the conference. Use the "Conference1" network with password `Hahnd0rf8521#` (note it is a zero not an O).

4.5 Social Media

ANZIAM attendees are encouraged to use social media from their personal accounts to share ideas from the conference. The conference hashtag is #ANZIAM2024. It is good practice to include a reference to the presenter and their affiliation, and please seek permission from the presenter before posting a photo of them or their presentation online.

4.6 Invited Lectures and Contributed Talks

All invited lectures will take place in the combined Upper North and South rooms. There will be a 10 minute break between each invited lecture and the preceding or following contributed talks to allow for the rooms to be separated. Contributed talks will be held in parallel sessions in **Upper North**, **Upper South**, the **Lakeview**, the **Business Centre** and the **Summit Centre**. The duration of each contributed talk will be fifteen minutes with an additional five minutes for questions and room change over.

4.7 Engagement with Japan Session

We thank Professor Kenji Kajiwara and Professor Ken Hayami, the President of JSIAM, for their initiative to promote JSIAM–ANZIAM links through conferences such as ANZIAM and we note that other similar interactions have been organised in the past. For example, the JSIAM conference in 2016 in Japan featured Australian and New Zealand speakers, and there were a significant number of Japanese participants at ANZIAM 2017 and the Mathematics in Industry Study Group in 2017. Since then ANZIAM and MISG have continuously welcomed the participants from JSIAM.

Speakers who wish to be involved in fostering links between JSIAM and ANZIAM have been marked in the conference timetable with a superscript J.

4.8 Early Career Workshop

The ANZIAM Early Career Workshop will be held at the University of Adelaide over the Saturday and Sunday prior to the ANZIAM conference. This workshop is a professional development and networking opportunity for PhD students and early career researchers. It will feature sessions on communication, the supervision relationship, working in industry, project scoping, and time management. Sessions will be presented by Dr Hayden Tronnolone, Prof Amie Albrecht, Prof Jennifer Flegg, Dr David Skene, Assoc Prof Alys Clark, Dr Matthew Tam, and Prof Yvonne Stokes. The workshop will also include a session on Respectful Behaviour: Practical Approaches by Sally Woolford from Diversify Consulting.

The 2024 workshop has been organised by Dr Claire Miller and Dr Jordan Pitt and is supported by AMSI, the AustMS, and ANZIAM.

4.9 Student Event

All students are invited to the Hahndorf Inn on Monday 12 February for the student event. The event provides a chance to meet fellow students in an informal setting, with food provided and drinks available for purchase. This event has been organised by the ANZIAM student representative Brock Sherlock and Amy-Rose Westcott.

4.10 Women in Mathematics Special Interest Group Lunch

The WIMSIG lunch is held at national ANZIAM conferences to promote and celebrate the contribution of women, trans and gender diverse people in the mathematical sciences. In 2024, the event will feature a presentation of achievements of women, trans and gender diverse people in ANZIAM, a "Guess Who" game, an audience poll and a presentation on a gender perception study currently underway. Conference delegates of any gender are encouraged to attend and participate in the discussion. Tickets are free but you must have registered through the conference registration system before 19th January.

The lunch will be held in parallel to the main conference lunch on Tuesday 13 February and will be held on The Deck.

For information on and some advice from our female invited speakers please see the Question-and-Answer interviews at: austms.org.au/special-interest-groups/wimsig/wimsig-qas/anziam-2024-qa/

The 2024 WIMSIG Lunch has been organised by Dr Adriana Zanca, Lucy Harrison, Isobel Abell, Dr Punya Alahakoon, and Prof Jennifer Flegg on behalf of the AustMS WIMSIG. Information on WIMSIG is available at austms.org.au/special-interest-groups/wimsig/

Lunch is supported by ANZIAM, WIMSIG, the School of Mathematics and Statistics at the University of Melbourne and the Australian Research Council through Jennifer Flegg's Future Fellowship.

4.11 ANZIAM AGM

The 49th AGM of ANZIAM will be held at 7:30 pm (ACDT) on Tuesday 13th February in the Plenary Room and on Zoom (http://tinyurl.com/bdz2s2ak). All ANZIAM members are welcome and encouraged to attend this meeting. The link for agenda and reports will be emailed to all members a week prior to the AGM.

4.12 SigmaOpt Workshop

SigmaOpt, the optimisation special interest group of ANZIAM, is holding a one-day workshop in Adelaide City on the day after the 2024 ANZIAM Conference. The workshop will feature talks from five invited speakers as well as the Winner of the Student Best Paper Prize.

- *When:* Friday 16 February 2024, 9:45am–2:15pm
- *Where:* Room RR5-09 at the City West Campus of UniSA
- *Cost:* $50 AUD. (You must have registered through the conference registration system before 19th January.)
- *Invited Speakers:*
  - Kate Helmstedt (QUT)
  - Yalcin Kaya (UniSA)
  - Vicky Mak (Deakin)
  - Lindon Roberts (USyd)
  - Golbon Zakeri (UMas Amherst, USA)
  - The Winner of the Student Best Paper Prize (announced at the workshop)

4.13 Mathematical Biology Special Interest Group Meeting

The annual one-day Mathematical Biology Special Interest Group (MBSIG) Workshop will be held after the main ANZIAM Conference. The Workshop will feature talks from five invited speakers and the Winner of the Student Best Paper Prize, and a panel discussion on interdisciplinary research in mathematics and biology.

- *When:* Friday 16 February 2024, 9:45am–3pm
- *Where:* Bradley Forum, City West Campus, UniSA, North Terrace, Adelaide
- *Cost:* $30 AUD. (You must have registered through the conference registration system before 19th January.)
- *Invited Speakers:*
  - Bronwyn Gillanders (The University of Adelaide)
  - Matthew Holden (The University of Queensland)
  - Noa Levi (Queensland University of Technology)
  - Pantea Pooladvand (UNSW Sydney)
  - Michael Samuel (Centre for Cancer Biology, UniSA)
  - Antony Selvan (The University of Melbourne; Best Student Paper Prize Winner)

5 Conference Events at a Glance

Time	Sun 11 Feb	Mon 12 Feb	Tue 13 Feb	Wed 14 Feb	Thu 15 Feb	Time
7:30–8:20			LGBTIQA+ and Allies breakfast			7:30–8:20

Time	Sun 11 Feb	Mon 12 Feb	Tue 13 Feb	Wed 14 Feb	Thu 15 Feb	Time
8:40		Welcome	Plenary Zakeri			8:40
9:00		Plenary Abrahams		Plenary Nataraj	Plenary Roberts	9:00
9:20						9:20
9:40			Contributed talks			9:40
10:00		Contributed talks		Contributed talks	Contributed talks	10:00
10:20						10:20
10:40			Morning tea		Morning tea	10:40
11:00		Morning tea	Contributed talks	Morning tea	Contributed talks	11:00
11:20		Contributed talks		Contributed talks		11:20
11:40						11:40
12:00			Plenary Bennetts		Plenary Jenner	12:00
12:20						12:20
12:40						12:40
1:00		Lunch	Lunch / WIMSIG Lunch	Lunch	Lunch	1:00
1:20						1:20
1:40						1:40
2:00		Plenary Fulton		Plenary Lustri		2:00
2:20						2:20
2:40						2:40
3:00		Contributed talks		Contributed talks		3:00
3:20						3:20
3:40	Registration opens	Afternoon tea		Afternoon tea		3:40
4:00	ANZIAM Exec (4-6pm)	Contributed talks		Contributed talks		4:00
4:20						4:20
4:40						4:40
5:00						5:00
5:20						5:20

Time	Sun 11 Feb	Mon 12 Feb	Tue 13 Feb	Wed 14 Feb	Thu 15 Feb	Time
6:30	Opening BBQ	Student social event		Conference dinner		6:30
7:30			ANZIAM AGM			7:30
8:30						8:30

6 Plenary Lectures and Invited Speakers Information

Day and Time	Speaker	Invited talk title
Monday 9:00	David Abrahams	A historical look at analytical approaches to wave diffraction and scattering
Monday 2:00	Beth Fulton	Our complex world creates holes in predictive capacity, is that really a bad thing?
Tuesday 8:40	Golbon Zakeri	Optimal investment and operation of green electricity systems
Tuesday 12:00	Luke Bennetts	Of ocean waves and ice shelves
Wednesday 9:00	Neela Nataraj	A unified framework for lowest-order FEM for fourth-order plates
Wednesday 2:00	Christopher Lustri	Stokes' phenomenon and numerical analytic continuation
Thursday 9:00	Tony J. Roberts	Form macroscale models via an ensemble of microscale phase-shifts
Thursday 12:00	Adrianne Jenner	Compare the pair: mathematics of disease responses and treatment variability

A historical look at analytical approaches to wave diffraction and scattering

David Abrahams
University of Cambridge

This historical talk aims to offer an overview of the elegant and powerful methods, developed over more than a century, to obtain explicit expressions for diffracted (and scattered) wave fields in certain canonical geometries. It will not be a chronology of key results, nor exhaustive in its scope, but will aim to inform, and hopefully interest, a broad applied mathematics audience about a few of the key (mostly complex variable) techniques employed and results obtained. The latter have found direct and enduring application in many areas of physics and engineering, including acoustics, non-destructive evaluation (NDE) of materials, water waves, seismology, sonar, radar and medical imaging.

Bio: David Abrahams is Professor of Applied Mathematics at the University of Cambridge, United Kingdom. He received his PhD in theoretical acoustics from Imperial College London in 1982, and then held a number of academic positions in the UK before being appointed to the Beyer Chair in Applied Mathematics at the University of Manchester UK in 1998. He held that post for over 18 years until becoming Director of the Isaac Newton Institute for Mathematical Sciences, Cambridge UK (2016-2021). David specialises in the mathematical modelling, analysis and application of waves in physics and engineering, and has had close links with a number of industrial partners, as well as supporting multidisciplinary research activity. He has made contributions in the fields of underwater and aero acoustics, water waves, elasticity, electromagnetics and non-destructive evaluation. Over the last two decades David and colleagues have been concerned with wave propagation through materials containing complex microstructure with the aim of obtaining effective properties.

David plays an active role within the national and international mathematics communities. In particular, he is a past-President of the Institute of Mathematics and its Application (IMA), and was Scientific Director of the International Centre for Mathematical Sciences, Edinburgh, UK (2014-2016). He also serves on the Board of the International Council for Industrial and Applied Mathematics and the General Assembly of the International Union of Theoretical and Applied Mechanics. David is a Fellow of the Royal Society of Edinburgh and holds honorary/visiting positions at the Universities of Aberystwyth, Edinburgh, Keele and Manchester.

Of ocean waves and ice shelves

Luke Bennetts
The University of Adelaide

Antarctic ice shelves play a crucial role in the climate system. Without their buttressing effect the Antarctic Ice Sheet would flow far more rapidly into the surrounding ocean. But many ice shelves are losing mass, which can initiate dynamic ice sheet instabilities that have the potential to accelerate sea level rise far beyond current projections. Iceberg calving is the source of half of the mass loss from ice shelves, and it is being exacerbated by weakening of the sea ice barrier around the ice shelves. This is allowing large amplitude ocean waves to reach ice shelves, which promote calving through flexure. Sea ice loss and wave impacts have triggered sudden ice shelf disintegration events at the most northerly reaches of Antarctica over recent decades. I will talk about how mathematical models combined with satellite observations are being used to predict the susceptibility of the remaining ice shelves, with a focus on wave-induced strains around ice shelf weaknesses.

Bio: Luke Bennetts has been at the University of Adelaide since 2011, and is currently an Associate Professor of Applied Mathematics. During that time, he has been an ARC DECRA Fellow and is in the final few months of a Future Fellowship. Prior to moving to Adelaide, he received a PhD in Applied Mathematics in 2007 from the University of Reading, UK, and was a postdoc at the University of Otago, NZ, from 2007–2011. His research interests are in water waves, metamaterials and Antarctic/Southern Ocean science. He works on multidisciplinary projects and has close collaborations with members of CSIRO, BoM, the Australian Antarctic Division and DSTG. He is active in his research communities, as the Chair of the KOZWaves wave science community, as a lead organiser of a 6-month Isaac Newton Institute Programme in 2023, as the AustMS Vice President—Annual Conferences, and as co-Chair of ANZIAM 2024.

The 2023 E. O. Tuck Medal was awarded to Luke for outstanding research and distinguished service to the field of applied mathematics.

Our complex world creates holes in predictive capacity, is that really a bad thing?

Beth Fulton
CSIRO

Mathematics has proved to have immense predictive skill in ocean environments, especially in terms of physical processes. Predictive capacity is not as strong as biological and human dimensions are drawn into models or at decadal scales. However, given that we live at a time of unprecedented change even models with only moderate skill still outperform intuitive human expectations. This talk touches on where gaps remain (and skill can continue to improve) but also how combining the rigour of mathematics with human imagination can take people a long way in planning for an uncertain future.

Bio: Dr Beth Fulton is a Chief Research Scientist with CSIRO. Beth is the CSIRO's research domain leader for integrated oceans stewardship and the blue economy. In shaping the strategic direction for CSIRO's research in this area, she is building off more than 20 years of work developing various system modelling tools for looking at marine ecosystems and sustainability. Beth is also an Adjunct Professor and Deputy Director at the Centre of Marine Socioecology, a collaboration between University of Tasmania, CSIRO and the Australian Antarctic Division, which focuses on finding transdisciplinary, equitable and sustainable solutions to the problems facing coasts and oceans. The common theme to Beth's work has been on developing system-scale decision support tools in support of sustainable management of potentially competing uses of marine environments and adaptation to global change. Beth has more than 200 peer reviewed publications, has contributed to IPCC and IPBES reports; and is a highly cited researcher in her field. Her contribution to marine resource management and science have been recognised with numerous awards, including election to the Australian Academy of Science (2022) and the Australian Academy of Technological Sciences and Engineering (2022); the Beverton Medal (2020) and Kay Radway Allen award (2019) for lifelong and outstanding contributions to fisheries science; biennial medal of the Modelling and Simulation Society of Australia and New Zealand (2017); Ecological Society of America Sustainability Science Award (2011); a Pew Marine Conservation Fellowship (2010-2014); and the 2007 Australian Science Minister's Prize for Life Scientist of the Year.

Compare the pair: mathematics of disease responses and treatment variability

Adrianne Jenner
Queensland University of Technology

We are all unique and, as a result, experience different disease courses and responses to treatment. A great example of this is Coronavirus disease (COVID-19) where we see huge variation in individual responses to infection, with some people experiencing mild symptoms and other's experiencing severe, long-term effects. Capturing the variability in population-level responses to a disease and its treatment can be challenging and while mathematical modelling is useful in allowing us to formulate a picture of a disease, it can be hard to know how to capture this inherent human variability. Fortunately, mathematical techniques, such as agent-based models, digital twins and in silico clinical trials, provide a way to model heterogeneity in individual disease responses and allow for more reliable predictions of patient outcomes.

In this talk, I'll present how we've been using data, combined with mathematical modelling, to improve our understanding of diseases such as cancer and COVID-19. This talk will cover a range of techniques, including ordinary/partial differential equations, and how we can build these models to represent our body's response to infection and the presence of cancer cells.

Bio: Adrianne Jenner obtained her PhD in Applied Mathematics from the University of Sydney in 2019. At the end of her PhD, she was awarded a Quebec Postdoctoral Fellowship and moved to Montreal, Canada, to undertake research at the University of Montreal. In early 2021, she was offered a position at Queensland University of Technology and moved back to Australia where she is now a Lecturer in the School of Mathematical Sciences at QUT.

Adrianne's research focuses on the applications of mathematical modelling in biology and medicine. This includes the use of deterministic and stochastic modelling to answer fundamental questions that improve our understanding of diseases, such as cancer, COVID-19 and multiple sclerosis. For the most part, Adrianne's research has been in developing mathematical models of biological phenomenon that are closely calibrated to data. Since 2018, she has published 26 papers in a range of mathematical, biological and medical journals. Recently, Adrianne was awarded an ARC Discovery Early Career Researcher Award (DECRA) for her research titled "Behind the barrier: using mathematics to understand the neuro-immune system".

Stokes' phenomenon and numerical analytic continuation

Christopher Lustri
University of Sydney

Stokes' phenomenon is an asymptotic effect in singularly-perturbed systems that can't be seen using classical power series methods. I will provide a survey of what it is, why it happens, and some physical contexts in which it plays an important role. I will then explain how Stokes' phenomenon is studied using methods known as "exponential asymptotics".

These methods have been used to study nonlinear waves in particle chains, and to explain the appearance of generalised solitary waves. I will explain why "standard" exponential asymptotics is effective in studying certain particle chains, but also the limitations that restrict its usefulness in others (including the significant case of Hertzian chains).

Finally, I will show that these limitations can be overcome using numerical analytic continuation, such as the AAA method, to study the structure of complex-plane singularities in the underlying nonlinear waves. By combining this with exponential asymptotics, I will calculate the nonlinear wave behaviour seen in challenging Hertzian particle systems, and explain why this hybrid method substantially increases the utility of exponential asymptotics.

Bio: Chris studied for his undergraduate degree at the Queensland University of Technology, before pursuing a doctorate at The University of Oxford, studying exponential asymptotics in free-surface flows. He spent time as a postdoctoral researcher at The University of Sydney working on discrete integrable systems, and was then employed in continuing positions at Macquarie University and now at The University of Sydney.

Chris' research interests revolve around the development and application of asymptotic methodology. He specialises in contemporary asymptotics techniques including exponential asymptotics and transasymptotic analysis, as well as discrete-to-continuum asymptotics. He has used these techniques to study problems with physical applications such as water waves and Hele-Shaw flow, particle chain behaviour, and period-doubling bifurcations, as well as the evolution of PDE solutions in the complex plane. In addition to his mathematical work, Chris has worked in interdisciplinary teams with researchers from biology and physics, and has published results in multidisciplinary journals including Carbon and PNAS. Chris' career highlights include receiving the J. H. Michell medal in 2023, the organisation of two Newton Institute programmes, and the publication of an invited article in the Transactions of the Royal Society issue commemorating the 200th anniversary of the birth of G. G. Stokes.

The 2023 J. H. Michell Medal was awarded to Chris for distinguished research in applied and/or industrial mathematics within ten years of Ph. D.

A unified framework for lowest-order FEM for fourth-order plates

Neela Nataraj
Indian Institute of Technology Bombay

A unified framework for fourth-order plate problems with general sources allows for quasi-best approximation with lowest-order finite element methods. The talk discusses the stability and error control in the piecewise energy and weaker Sobolev norms under minimal hypotheses. Applications include the biharmonic problem, stream function vorticity formulation of the incompressible 2D Navier-Stokes equations, and the von Kármán equations with Morley, discontinuous Galerkin, and the C0 interior penalty schemes.

Bio: Professor Neela Nataraj obtained her Ph.D. in 1998 from IIT (Indian Institute of Technology) Delhi under the supervision of Prof. P.K. Bhattacharyya. She was appointed a faculty member in the Department of Mathematics at the same institute in 1999. Neela has been at IIT Bombay since 2003 and became a full professor in 2014. She served as the Head of the Mathematics department during 2015–2018 and Professor-in-Charge at the IIT Bombay Monash Research Academy during 2019–2021. She served as the Chairperson of the Indian Women and Mathematics (IWM) in the past and is now a member of the International Advisory board. She has also served as a Member of IMU CWM in the past. Currently, she is the Dean of Faculty Affairs at IIT Bombay.

Neela's research interests include finite element methods, finite volume methods and discontinuous Galerkin methods for linear and nonlinear elliptic problems. She is an elected Fellow of Indian Science Academies (FNASc and FASc) and has been a recipient of the INSA Teaching Award (2019) and IIT Bombay Excellence in Teaching Award several times.

Form macroscale models via an ensemble of microscale phase-shifts

Tony J Roberts
The University of Adelaide

Many physical scenarios involve detailed microscale physics in large-scale macroscale domains. For example, modern 'smart' materials have complex microscale structure, often with unknown macroscale closure. For such multiscale systems, we research the relation between the descriptions at the different space and time scales. Here let's explore the closures required to translate microscale knowledge to a system-level macroscopic description. Endemic practice is to identify processes in 'Representative Volume Elements' (RVEs), typically leading to macroscale continuum PDEs. The example of Brownian Bugs shows that such RVE arguments are unsound. Instead, RVEs should be reinterpreted via ensemble averages. Similarly, homogenised models of heterogeneous microscale structures invariably invoke RVEs. Simple heterogeneous problems illustrate that we should instead homogenise via the ensemble of all phase-shifts of the heterogeneity. Such a framework also empowers efficient and accurate computational homogenisation.

Bio: Tony Roberts obtained his PhD from the University of Cambridge in 1982 for the dissertation 'Nonlinear buoyancy effects in fluids'. After a lectureship at The University of Adelaide, in 1993 Tony became the Foundation Professor of Applied Mathematics at the University of Southern Queensland. In 2008, Tony returned to The University of Adelaide as Professor of Applied Mathematics, and since 2020 has been Emeritus Professor at Adelaide. Throughout his career, Tony has given extensive support to Australian mathematics though a variety of positions, such as member of the Council of the AustMS and member of the College of Experts of the ARC. In 1997 he founded the Electronic Supplement of the ANZIAM J, and was the Electronic Editor for over 25 years.

Tony is a world leader in developing and applying modern dynamical systems theory, in conjunction with new computer algebra algorithms, to derive and interpret mathematical and computational models of complex multiscale systems. He works primarily on the emergent complexities and computational modelling of spatio-temporal dynamics in engineering and physics, with his research covering diverse topics such as turbulent floods, thin film flows, fractionation, thermoviscoelasticity, the quasi-geostrophic approximation, and numerical discretisation. Tony has provided free, fast and flexible computer-algebra algorithms, shown how normal form transforms provide slow and fast modes in stochastic systems, and contributed to 'equation-free' modelling for the computation of the evolution of complicated microscopic systems at a macroscopic scale. Tony's excellence in research has been recognised and supported by nineteen ARC research grants.

The 2023 ANZIAM Medal was awarded to Tony in recognition of his substantial contributions to applied mathematics research and his dedication to the Australian mathematics community.

Optimal investment and operation of green electricity systems

Golbon Zakeri
University of Massachusetts Amherst

We consider Markov decision processes (MDPs) arising from a Markov model of an underlying natural phenomenon, in particular (power generation from) wind, electricity demand and inflows into a hydro-lake. Such phenomena are usually periodic (*e.g.* annual) in time, and so the Markov processes modelling them must be time-inhomogeneous, with cyclostationary rather than stationary behaviour.

We describe a technique for constructing such processes that allows for periodic variations both in the values taken by the process and in the serial dependence structure. The formulated MDPs allow us to capture the steady state operation of an electricity system succinctly. Such compact operational formulation in turn allows us to add an upper level problem that would guide the capital expenditure investment for reliability and efficiency of the system.

This is work conducted with Arash Khojaste and Geoff Pritchard.

Bio: Golbon Zakeri is Professor of Operations Research at the University of Massachusetts, Amherst, Department of Mechanical and Industrial Engineering. She is the Director of Northeast Power Economics and Analytics Research Lab (PEARL). Prior to joining UMass Amherst, she was an Associate Professor at the University of Auckland, New Zealand, where she worked closely with the New Zealand electricity sector and where she served as the President of the Operations Research Society of New Zealand (20132017). She received a Ph.D. in Mathematics and Computer Sciences from the University of Wisconsin-Madison and was a Postdoctoral Research Associate at Argonne National Lab.

Golbon's research focuses on decision making under uncertainty with particular emphasis on economics and analytics of power systems. She uses mathematical modelling to translate energy problems into optimization under uncertainty and equilibrium models to derive insight on how to best design policies and systems that result in efficient, reliable, resilient and equitable procurement of energy. She has published in flagship journals of Operations Research, Mathematics of Operations Research, SIAM Journal on Optimization, Mathematical Programming, Applied Energy, IEEE Transactions on Power Systems, etc. She is the Editor of INFORMS-Springer collection and serves as an Associate Editor for Operations Research and Computational Management Science journals.

7 Contributed Talks

The program is shown on the following pages. The duration of each contributed talk will be 15 minutes with an additional 5 minutes for questions and changeover.

Monday morning

*student talk   [J]JSIAM/ANZIAM collaboration

8:00-8:30 8:30–9:00	Registration Conference Opening
9:00–9:50	**Invited talk: Abrahams, David** A historical look at analytical approaches to wave diffraction and scattering (p19) *Chair: Yvonne Stokes*

	Upper North *Chair: Adelle Coster*	**Upper South** *Chair: P. Pooladvand*	**Lakeview** *Chair: Rahil Valani*	**Business Centre** *Chair: Tony P. Roberts*	**Summit Centre** *Chair: Hinke Osinga*
10:00–10:20	**Gray, Catheryn** Right place, right time, right activation (p62)	**Korsah, Maame*** Mathematical assessment of the role of intervention programs for malaria control (p79)	**Meylan, Mike** Theory of piezolectric and other hydroleastic wave energy converters (p91)	**Rajapaksha, Thakshila*** Linear convergence of tilt-correct DFO proximal bundle method (p107)	**Wechselberger, Martin** Shock selection rules in composite regularised reaction-nonlinear diffusion models (p123)
10:20–10:40	**Levi, Noa*** Mathematical models of therapeutic intervention in robust chemical reaction networks (p84)	**Foo, Yong See*** Interplay between model fitting and model construction for biological dynamical systems (p59)	**Westcott, Amy-Rose*** Broadband energy capture by an array of heaving buoys (p125)	**Challis, Vivien** Optimisation of a multi-functional piezoelectric component for a climbing robot (p52)	**Marangell, Robert** Stability of asymptotic waves in the Fisher-Stefan equation (p87)
10:40–11:00	**Kuba, Shahak*** Incorporating cell mechanics into a model of biological tissue growth within confined spaces (p80)	**Harrison, Lucinda*** Near optimal selection of sites for mosquito surveillance of Japanese encephalitis virus in Australia (p66)	**McCue, Scott** Three-dimensional linear gravity-capillary wave patterns (p89)	**Bui, Thi Hoa** Cutting plane algorithms are exact for Euclidean max-sum problems (p49)	**Miller, Thomas*** Shock positions for regularized reaction-diffusion equations with negative diffusivity (p92)
11:00–11:20	Morning tea on The Deck				

Monday morning (continued)

*student talk   [J]JSIAM/ANZIAM collaboration

	Upper North *Chair: Zoltan Neufeld*	Upper South *Chair: Michael Plank*	Lakeview *Chair: Scott McCue*	Business Centre *Chair: M. Wechselberger*	Summit Centre *Chair: Peter Taylor*
11:20–11:40	**Johnston, Stuart** Efficient modelling of heterogeneous cell populations (p74)	**Anwar, Md Nurul*** Investigation of Plasmodium vivax elimination under mass drug administration (MDA) (p42)	**Amarathunge Achchige, Tharindi*** Pattern formation of precursor films: a new mathematical model (p42)	**Smith, Lauren** Model reduction for finite networks of coupled oscillators with higher order interactions (p114)	**Huang, Boris*** Compounded Sibuya random walks and the fractional graph Laplacian (p71)
11:40–12:00	**Georgiou, Fillipe** Including organism and environmental heterogeneity in collective behaviour: looking at locusts (p60)	**Nitschke, Cody** Modelling the impact of infectious disease introduced to Australia through European contact (p99)	**Kedda, Steven*** Self-similarity in non-Newtonian thin films (p76)	**Subramanian, Priya** Rogue bursts as an effect of broken symmetry (p116)	**McArthur, Harry*** Balancing the privacy and utility with margin-consistent noise (p89)
12:00–12:20	**Oelz, Dietmar** Emergence of asymmetry in Hydra spheroids (p101)	**Lydeamore, Michael** Generating synthetic contact matrices using open-source data (p86)	**Yang, Xinyi*** Escape motility of multicellular magnetotactic prokaryotes (p127)	**Krauskopf, Bernd** Emergence of a blender: weaving a carpet from one-dimensional global manifolds (p80)	**Xing, Chenchen*** Pricing for perishable goods in a queueing system (p127)
12:20–12:40	**Dharma, Rodney*** Resolving spatial heterogeneity in microbial symbiosis (p54)	**Ryan, Matt** BaD transmission modelling: Incorporating human behaviour into simple models of disease transmission (p108)	**Dallaston, Michael** Thin filament modelling of Hele-Shaw flow (p53)	**Osinga, Hinke** A dynamical systems approach to low-damage seismic design (p102)	**Zhang, Xinyi*** Pricing American down-and-out call options with transaction costs (p129)
12:40–1:00	**Murphy, Ryan** Quantifying biological heterogeneity in nanoparticle-cell interaction experiments (p95)	**Hickson, Roslyn** Buzz off! Suppressing the neglected mosquitoes transmitting neglected diseases (p67)	**Pototsky, Andrey** Electromagnetically driven flow in unsupported electrolyte layers: lubrication theory and linear stability of annular flow (p106)	**Bailie, John*** Resonance structure due to periodic forcing: case study of a climate model with seasonal variation (p45)	**Roughan, Matthew1** Randomly surreal (numbers) (p107)
1:00–2:00	Lunch on The Deck				

Monday afternoon

*student talk [J]JSIAM/ANZIAM collaboration

	Upper North *Chair: Stuart Johnston*	Upper South *Chair: Matt Ryan*	Lakeview *Chair: Steve Taylor*	Business Centre *Chair: Ryan Murphy*	Summit Centre *Chair: Boris Baeumer*
2:00–2:50	**Invited talk: Fulton, Beth** Our complex world creates holes in predictive capacity, is that really a bad thing? (p21) *Chair: Melanie Roberts*				
3:00–3:20	**Ivory, Elizabeth*** Agent-based modelling of *Plasmodium vivax* under treatment with radical cure (p73)	**Flegg, Jennifer** A spatiotemporal model of multi-marker antimalarial resistance (p58)	**O'Kane, Terence2** Bayesian structure learning for climate model evaluation (p100)	**Roughan, Matthew2** The polylogarithm function in Julia (p108)	**Joshi, Nalini** Dynamics through the lens of cryptography (p74)
3:20–3:40	**Stadler, Eva** Translation of the resistance risk for the antimalarial drug cabamiquine across infection models (p115)	**Baker, Christopher** Developing real-time modelling capabilities for emergency animal disease outbreaks. (p45)	**Grant, Patrick*** Simple wood, complex challenges: modelling moisture migration and swelling in timber boards (p62)	**Wegert, Zachary2*** An extendable *Julia*-based set of scalable computational tools for level set-based topology optimisation (p124)	**Morrison, Peter*** Hyperbolic special functions and the projection-slice theorem (p94)
3:40–4:00	Afternoon tea on The Deck				

Monday afternoon (continued)

*student talk [J]JSIAM/ANZIAM collaboration

	Upper North *Chair: Adrianne Jenner*	Upper South *Chair: Maud El-Hachem*	Lakeview *Chair: Edward Hinton*	Business Centre *Chair: Bernd Krauskopf*	Summit Centre *Chair: Mark McGuinness*
4:00–4:20	**Williams, Thomas*** Incorporating the structure of the lung into models of respiratory viral infections (p126)	**Holden, Matthew** The value of information paradox (p68)	**Oliver, Dylan*** Dual-grid mapping method for the advection-diffusion-reaction equation in a heterogeneous medium (p101)	**Dipierro, Serena** Analysis of an ecological niche: competition versus cooperation (p55)	**Kapsis, Maria*** Managing peak power demand for a fleet of trains (p75)
4:20–4:40	**Jayathilake, Chathranee*** Tractability of biochemical signalling models (p73)	**Pascal, Luz*** When to stop investing in technology development for ecosystem management? (p103)	**Mansoor, Wafaa Faisal** Modelling of dispersal of hydrogen in the retina: Axisymmetric solution (p87)	**Burney, Stuart-James*** Properties of novel exact solutions to advection equations and diffusion equations with time-delay (p50)	**Bala, Indu** Optimizing neural network training: the impact of Levy-Flight and Chaos in Artificial Electric Field Algorithm (p46)
4:40–5:00	**Lee, Lloyd*** The effect of calcium influx on calcium signalling (p83)	**Stewart, Owen*** Applying modern portfolio theory to marine spatial management (p102)	**Watt, Simon** Critical initial conditions in competitive exothermic-endothermic reaction systems (p122)	**Suda, Tomoharu**[J] Effective reaction rates in chemical reaction networks (p117)	**Kolyaei, Mary*** A reinforcement learning method for optimizing the omnichannel retail problems (p79)
5:00–5:20	**Sharma, Akshay** Uncovering the secrets of cancer: discover how microRNA-17-92 utilises transcriptional and translational time delays to control the gene expression network (p111)	**Mills, Elise*** A generalised sigmoid population growth model with energy dependence: application to quantify the tipping point for Antarctic shallow seabed algae (p92)	**Myerscough, Mary** Mathematical tools for science students—a context-driven applied mathematics service unit (p95)	**Mancini, Renzo*** Bifurcation analysis of a two-delay model for the Atlantic Meridional Overturning Circulation (p86)	**Sadegh Zadeh, Hajar*** Comprehensive forecasting of emergency cases arrivals for surgical departments: a comparative analysis of existing approaches (p109)
6:30	Student social event at the Hahndorf Inn				

Tuesday morning

*student talk [J]JSIAM/ANZIAM collaboration

7:30–8:20	LGBTIQA+ and Allies Breakfast on The Deck				
8:40–9:30	**Invited talk: Zakeri, Golbon** Optimal investment and operation of green electricity systems (p26) *Chair: Matthew Tam*				
	Upper North *Chair: D.Netherwood*	**Upper South** *Chair: Roslyn Hickson*	**Lakeview** *Chair: Judy Bunder*	**Business Centre** *Chair: Simon Clarke*	**Summit Centre** *Chair: Amie Albrecht*
9:40–10:00	**Kearney, Taylor*** Enzyme kinetics simulation at the scale of individual particles (p75)	**Le, Thao** Agent-based modelling in the post-Omicron era of COVID-19 management (p83)	**Peter, Malte** Identification of microstructural information from macroscopic boundary measurements in linear elasticity (p104)	**McGowan, Sean*** Modal error analysis and prediction compensation for Earth system models (p90)	**Bottema, Murk** Information geometry for bats (p48)
10:00–10:20	**Binder, Benjamin** Modelling spatial growth pattern formation in yeast colonies (p48)	**Sexton, Justin** Weather or not? Exploring the impact of human movement and weather on dengue outbreaks in Pacific Island Countries (p110)	**Saini, Babita** Mathematical modelling of empirical correlations and validation of shear strength of high strength steel fibres reinforced concrete beams (p109)	**Axelsen, Andrew*** Hyperbolicity and southern climate dynamics (p44)	**Newcombe, Alex** Implementation aspects of passive geolocation (p98)
10:20–10:40	**Li, Kai*** Modelling of cylindrical yeast colony growth (p85)	**Diao, Jiahao** Effectiveness of isolating infected cases with low viral loads at different stages of outbreak (p55)	**Kajiwara, Kenji**[J] A truss structure with mechanical optimality, integrability and artisiticity (p74)	**Kitsios, Vassili** Data-driven and physics-constrained reduced order model of the global oceans (p78)	**Oishi-Tomiyasu, Ryoko**[J] Packing theory derived from phyllotaxis and products of linear forms (p101)
10:40–11:00	Morning tea on The Deck				

Tuesday morning (continued)

*student talk [J]JSIAM/ANZIAM collaboration

	Upper North *Chair: Mary Myerscough*	Upper South *Chair: Lewis Mitchell*	Lakeview *Chair: Malte Peter*	Business Centre *Chair: Robert Marangell*	Summit Centre *Chair: Sergiy Shelyag*
11:00–11:20	**Hancock, Edward** Mechanisms of plateau formation for oscillations in lymphatic muscle cells (p65)	**Kollepara, Pratyush*** Heterogeneity in network structure switches the dominant transmission mode of infectious diseases (p78)	**Aljabri, Rehab*** Time-dependent vibrations of an ice shelf (p41)	**Lapuz, Timothy*** A multiple time scale analysis of an immunogenic tumour model (p81)	**O'Kane, Terence1** Realizable Markovian closures for anisotropic and inhomogeneous turbulent flows (p100)
11:20–11:40	**Ndenda, Joseph** A mathematical model for the role of smooth muscle cells phenotype switching in atherosclerotic plaque (p96)	**Abell, Isobel*** Modelling the spread of varroa mite on a network of European honeybee hives (p40)	**Alberello, Alberto** Dynamics of nonlinear water waves in dissipative media (p41)	**Groothuizen Dijkema, David*** Switching near heteroclinic networks as a piecewise-smooth dynamical system (p64)	**Li, Dan** Forecasting climate change impacts on the production of crops key to food security (p84)
11:40–12:00	**Filippini, Luke*** Surrogate models for diffusive transport in radially-symmetric media (p58)	**Isaac, Zac*** Modelling light presented to the human fetus using Monte Carlo simulations (p71)	**Liang, Jie*** Pan-Antarctic assessment of ocean wave induced flexural stresses on ice shelves (p85)	**Moolchand, Prannath** Understanding the active metabolic oscillatory subsystem in pancreatic beta cells using geometric singular perturbation techniques. (p93)	**Groom, Michael** Data-driven prediction of the El Niño–Southern Oscillation using entropy-optimal Scalable Probabilistic Approximations (p63)
12:10–1:00	**Invited talk: Bennetts, Luke** Of ocean waves and ice shelves (p20) *Chair: Mike Meylan*				
1:00–2:00 1:00–2:30	Lunch on the Upper Level WIMSIG Lunch on The Deck				
7:30–8:30	ANZIAM AGM in Upper North and Upper South				

Wednesday morning

*student talk [J]JSIAM/ANZIAM collaboration

9:00–9:50	**Invited talk: Nataraj, Neela** A unified framework for lowest-order FEM for fourth-order plates (p24) *Chair: Brendan Harding*

	Upper North *Chair: Ben Binder*	**Upper South** *Chair: Matthew Holden*	**Lakeview** *Chair: Larry Forbes*	**Business Centre** *Chair: Tony J. Roberts*	**Summit Centre** *Chair: Michael Haythorpe*
10:00–10:20	**Buenzli, Pascal** Solving hard reaction–diffusion PDEs with simple discrete models (p49)	**Zarebski, Alexander** Deep learning for genetic epidemiology (p129)	**Huppert, Herbert** Chemical gardens: the origin of life? (p71)	**Aldosri, Afnan*** Mode matching analysis of the two-dimensional waveguides (p41)	**Boyle, Laura** Simulation modelling of the delayed discharge problem in hospitals (p48)
10:20–10:40	**Tam, Alex** Though the yeasty waves confound (p118)	**Eales, Oliver** The effect of antigenic seniority on the timescales of influenza infection risk following vaccination (p56)	**Iqbal, Tasawar*** Hydrodynamics of filter feeders (p72)	**Bunder, Judy** Boundary conditions with macroscale equation-free modelling (p50)	**Wu, David** Temporal trends of hospital transfer networks in Victoria for controlling the spread of antibiotic resistance (p126)
10:40–11:00	**Netherwood, Daniel** A model for accidental and regulated cell death during the expansion of yeast biofilms (p97)	**Pooladvand, Pantea** How cultural innovations trigger the emergence of new pathogens (p105)	**Harding, Brendan** Fluid flow through an involute spiral (p65)	**Soenjaya, Agus*** Finite element methods for some micromagnetic models at elevated temperature (p114)	**Gupta, Hritika*** Transient waiting time distributions in call centres with skills-based routing (p64)
11:00–11:20	Morning tea on The Deck				

Wednesday morning (continued)

*student talk [J]JSIAM/ANZIAM collaboration

	Upper North *Chair: Mat Simpson*	Upper South *Chair: M. Lydeamore*	Lakeview *Chair: Andrey Pototsky*	Business Centre *Chair: N. Thamwattana*	Summit Centre *Chair: David Skene*
11:20–11:40	**Neufeld, Zoltan** Travelling wave model of competitive cell invasion (p98)	**Sherlock, Brock*** A closed queuing model for GLUT4 dynamics: an exploration of mechanisms (p112)	**Cockerill, Madeleine*** A Boussinesq model of a non-spherical bubble with a magnetic field (p53)	**Mitchell, Lewis** Complex systems and networks approaches to modelling atrial fibrillation (p93)	**Burdett, Ryan*** An effective heuristic approach for the domination problem and its variants (p50)
11:40–12:00	**Alsubaie, Faris*** The effect of cell motility on competitive invasion of epithelial monolayers (p57)	**Tobin, Ruarai*** Compartmental models of infectious disease dynamics with correlates of immunity (p121)	**Nisar, Muhammad*** Absolute and convective instability of a radial jet with swirl (p99)	**Baeumer, Boris** Super-diffusive approximations of solutions to non-linear stochastic PDEs (p44)	**de Jong van Lier, Matias*** Topological smoothing of a signal over a planar graph (p54)
12:00–12:20	**Marriott, Rory*** Mathematical modelling of solute pathways and residence in human stratum corneum (p88)	**Morris, Dylan*** Computation of random time-shift distributions for stochastic population models (p94)	**Hinton, Edward** Starting vortices generated at the sharp edges of an arbitrary body (p68)	**Shahriari, Zahra*** Ordinal Poincaré sections: reconstructing the first return map from an ordinal segmentation of time series (p111)	**Cesana, Pierluigi** Fully automatized optimization of ring-opening reactions in lactone derivatives via 2-step machine learning (p51)
12:20–12:40	**Khodabakhsh, Neda*** Mathematical model of corneal epithelial cell behaviour (p77)	**Claassen, Daniel*** Statistical Finite Element Modelling for misspecified SST simulation and inversion (p52)	**Suslov, Sergey** Hierarchy of catastrophes in swirling electrolyte (p117)	**Tzou, Justin** Lévy flight versus Brownian search strategies (p121)	**Nakano, Naoto**[J] Path integral approach to universal dynamics of reservoir computers (p96)
12:40–1:00	**Khatun, Mst Shanta*** Voronoi cell-based model of epithelial carcinogenesis evolution (p77)	**Germano, Domenic** Jump-Switch-Flow: hybrid deterministic-stochastic trajectories of compartmental systems (p61)	**Wichmann, Joern** Approximation of stochastic fluid models (p125)	**Taylor, Steve** Velocity jump process with volume exclusions in a narrow channel (p120)	**Qureshi, Naik Bakht Sania*** Utilising machine learning to predict zoonotic spillover risk (p106)
1:00–2:00	Lunch on The Deck				

Wednesday afternoon

*student talk   [J]JSIAM/ANZIAM collaboration

2:00–2:50	**Invited talk: Lustri, Christopher** Stokes' phenomenon and numerical analytic continuation (p23) *Chair: Nalini Joshi*

	Upper North *Chair: Rebecca Chisholm*	**Upper South** *Chair: Cody Nitschke*	**Lakeview** *Chair: Joern Wichmann*	**Business Centre** *Chair: Hoa Bui*	**Summit Centre** *Chair: Jody McKerral*
3:00–3:20	**Weatherley, Georgia*** Tackling the erosion of neurological function: can we restore functional deficits in multiple sclerosis patients? (p123)	**Le, Anthia*** Grandmother care and the origin of menopause (p82)	**Michalski, Hugh*** The effect of bump height and length on the free-surface in open channel flows (p91)	**Taylor, Peter** Using random walks for inference on networks (p119)	**Skene, David** Modelling weapon engagement zones using machine learning (p113)
3:20–3:40	**Yang, Qianqian** Characterising brain cell morphology using a sub-diffusion model for MRI (p127)	**Tan, Eugene*** Being selfish with your relationships: A selfish agent model for opinion dynamics and echo chamber formation (p119)	**Mandoora, Kholod*** Unsteady solutions of the forced Korteweg–de Vries equation with negative forcing and weak dispersion (p87)	**Yeh, Wei-Chang** Efficient allocation of financial resources to ensure dependable resilience in networks (p128)	**Shelyag, Sergiy** Modelling of decision-making in complex conflict environments (p112)
3:40–4:00	Afternoon tea on The Deck				

Wednesday afternoon (continued)

*student talk [J]JSIAM/ANZIAM collaboration

	Upper North *Chair: Alex Tam*	Upper South *Chair: Nick Beeton*	Lakeview *Chair: Terry O'Kane*	Business Centre *Chair: Vivien Challis*	Summit Centre *Chair: Amie Albrecht*
4:00–4:20	**Ahmed, Ishraq** Macrophage motility and cellular cargo transport in a multiphase model for atherosclerotic plaques (p40)	**Holloway-Brown, Jacinta** Improved short-term Antarctic sea ice extent predictions with machine learning and remote sensing data (p70)	**Asiri, Zayed*** Mathematical modelling of the vulnerability of subsea aquifers to seawater intrusion (p43)	**Hoshino, Hidetomo** *[J] Improving stability of covariant BSSN formulation of the Einstein equations against homogeneous and isotropic spacetime background (p70)	**Yoshizumi, Ryo*** Construction of Castryck-Decru attack for B-SIDH and its implementation (p128)
4:20–4:40	**Zanca, Adriana** Cell differentiation architectures (p128)	**Holdorf, Jordan*** When to invest in conservation with climate uncertainty (p69)	**McGuinness, Mark** Bauxite moisture measurement using microwaves (p90)	**Wegert, Zachary1*** Level set-based inverse homogenisation of piezoelectric metamaterials (p124)	**Bandara, Ishara*** Winning with chaos in soccer: entropy-based analysis for team performance evaluation (p67)
4:40–5:00	**Miller, Claire** Modelling immune cell interactions with endometrial cells in endometriosis (p91)	**El-Hachem, Maud** Coexistence in two-species competition with delayed maturation (p57)	**Hocking, Graeme** Putting the eggs before the chickens: a model of chicken farming in Ethiopia (p68)	**Tagami, Daisuke** Numerical analysis of an incomplete balancing Domain Decomposition Method based on Polytopal Elements (p118)	**Keegan-Treloar, Jamie*** Complex-valued neural networks (p76)
5:00–5:20			**Valani, Rahil** Tipping phenomena in inertial focusing and separation of particles (p121)	**Ishida, Sachiko**[J] Geometrical design and mechanical properties of origami-inspired cylindrical honeycomb cores (p72)	**Aksamit, Anna** Entropy and enlargement of filtrations (p41)
6:30	Conference dinner in Upper North and Upper South				

Thursday morning

*student talk   J JSIAM/ANZIAM collaboration

9:00–9:50	**Invited talk: Roberts, Tony J.** Form macroscale models via an ensemble of microscale phase-shifts (p25) *Chair: Herbert Huppert*

	Upper North *Chair: Pascal Buenzli*	**Upper South** *Chair: Mark Flegg*	**Lakeview** *Chair: Bronwyn Hajek*	**Business Centre** *Chair: Phil Broadbridge*	**Summit Centre** *Chair: Pierluigi Cesana*
10:00–10:20	**Han, Daniel Seungmin** Self-reinforcing persistent random walks (p64)	**Roberts, Melanie** Modelling interventions in the MERGE gully erosion model (p107)	**Valdinoci, Enrico** Long-range capillarity theory (p122)	**Kukreja, Vijay** Solution of Fisher's and Burger's-Fisher equation using septic Hermite collocation method (p81)	**Warne, David** Generalised likelihood profiles for models with intractable likelihoods (p122)
10:20–10:40	**Pan, Michael** Modelling resource limitation and competition in gene regulatory networks (p103)	**Plank, Michael** Forecasting Covid-19 in Aotearoa New Zealand (p105)	**Stokes, Yvonne** The effect of internal structure on the stability of fibre drawing (p116)		**Saini, Lalit Mohan** Optimization of switching frequency and pulse width of buck converter based inverter (p110)
10:40–11:00	Morning tea on The Deck				

Thursday morning (continued)

*student talk [J]JSIAM/ANZIAM collaboration

	Upper North *Chair: J. Flegg*	Upper South *Chair: J. Holloway-Brown*	Lakeview *Chair: Mike Chen*	Business Centre *Chair: Graeme Hocking*	Summit Centre *Chair: Murk Bottema*
11:00–11:20	**Berry, Matthew** Predicting protection against Mpox infection (p47)	**Simpson, Matthew** Efficient prediction, estimation and identifiability analysis with mechanistic mathematical models (p113)	**Thamwattana, Natalie** Bio-geochemical clogging in permeable reactive barriers when treating acidic groundwater (p120)	**Campbell, Daniel** Injectivity in second-gradient nonlinear elasticity (p51)	**Haythorpe, Michael** Determining the crossing numbers of certain graph products (p66)
11:20–11:40	**Penington, Catherine** Spatial dynamics of inflammation-causing and commensal bacteria in the gastrointestinal tract (p104)	**Beeton, Nick** Spatial modelling for population replacement of mosquito vectors at continental scale (p47)	**Broadbridge, Philip** Reaction-diffusion models for fish populations with realistic mobility (p49)	**Lather, Jagdeep Singh** Synchronization of two coupled quadcopters using contraction theory (p82)	**Neogy, Samir Kumar** On solving a class of graph theoretic nonconvex optimization problems (p97)
11:40–12:00	**Sohail, Ayesha** Optimizing noninvasive ventilation strategies: a comparative study of mathematical models and machine learning approaches (p115)	**Flegg, Mark** Exact SSA for disease population dynamics coupled to within-host dynamics (p59)	**Forbes, Larry** FireNado! (p59)	**Matsue, Kaname**[J] A unified characterization of blow-up solutions for ODEs through dynamics at infinity (p88)	**Tam, Matthew** A decentralised algorithms for min-max problems (p118)

12:10–1:00	**Invited talk: Jenner, Adrianne** Compare the pair: mathematics of disease responses and treatment variability (p22) *Chair: Alys Clark*
1:00–1:10	Closing remarks and presentation of the Cherry Ripe Prize
1:10–2:00	Lunch on The Deck

8 Contributed Abstracts

Modelling the spread of varroa mite on a network of European honeybee hives

Isobel Abell
The University of Melbourne

Varroa mites are one of the most damaging honeybee pests, impacting beekeeping and agricultural industries globally. Varroa mite infestation can lead to the death of honeybee colonies, with varroa mites often acting as vectors for diseases such as Deformed Wing Virus and Acute Bee Paralysis Virus. In June 2022, varroa mites were detected in biosecurity surveillance hives in the Port of Newcastle (NSW). Since then, they have spread through hives in NSW, but currently have not been detected outside the state. Australia initially attempted to eradicate the mite through hive elimination, but has since moved to a management strategy as of September 2023.

This work is focused on modelling the spread of varroa mites through European honeybee colonies on a network. I consider the reproduction of varroa mites within colonies, and the movement of mites between neighbouring colonies for both feral and managed honeybees. I investigate how factors such as time to initial detection, frequency of testing and sensitivity of testing contribute to how varroa mites spread through managed honeybee colonies, and how long it takes to reach feral honeybee colonies. This work allows us to explore under which scenarios elimination of varroa mites on the network of hives is possible.

Macrophage motility and cellular cargo transport in a multiphase model for atherosclerotic plaques

Ishraq U. Ahmed and Mary R. Myerscough
The University of Sydney

Advanced atherosclerotic plaques contain a large core of necrotic material which is physically inaccessible to newly recruited immune cells. Studies in mice involving latex bead-tagged monocytes (Williams et al 2018) found that labelled monocytes failed to localise in the deep plaque in both progressing and regressing plaques. This suggests that new monocytes were layering superficially over existing material, rather than actively penetrating into the necrotic core. In mathematical terms, this suggests that bulk advective transport is the dominant mechanism of macrophage movement in advanced plaques.

In this talk, we present a free boundary multiphase model for early atherosclerotic plaques that focuses on macrophage motility during plaque progression. A key feature of the model is the inclusion of a latex bead species that is trafficked by the macrophage phase. We discuss how multiphase tissue models can be adapted to account for the transport of cellular cargo species such as beads or cholesterol. We then use our model to simulate several experimental scenarios involving macrophage bead tagging. We discuss how the evolving spatial distribution of the beads offers insight into the dominant mechanisms of macrophage movement in plaques.

Entropy and enlargement of filtrations

Anna Aksamit
The University of Sydney

I will discuss entropy as a measurement of additional information under filtration enlargement. Starting with a reference filtration we look at the stability of appropriate martingale and semi-martingale spaces when considered in the filtration enlarged with a thin random time. The sufficient condition for the stability is expressed in terms of the new notion of entropy of a thin random time. Additionally we give a utility maximisation interpretation of this notion of entropy.

Dynamics of nonlinear water waves in dissipative media

Alberto Alberello, Emilian Parau, Ben Humphries and Amin Chabchoub
University of East Anglia

The nonlinear Schrödinger equation (NLS), a fundamental model for ocean waves, describes the full growth-decay cycles of unstable modes, also known as modulational instability (MI). In this talk I will present a dissipative NLS to model the effect of viscous losses on the ocean surface and I will explore the MI dynamics in the proposed d-NLS framework. Applications to ocean waves propagating in ice-covered regions will be discussed.

Mode matching analysis of the two-dimensional waveguides

Afnan Aldosri
The University of Newcastle

In this work, the propagation and scattering of waves in waveguides or channels connected through rectangular regions is solved by mode matching. We exploit symmetry to find the solution. The final problem we consider is the scattering by two ducts at right angles connected through a rectangular region. The solution has applications in understanding the scattering of acoustic waves in wave guides and to water waves in channels. Time-domain simulations will be given.

Time-dependent vibrations of an ice shelf

Rehab Aljabri
The University of Newcastle

I will explain a method to calculate the vibrations of an ice shelf floating on shallow water under different boundary conditions. In addition, we will examine two conditions at the seaward edge of the ice shelf, no-flux and no pressure. Furthermore, the method extends to find the mode shapes of the ice shelf-water system. These mode shapes describe the system's behaviour and explain what happened in the ice shelf/cavity system. The solutions for the two cases will be simulated in the time domain for the vertical displacement and the potential velocity for different initial conditions. These solutions are obtained through a numerical method that reduces all the calculations to matrix multiplication.

Pattern formation of precursor films: a new mathematical model

Tharindi Amarathunge Achchige, Bronwyn Hajek, Alex Tam and Marta Krasowska
University of South Australia

Ionic liquids are salts that are liquid at room temperature and have great potential as lubricants in high-end applications. However, effective lubrication relies on the ionic liquid forming a stable precursor film over the substrate. These precursor films create different types of patterns on different substrates, and a stable precursor film depends on the type of ionic liquid and the surface of interaction. The ionic liquid and substrate pairs that produce best lubrication are unknown, and at present there is no way to predict the pattern that particular ionic liquid-substrate pairs will form. This study uses mathematical modelling to develop a mathematical tool to screen ionic liquid-substrate pairs that form precursor films of desired patterns for targeted lubrication applications.

Investigation of Plasmodium vivax elimination under mass drug administration (MDA)

Md Nurul Anwar, Roslyn Hickson, James McCaw and Jennifer Flegg
The University of Melbourne

Plasmodium vivax is one of the most geographically widespread malaria parasites and is mainly found in South-East Asia, Latin America, and some parts of Africa. P. vivax is unique compared to most other Plasmodium parasites due to its ability to remain dormant in the human liver as hypnozoites and subsequently reactivate after the initial infection (i.e. relapse infections). More than 80% of P. vivax infections are due to hypnozoite reactivation. Hence, it is crucial to target the hypnozoite reservoir in order to eliminate P. vivax. In this study, we use a stochastic multiscale model to study the impact of multiple mass drug administration (MDA) rounds with a radical cure on P. vivax elimination. We explicitly model the impact of the radical cure drug on each of the hypnozoites and infections. We derive the optimal timings of MDA rounds (under a deterministic framework) and obtain the probability of P. vivax elimination. Our model indicates that the more rounds of MDA, the better the chance of P. vivax elimination and up to two MDA rounds will have a very minimal effect on the probability of elimination (this depends on other model parameters as well). To achieve a higher probability of elimination, MDA with a very high-efficacy drug should be considered.

Mathematical modelling of the vulnerability of subsea aquifers to seawater intrusion

Zayed M. Asiri, Anthony D. Miller, Adrian D. Werner, S. Cristina Solórzano-Rivas and Sergiy Shelyag
Flinders University

Mathematical modelling and non-dimensional sensitivity analysis of the vulnerability of coastal aquifers with offshore extensions to seawater intrusion are described. This extends prior modelling by Werner et al (2012) that considered onshore coastal aquifers. The freshwater-seawater interface is characterised by the tip location (where the interface intercepts the top of the aquifer), the toe location (where the interface intercepts the base of the aquifer), the volume of freshwater in the offshore region and the volume of seawater in the onshore region. The tip location and the offshore freshwater volume are new descriptors for the evaluation of seawater intrusion specific to subsea aquifers, adding to those adopted previously for onshore aquifers. The sensitivity analysis uses an existing steady-state, semi-analytical, sharp-interface model of coastal aquifers with semi-confined offshore extensions.

We solve an ordinary differential equation, which describes the position of the seawater-freshwater interface analytically and numerically. Further, we study the sensitivity of the solution to variation of the parameters, describing the incoming fresh water flow and the length of the offshore aquifer, which may be affected by the climate change. It is found that the toe location and the offshore freshwater volume are very sensitive to changes in the incoming non-dimensional freshwater flow rate Q_{in} when Q_{in} is small, while the tip location is less (or equally) sensitive than the toe location. The offshore freshwater volume increases with Q_{in} and the distance to the offshore limit of the aquifer, as expected. Our analysis demonstrates that the distance between the tip and the toe is constant for different rates of fresh groundwater discharge if both are offshore and the tip has not reached the offshore limit of the aquifer. Sensitivity analysis is applied to seven case studies of subsea aquifers to assess aquifer vulnerability to sea water intrusion caused by climate change effects such as sea-level rise and recharge change. We finally demonstrate that the sensitivity of the freshwater-seawater interface to environmental factors is an important consideration in the management of coastal aquifers.

Hyperbolicity and southern climate dynamics

Andrew Axelsen, Terence O'Kane, Courtney Quinn and Andrew Bassom
University of Tasmania

A major question arises as to how anthropogenic forcing drives secular changes in the metastable states of the weather and climate systems. Answering this question first requires extracting the structures of coherent states within the typically high-dimensional multiscale domains of the earth system. Lorenz famously first applied singular value decomposition (SVD) to isolate time-invariant patterns (empirical orthogonal functions) of the major tropospheric modes and their associated time-series (principal components). Here, we first apply a nonparametric, temporally-regularised, vector autoregressive approach to assign observed data instances (features) to one of k locally stationary states. This allows for an evolving spatio-temporal feature space within the context of an underlying reduced order model whose parameters are fixed.

By applying SVD to the model's matrix cocycle (tangent linear propagator) over a chosen finite time window, we allow the targeting of locally unstable dynamics in terms of mixed initial (right) and evolved (left) singular vectors (MSVs) in an otherwise asymptotically stable, reduced-order model. Transitions to persistent periods where one state is dominant are often characterised by changes in the alignment of the systems MSVs reflected in local hyperbolicity measures. Using this approach, we examine the dynamics of persistent features within the south Pacific mid-troposphere and their association with the Pacific-South American climate modes. The insights from this work are important not only for dynamical approaches applicable to high dimensional multi-scale systems, but are of direct relevance to the development of modern operational ensemble numerical weather prediction systems.

Super-diffusive approximations of solutions to non-linear stochastic PDEs

Boris Baeumer
University of Otago

Maximal regularity for Volterra integral equations can provide solutions to a larger class of non-linear equations. We explore the effects of different kernels, approximating the identity, to the solution behaviour. We use global solutions to the superdiffusive backward heat equation with additive noise as an illustrative example.

Resonance structure due to periodic forcing: case study of a climate model with seasonal variation

John Bailie, Priya Subramanian and Bernd Krauskopf
The University of Auckland

We study a conceptual model that describes the vertical mixing process in the North Atlantic Ocean between surface and deep waters, which plays a significant role in the strength of the Atlantic Meridian Overturning Circulation. The model takes the form of a periodically forced planar vector field for (appropriately rescaled) temperature and salinity. Its three parameters are a density threshold η and the virtual salinity flux μ, which is modulated with amplitude c. For fixed η, one finds dynamics on an invariant torus in a region of the (μ, c)-plane bounded by a curve of torus bifurcation.

We take a mathematical approach and classify the associated structure of resonance tongues, and how it changes with η. To aid our analysis, we implement an algorithm to compute the rotation number ρ on the torus as a graph over the (μ, c)-plane, which enables the determination and visualization of higher-order resonance tongues. By means of singularity theory we identify generic transitions of the overall resonance structure. Specifically, we find merging and disconnecting resonance tongues at extrema of ρ along the boundary, as well as transitions involving singularities of ρ within the interior of the region.

Developing real-time modelling capabilities for emergency animal disease outbreaks.

Christopher Baker, Meryl Theng and Simon Firestone
The University of Melbourne

Emergency animal diseases pose a significant threat to food security. Notable examples are the devastating UK foot and mouth outbreak in 2001 and the 2023 South Korean lumpy skin disease outbreak. These are just two of many animal diseases, which include African swine fever, bluetongue, and highly pathogenic avian influenza. As seen throughout the COVID-19 pandemic, mathematical modelling can provide important and novel insights from data as it gets collected, which provides an evidence base that can support policy and decision-making. To ensure that Australia has a modelling capability to support decisions in an emergency animal disease outbreak, we are developing a suit of modelling workflows to estimate spread and create forecasts of future spread using outbreak data. In this presentation I will describe the generalized modelling framework that we have developed to estimate spatial spread of animal diseases. We assume that the locations of premises with susceptible animals is known, and we model how infections spread within and between these properties. As an outbreak progresses, we gain updated information on confirmed infected premises, and we use this timeseries data to estimate parameters in our spread model using Bayesian inference. As part of develop a spread modelling workflow, we have created a series of models, with a range of different complexity and different data requirements. As such we are able to quantify how model complexity flows through to forecast accuracy in the animal disease context and generate evidence about what type of model is most appropriate for different scenarios.

Optimizing neural network training: the impact of Levy-Flight and Chaos in Artificial Electric Field Algorithm

Indu Bala and Lewis Mitchell
The University of Adelaide

The Artificial Electric Field Algorithm (AEFA) is a widely used optimization technique in engineering, but it has limitations, such as susceptibility to local minima and a lack of global search capabilities. To address these issues, we propose a novel solution, the Levy-Flight and Chaos dynamical system-focused Artificial Electric Field Algorithm (LCAEFA). By integrating Levy flight, this approach facilitates more efficient exploration in the search space, allowing particles to take longer jumps guided by the Levy distribution. Simultaneously, the introduction of a chaotic dynamical system introduces perturbations to the search direction, promoting diversity and exploratory behavior during optimization. This balance between exploration and exploitation enhances the algorithm's ability to discover solutions across diverse regions of the search space. We comprehensively evaluate LCAEFA on unimodal, multimodal, and fixed-dimensional benchmark functions, analyzing its behavior using solely the Levy strategy and subsequently with the integration of a chaotic map considering various Levy parameters. Additionally, we validate the algorithm's efficacy in real-world scenarios by testing it on Multilayer Perceptron (MLP) neural network training, including three classification datasets and two approximation datasets. The comprehensive assessment compares LCAEFA's outcomes with 10 alternative heuristic algorithms, considering both quantitative and qualitative analyses. Quantitative measures involve metrics such as CPU time analysis, mean square error, and mean test error calculation, while qualitative evaluations encompass analyses of convergence rate, box plots, and the evaluation of approximation curves. The statistical significance of the outcomes is established through the Wilcoxon rank test. Through the incorporation of Levy flight and chaotic theory, LCAEFA overcomes the limitations of standard AEFA, resulting in enhanced optimization outcomes and improved performance across diverse benchmark functions and real-world datasets.

Spatial modelling for population replacement of mosquito vectors at continental scale

Nicholas J Beeton, Andrew Wilkins, Maud El-Hachem, Adrien Ickowicz, Keith R Hayes and Geoffrey R Hosack
CSIRO

Malaria is one of the deadliest vector-borne diseases in the world, with the two mosquito species *Anopheles gambiae* sensu stricto (s.s.) and *Anopheles coluzzii* among the dominant malaria vectors. They are closely related, and readily hybridise and compete in the wild, despite having distinct geographic niches.

We model the spread and persistence of a population-modifying gene drive system in these species across sub-Saharan Africa using a delayed reaction-advection-diffusion model. This model is solved using a finite difference approximation based on a mosquito home range (5 km) and a daily timestep, using daily wind data to model advection, and allows for delays in offspring maturation. We also incorporate spatial and temporal variation in carrying capacity for each species based on precipitation and land use factors.

Using this model, we simulate introductions of genetically modified mosquitoes across the African mainland and its offshore islands. We explore the potential of the gene drive to spread between the two subspecies, the effects of both local dispersal and wind-aided migration to the spread, and the development of resistance to the gene drive.

Our model accounts for regional to continental scale mechanisms, and demonstrates a range of realistic dynamics including the daily effect of wind on spread and spatio-temporally varying carrying capacities for subspecies. As a result, it is well-placed to answer future questions relating to mosquito gene drives as important life history parameters become better understood.

Predicting protection against Mpox infection

Matthew Berry, Shanchita Khan, Timothy Schlubb, Miles Davenport and David Khoury
University of New South Wales

Vaccination has proved a highly effective tool for providing protection against many viral infections. During the global outbreak of Mpox, vaccination was used as a tool to mitigate the number of infections. The Mpox vaccine was approved on the basis of immune markers commonly used as a surrogate for protection. Using the ELISA antibody titers induced through vaccination we develop a model for vaccine protection and use this to predict the long-term protection from vaccination. By modelling the decay kinetics of the ELISA titers, we can predict levels of protection beyond the current available data.

Modelling spatial growth pattern formation in yeast colonies

Ben Binder
The University of Adelaide

Yeasts have been used for biotechnology throughout recorded history. They are important human pathogens, and major experimental models of eukaryotic cells. Although yeasts are some of the most studied organisms in biology, their modes of colony pattern formation are not fully understood. In this talk, continuum and discrete modelling approaches are implemented to investigate the mechanisms that produce spatially non-uniform colony formation. We show the continuum approach can model spatial patterning observed in floral biofilm colonies and use a discrete model to capture highly non-uniform patterning in filamentous colonies. This research challenges the ground-breaking work of Pirt (1967), who proposed that yeast growth patterns were exclusively caused by limitations due to nutrient diffusion. Thus, our ongoing aim is to provide a deeper understanding of the fundamental mechanisms for colonial morphology in the different modes of growth of Saccharomyces cerevisiae, with implications for this and other biofilm-forming yeasts of biotechnological or medical importance.

Information geometry for bats

Anthony Marshall, Murk J Bottema and Simon Williams
Flinders University

A hungry bat flies along seeking food by echolocation. Searching far and wide, the pulses are long, well separated, and of low chirp rate. When moth is detected, the bat starts to home in. The echolocation pulses get shorter, more closely spaced and the chirp rate goes up as the bat approaches the moth. The bat wants to continuously adjust the echolocation parameters (pulse width, pulse rate, and chirp rate) so as to gain as much information as possible about the moth during the chase. To do so, the bat might consider computing the Fisher information metric parameterised by the echolocation parameters. Here the bat's calculation are explained. No actual bats will be present.

Simulation modelling of the delayed discharge problem in hospitals

Laura Boyle
Queen's University Belfast

Patients, particularly those who are elderly or have additional care needs, can experience a delayed transfer of care' or a delayed discharge' at the end of their hospital stay, which means there is a delay between their being deemed medically optimised for discharge and their actual departure from hospital. Delayed discharge from hospital is a major problem in the UK National Health Service. These delays tend to result in poorer health outcomes for patients. Delayed discharges also limit the number of beds available for new patients and create a problem in the flow of patients through hospital. This is most visible in Emergency Departments which are under extreme pressure with record high waiting times. In this work we present a discrete event simulation of the delayed discharge problem, where we model the flow of patients from hospital to home (with a care at home arrangement) or to placement in a nursing home. The work is currently applied to a hospital in England, but future iterations of the work will consider a reusable model that can be applied in multiple settings.

Reaction-diffusion models for fish populations with realistic mobility

Phil Broadbridge
La Trobe University

Nonlinear reaction-diffusion equations, with Fisher logistic growth and constant diffusion coefficient, have been used in fisheries research to estimate sustainable harvesting rates and critical domain sizes of no-take areas. However, constant diffusivity in a population density corresponds to standard Brownian motion of individuals, with a normal distribution for displacement over a fixed time interval. For available good data sets on mobile fish populations, the distribution is certainly not normal. The data can be fitted with a long-tailed Lévy distribution that corresponds to diffusion by fractional Laplacian.

We have developed exact solutions for realistic Fisher-Kolmogorov-Petrovski-Piscounov models with diffusion by fractional Laplacian. These can also account for a delay in the reaction term. It is then shown how to modify critical domain sizes of protected areas.

Solving hard reaction–diffusion PDEs with simple discrete models

Pascal R. Buenzli
Queensland University of Technology

Many mathematical models in ecology, epidemiology, and biology are developed as individual-based models in which individuals obey certain rules governing their motion, interaction, birth, and death. Often these discrete population models admit continuum limits where the density of individuals is governed by reaction–diffusion PDEs with diffusivities and reaction rates that may be inhomogeneous, discontinuous, and nonlinear. Several numerical techniques exist to discretise and solve such PDEs, but they can often become involved to ensure conservation and sufficient precision when coefficients have sharp variations. In this contribution, we examine how such PDEs can alternatively be solved efficiently in one-dimensional space by running simple discrete models that have these PDEs as their continuum limit. The first model is a deterministic version of a random walk model to solve inhomogeneous reaction–diffusion–advection equations on arbitrary grids. The second model is a discrete model of chains of springs to solve a reaction–diffusion PDE with nonlinear diffusivity on moving interfaces.

Cutting plane algorithms are exact for Euclidean max-sum problems

Thi Hoa Bui
Curtin University

This talk studies binary quadratic programs in which the objective is defined by a Euclidean distance matrix, subject to a general polyhedral constraint set. This class of nonconcave maximisation problems includes the capacitated, generalised and bi-level diversity problems as special cases. We introduce two exact cutting plane algorithms to solve this class of optimisation problems. The new algorithms remove the need for a concave reformulation, which is known to significantly slow down convergence. We establish exactness of the new algorithms by examining the concavity of the quadratic objective in a given direction, a concept we refer to as directional concavity. Numerical results show that the algorithms outperform other exact methods for benchmark diversity problems (capacitated, generalised and bi-level), and can easily solve problems of up to three thousand variables.

Boundary conditions with macroscale equation-free modelling

Judy Bunder, Tony Roberts and Thien Tran Duc
University of South Australia

Macroscale equation-free modelling is a computational scheme for constructing a macroscale simulation from a given microscale problem. The methodology is made efficient by only simulating within small, isolated patches distributed across the physical domain. To couple the patches and capture the dynamics across the full domain, interpolated data defines field values along patch edges. A significant complication in applying this interpolation is when the given microscale problem has complicated boundary conditions. We explore this issue for some diffusive and elastic problems.

An effective heuristic approach for the domination problem and its variants

Ryan Burdett
Flinders University

In this talk we consider the domination problem and some of its variants. Having many applications, the domination problem has been the subject of research for decades, however there are some limitations to the applicability of domination to real-world problems. As such, many variants of domination have been introduced to better fit these applications. Since so many variants are described in the literature, and each is often applicable only to a niche area, relatively little work has been done of producing algorithms for solving these variants. We address this by presenting an effective heuristic method to generate solutions to the domination problem. The heuristic approach uses a relatively simple greedy approach to generate dominating sets, however the novelty comes from using relaxations of binary or mixed integer linear programming formulations to rank the vertices. The approach can then be applied to any variant of domination for which a binary or mixed-integer linear programming formulation exists, subject to some (rather loose) requirements on the formulation. Thorough testing of the approach shows that it is effective in rapidly generating solutions of high quality, compared to existing approaches. This high solution quality was retained for all variants of domination that were tested.

Properties of novel exact solutions to advection equations and diffusion equations with time-delay

Stuart-James Burney
UNSW Sydney

Delay differential equations are an interesting class of non-local equations that involve a function and its derivatives evaluated at different points in time. In recent work, we introduced a class of delay functions that can be employed in solving linear integer-order and linear fractional-order delay differential equations. By incorporating this new class of delay functions in a separation of variables approach, we have been able to provide exact solutions to a time-delay advection equation and a time-delay diffusion equation. We also generalise our approach to obtain exact solutions to both of these equations with the Caputo time-fractional derivative. These new exact solutions, while mathematically interesting on their own, can lead to unphysical states that challenge their use in models across a wide variety of mathematical fields.

Injectivity in second-gradient nonlinear elasticity

D. Campbell, S. Hencl, A. Menovschikov and S. Schwarzacher
Charles University

We study models of Nonlinear Elasticity that involve the second gradient. Such models were introduced by Toupin and later considered by many other authors e.g. Ball, Curie, Ciarlet, Olver, Mora-Corral, Müller among others. The higher gradient term can be considered as a regularizing term but is also physically usually connected with interfacial energies and is used to model various phenomena like elastoplasticity or damage. We assume that $\Omega \subset \mathbb{R}^n$ is a domain, $f \in W^{2,q}(\Omega, \mathbb{R}^n)$ satisfies $|J_f|^{-a} \in L^1$ and that f equals a given homeomorphism on $\partial\Omega$. Under suitable conditions on q and a we show that f must be a homeomorphism. As a main new tool we find an optimal condition for a and q that imply that $\mathcal{H}^{n-1}(\{J_f = 0\}) = 0$ and hence J_f cannot change sign. We further specify in dependence of q and a the maximal Hausdorff dimension d of the critical set $\{J_f = 0\}$. The sharpness of our conditions for d is demonstrated by constructing respective counterexamples. This is a joint work with S. Hencl, A. Menovschikov and S. Schwarzacher.

Fully automatized optimization of ring-opening reactions in lactone derivatives via 2-step machine learning

Linh Thi Hoai Nguyen, Yasuhide Fukumoto, Pierluigi Cesana and Aleksandar Staykov
Kyushu University

Cyclization and cycloreversion of organic compounds are fundamental kinetic processes in the design of functional molecules, molecular machines, nanoscale sensors and switches in the field of molecular and nano electronics. We present a fully automatic computational platform for the design of a class of 5- and 6- membered ring lactones by optimizing the ring-opening reaction rate. Starting from a minimal initial parent set, our program generates iteratively cascades of pools of candidate lactone derivatives where optimization and down-selection are performed not requiring human supervision at any stage. We use Density Functional Theory combined with transition state theory to elucidate the exact mechanism leading to lactone ring opening reaction. Based on the analysis of the reaction pathway and the frontier molecular orbitals, we identify a simple descriptor which can easily correlate with the reaction rate. Consequently, we can omit computationally expensive transition state calculations and deduce the reaction rate from simple ground state and ionic calculations. To accelerate the platform, we use a dataset of the order of 800 molecules to train machine learning models for the prediction of targeted chemical properties reducing the computational time by a 90% factor. We develop an evolutionary algorithm capable of generating datasets three orders of magnitude larger than the initial parent set. Thus, we can explore a large domain of the chemical space using minimal computational effort. Our entire platform is modular and our current implementation for lactone can be further generalized to more complex systems via substitution of the quantum chemical and fingerprinting modules.

Optimisation of a multi-functional piezoelectric component for a climbing robot

V.J Challis, Z.J Wegert, A.P. Roberts and T. Bandyopadhyay
Queensland University of Technology

Force sensors on climbing robots give important information to the robot control system. However, off-the-shelf sensors can be both heavy and bulky. I'll talk about our computational optimisation of a lightweight integrated force sensor made of piezoelectric material for the multi-limbed climbing robot MAGNETO (CSIRO). We focus on a compliance minimisation problem with constrained voltage and volume fraction. We present structurally optimised designs that satisfy the three main design criteria and improve upon baseline results from a reference component. While manufacturing challenges remain, our computational study demonstrates the potential of embedded robotic components for piezoelectric sensing.

Statistical Finite Element Modelling for misspecified SST simulation and inversion

Daniel Claassen, Thomas Stemler, Ed Cripps and Connor Duffin
The University of Western Australia

With the increasing abundance of data made available to both mathematical and statistical modellers, the problem of data synthesis and then resultant model error can often be neglected through model generalisations and assumptions. This can be responsible for larger issues in certain fields- for example, the continued struggle in Oceanography to identify the physical characteristics of processes such as upwelling, or cooling from cloud cover. In this work, we present the ongoing development of a method to tackle this general problem of uncertainty by using a limited, deliberately misspecified model for sea surface temperature (SST) on the Nino 3.4 region and simulating forward with additive noise via a Gaussian Process in a Statistical Finite Element Method (StatFEM). Physical model parameters are driven via re-analysis data, and an ensemble output from the model is filtered via an Ensemble Kalman Filter (EnKF). Inversion is to be performed inside the filtering process to identify the characteristics of some of the latent parameters of the model. The result is a posterior distribution over solutions for given temperature profile states that quantifies uncertainty in a number of ways, from the SST profile itself to the model's parameters.

A Boussinesq model of a non-spherical bubble with a magnetic field

Madeleine Cockerill
University of Tasmania

This talk will cover the effects of a magnetic field on the stability and morphology of an axisymmetric bubble. Interactions between bubbles and magnetic fields are important in a range of fields. It is known that magnetic fields can provide a stabilising effect similar to surface tension. Magnetic fields and bubbles can be used to control fluid flow in metallurgy and nuclear fusion reactors. In astrophysics, magnetic fields influence the shapes of wind-blown bubbles around massive stars.

In our investigation of this topic, we considered an electrically conducting fluid and used magnetohydrodynamic equations to model the evolution of the fluid and the magnetic field. We used a Boussinesq approximation which ignored variations in density except in terms multiplied by gravity. We developed semi-analytic, series solutions to turn the governing equations into a system of ODEs. Results will be provided for two possible magnetic field scenarios; firstly, that of a bubble with a toroidal magnetic field centred at the origin of the bubble, and secondly that of a bubble in a purely vertical magnetic field. In both cases, gravity points radially inward toward the centre of the initially spherical bubble, so the situation is relevant to flow around a gravitating star.

Thin filament modelling of Hele-Shaw flow

Michael C Dallaston, Michael J W Jackson, Liam C Morrow and Scott W McCue
Queensland University of Technology

In this talk we describe the behaviour of a thin liquid film or ‘filament’ trapped in a Hele–Shaw cell and pushed by a pressure difference. We derive a second-order lubrication model of the filament evolution that assumes the filament thickness (but not necessarily the curvature) is small. We show that the second order model is necessary, as even in the presence of surface tension, the leading order model generically blows up in finite time in self-similar fashion. We compare the lubrication model to level-set computation of the full two-dimensional problem.

Topological smoothing of a signal over a planar graph

Matias de Jong van Lier, Junyan Chu, Sebastin Elas Graiff Zurita and Shizuo Kaji
Kyushu University

Persistent homology furnishes us with crucial topological insights into a dataset, where each topological feature is represented by an interval, and the duration of this interval is referred to as the feature's lifetime. Features with short lifetimes are typically classified as noise, while those with long lifetimes are recognized as meaningful attributes of the dataset.

Exploiting this perspective, we introduce a novel method for the topological simplification of functions defined over the vertices of planar graphs. This method involves fine-tuning the function's values to eliminate features with lifetime smaller than a specified threshold, resulting in a refined function that retains the topologically significant aspects of the original function while discarding the noise.

Formally, this process can be viewed as an approximation problem for a given function by the class of functions without cycles whose persistence is shorter than a specified threshold.

We demonstrate the efficacy of our method through practical applications using images, treating them as signals defined over 2D grid graphs.

Resolving spatial heterogeneity in microbial symbiosis

Rodney Dharma
The University of Melbourne

Despite the prevalence of symbiosis in microbiological systems, the mechanisms by which mutualism is established and maintained remain an active area of research. Behaviours such as chemotaxis are known to influence metabolic exchanges between these organisms, and therefore mutualism. Since most studies assume a continuum (or bulk) approximation, individual interactions are often overlooked. Using agent-based modelling, we simulate metabolic exchanges between two microbial species in a spatially heterogeneous environment under well-mixed considerations; this allows us to resolve the microscopic interactions between microorganisms undergoing nutrient exchanges, and theoretically construct the nutrient landscape generated from these interactions. Our modelling demonstrates a trade-off between swimming speed and nutrient diffusion in the bacteria's ability to hone in on the moving source. Furthermore, this framework can ultimately be adapted to model other interspecies interactions between two or more populations.

Effectiveness of isolating infected cases with low viral loads at different stages of outbreak

Jiahao Diao, Nic Geard, Rebecca Chisholm and James M.McCaw
The University of Melbourne

The effectiveness of non-pharmaceutical intervention, such as the cases' isolation, is important for public health to make decisions at different epidemic stages. Furthermore, the within-host viral dynamics of each case lead to different transmission abilities at different times after infection, which is one of the key factors affecting decision-making. Therefore, the intervention policy, based on the detailed information at different stages of viral loads of the infected hosts, as the decision-making is important for public health, this research has rarely been studied. In this paper, we develop a multi-scale agent-based model to find out how each infected host with different viral loads may affect the outbreak at different times. We apply a sigmoid function to connect the viral load dynamics of each infected host to their transmission abilities (infectiousness). The viral load dynamics of each infected host are simulated by the target-limited-cell (TIV) model under the within-host level. At the population level, the model has the same structure as the susceptible-infected-removed (SIR) model, and each infected host, as an agent, can change the states from $S \to I$ or $I \to R$, based on their viral load levels. This multi-scale model allows us to record the states of the viral load levels of infected hosts during the whole epidemic. We can categorise the transmission abilities into four groups, reflecting phases of increasing or decreasing infectiousness with low/high viral loads, respectively, enhancing our understanding of the effect on the outbreak by the within-host dynamics. We observe that at an early stage of the epidemic, the infected hosts with low viral loads are more likely to be in the increasing phase, which means they will become highly contagious. However, after the epidemic's peak, most infected hosts with low viral loads are in the decreasing phase, which means they will be less contagious and recover soon. To evaluate how the isolation of infected hosts with low viral loads affects the control of an outbreak, we conduct five isolation policies based on the testing results of each infected host. We show that with different within-host dynamics, the low viral load infected host has a slightly different effect when the epidemic reaches its peak. Our results suggest that stopping isolating the low viral cases after the peak has minor effects on the outbreak. We also conduct a sensitivity analysis that stops isolating low viral load cases for different days after peak under different within-host dynamics and R_0.

Analysis of an ecological niche: competition versus cooperation

Serena Dipierro
The University of Western Australia

In this talk, we will analyse the situation of a biological population in competition for resources that occupies an ecological niche with zero-flux conditions. In the study of biological populations, the Allee effect detects a critical density below which the population is severely endangered and at risk of extinction. This effect supersedes the classical logistic model, in which low densities are favorable due to lack of competition, and includes situations related to deficit of genetic pools, inbreeding depression, mate limitations, unavailability of collaborative strategies due to lack of conspecifics, etc. The goal of this talk is to present some recent results related to the mathematical analysis of the Allee effect.

The effect of antigenic seniority on the timescales of influenza infection risk following vaccination

Oliver Eales, James M McCaw and Freya M Shearer
The University of Melbourne

Since its emergence in 1968, influenza A H3N2 has caused yearly epidemics in temperate regions. While infection confers immunity against antigenically similar strains, new antigenically distinct strains that evade existing immunity regularly emerge (antigenic drift'). Immunity at the individual level is complex, depending on an individual's lifetime infection history. An individual's first infection with influenza typically elicits the greatest response with subsequent infections eliciting progressively reduced responses. This is known as antigenic seniority. Yearly vaccination for all individuals over 6 months of age is currently recommended by the World Health Organization. However, it is not known how vaccination contributes to antigenic seniority, and what effect this will have on an individual's risk of infection. Here we develop an integrated modelling framework of influenza transmission, immunity, and antigenic drift, and use it to explore the effect of vaccination on an individual's short- and long-term risk of infection. The antibody response triggered by vaccination reduces the yearly risk of infection over the short-term (approximately 5 years). The long-term risk of infection is heavily dependent on if vaccination contributes to antigenic seniority. Under the assumption that vaccination does contribute to antigenic seniority, the suppression of subsequent immune responses (due to vaccination) increases an individual's risk of infection over the long-term. In contrast when we assume vaccination does not contribute to antigenic seniority, an individual's risk of infection decreases over the long-term (subsequent immune responses are not as suppressed due to vaccination preventing infections in the short-term). These long-term dynamics are most pronounced for individuals who are vaccinated at an early age and undergo frequent vaccination, with the effects heavily influencing the expected number of old-age infections (which are most likely to be severe). Our analyses suggest that optimum vaccination strategies (which primarily aim to reduce severe infections) will be heavily dependent on the role of vaccination to antigenic seniority highlighting an important knowledge gap.

Coexistence in two-species competition with delayed maturation

Maud El-Hachem and **Nicholas J Beeton**
CSIRO

Interspecific and intraspecific competition is most important during the immature life stage for many species of interest, such as multiple coexisting species of mosquitoes. Sexually mature individuals can be separated from immature individuals by using a delay of maturation. The end of the period of maturation signifies that the individual is now able to breed. Modelling a maturation delay provides a simpler alternative to including age-structured subpopulations that require an extensive number of parameters to characterise each subpopulation.

Mortality caused by competition that occurs during maturation is explicitly modelled in some alternative formulations of the Lotka-Volterra competition model. Looking back at the loss of population due to interspecific and intraspecific competition over the time of maturation helps define the remaining population able to reproduce. We generalise this approach by using a distributed delay for maturation time. The kernel of the distributed delay is represented by a truncated Erlang distribution. The resulting system of delay differential equations is transformed into a system of ordinary differential equations using the linear chain approximation. Numerical solutions are provided to demonstrate cases where competitive exclusion and coexistence occur. Stability conditions are determined using the nullclines method and local stability analysis, among others. We conclude that the introduction of a distributed delay promotes coexistence and survival of the species compared to the limiting case of a discrete delay, a result that could potentially affect management of relevant pests and of threatened species.

The effect of cell motility on competitive invasion of epithelial monolayers

Faris Alsubaie
The University of Queensland

Collective cell invasion underlies different biological processes such as wound healing, embryonic development, and cancerous invasion. The impact of cell motility on the invasion of epithelial monolayers coupled to cellular mechanical properties, such as cell-cell adhesion or cortex contractility, is not well understood. Here, we develop a two-dimensional model using the Cellular Potts Model which predicts that the cellular invasion speed is approximately independent of the biological and mechanical properties of the cells and is mainly determined by active cell motility. We also found that non-motile cells can occupy the area of the motile cells if their proliferation rate is sufficiently high and stable coexistence of the two cell types is possible for certain parameter combinations.

Surrogate models for diffusive transport in radially-symmetric media

Luke Filippini, Matthew Simpson and Elliot Carr
Queensland University of Technology

Surrogate models are frequently used in numerous disciplines to approximate more complex models of diffusion-controlled heat or mass transport. These models are appealing because they can be relatively simple, ease the process of fitting experimental release data, and highlight the influence of key physical parameters on the release profile. Recently, a moment-matching approach was proposed and used to develop a simple one-term exponential model for diffusion-controlled particle release from homogeneous radially-symmetric geometries. In this talk, I discuss the development of novel two-term and weighted two-term exponential models, using this moment-matching approach, to improve upon this existing research. Important applications of this work include drug delivery from cylindrical and spherical microcapsules and the drying of thin agricultural products.

A spatiotemporal model of multi-marker antimalarial resistance

Jennifer A. Flegg and Yong See Foo
The University of Melbourne

The emergence and spread of drug-resistant malaria parasites has hindered efforts to eliminate malaria. Monitoring the spread of drug resistance is vital, as drug resistance can lead to widespread treatment failure. We develop a Bayesian model to produce spatiotemporal maps that depict the spread of drug resistance, and apply our methods for the antimalarial sulfadoxine-pyrimethamine. We infer from genetic count data the prevalences over space and time of various malaria parasite haplotypes associated with drug resistance. Previous work has focused on inferring the prevalence of individual molecular markers. In reality, combinations of mutations at multiple markers confer varying degrees of drug resistance to the parasite, indicating that multiple markers should be modelled together. However, the reporting of genetic count data is often inconsistent as some studies report haplotype counts, whereas some studies report mutation counts of individual markers separately. In response, we introduce a latent multinomial Gaussian process model to handle partially-reported spatiotemporal count data. As drug-resistant mutations are often used as a proxy for treatment efficacy, point estimates from our spatiotemporal maps can help inform antimalarial drug policies, whereas the uncertainties from our maps can help with optimising sampling strategies for future monitoring of drug resistance.

Exact SSA for disease population dynamics coupled to within-host dynamics

Mark Flegg
Monash University

Exact stochastic simulation algorithms (SSAs) are useful to generate solutions stochastic processes such as those represented by well-mixed compartment-based models of disease spread. Importantly, the exactness of algorithms such as the Gillespie algorithm is guaranteed only when all events are discrete and Markovian (the infection of a susceptible, the recovery of an infected individual etc). Introducing within-host viral load to infected individuals in a stochastic model of disease spread in a population means that the infected class is (a) no longer well mixed and (b) contains the memory of the time since initial infection. In such models therefore, a more complicated approach is required to retain the exact SSA properties. A neat mathematical framework for dealing with these kinds of hybrid models will be discussed.

Interplay between model fitting and model construction for biological dynamical systems

Yong See Foo
The University of Melbourne

The construction of mathematical models for complex biological systems is challenging. We cannot place all our confidence in one single model – in fact, there are often multiple hypotheses for each biological mechanism. Given observed data and a family of candidate mechanistic models, how can one identify a handful of models that plausibly explain the data?

In this talk, I will discuss a model search framework for ordinary differential equation (ODE) models of network-based biological systems. Instead of exhaustive enumeration, candidate models are refined by iterative structural modifications to better explain the observed data. However, it is pertinent to design a search strategy that avoids proposing too many unpromising modifications. In response, I propose to adapt model fitting methods to elucidate which system components have mis-specified derivatives given an ODE model. Component-specific search heuristics provide an interplay between model fitting and model improvement, in contrast to the typical approach of treating model fitting as a separate task after model construction. I will compare the relative merits of various model fitting methods under the context of guiding model search. Results will be demonstrated through examples from gene regulation and biochemical reaction systems.

FireNado!

Larry Forbes
University of Tasmania

In severe bushfires, it is occasionally observed that the fire forms what looks like a 'tornado' structure. There is a whirling central vortex that is fed by the prevailing winds and the energy from the fire itself.

This talk will propose a fairly simple mathematical model for the 'firenado'. A linearized solution will be discussed, and some nonlinear numerical results will be presented.

Including organism and environmental heterogeneity in collective behaviour: looking at locusts

F. Georgiou, C. Buhl, J.E.F. Green, B Lamichhane and N. Thamwattana
University of Bath

Collective behaviour occurs at all levels of the natural world, from cells joining together to form complex structures, to locusts interacting to form large and destructive plagues. These complex behaviours arise from simple individual and environmental interactions, and thus lend themselves well to mathematical modelling. One simplifying assumption, that of relative homogeneity of organisms, is often applied to keep the mathematics tractable. However, heterogeneity arising due to the internal state of individuals has an impact on these interactions and thus plays a role in group structure and dynamics.

Through the lens of locust foraging, I introduce a continuum model that accounts for this heterogeneity in the form of a state space that maps this internal state to movement characteristics. Then using the model we explore the effect of food, hunger, and gregarisation on locust group formation and structure. Finding that the most gregarious and satiated locusts tend to be located towards the centre of locust groups (Conversely, hunger drives locusts towards the edges of the group). Finally, we find that locust group dispersal may be driven in part by hunger.

These results lend themselves to better outbreak prediction both in terms of the initial aggregation formation as well as the eventual dispersal. In addition, the technique itself is general enough that could potentially be used to explore a variety of different scales from microscopic to macroscopic.

Jump-Switch-Flow: hybrid deterministic-stochastic trajectories of compartmental systems

Domenic P.J. Germano, Alexander E. Zarebski, Sophie Hautphenne, Robert Moss, Jennifer A. Flegg and Mark B. Flegg
The University of Sydney

Many dynamical systems exhibit multiscale behaviour. A classic example of this is the atto-fox problem in the Lotka-Volterra predator-prey model where oscillations lead to populations becoming unfeasibly small. Similar issues arise in epidemiology, immunology, and molecular biology, where small populations may go extinct due to stochastic effects. One resolution is to represent the process as a continuous time Markov chain (CTMC) which accounts for the discrete nature of small populations. Unfortunately, for large populations, simulating this process is computationally intractable.

We have developed a way to approximate the CTMC which preserves the discrete stochastic behaviour of small population sizes, and continuous deterministic behaviour of large populations. Depending on the state of the system, the process switches between stochastically (jumping) and deterministically (flowing). We call this approach Jump-Switch-Flow' (JSF). In addition to incorporating small population stochastic effects, our approach also has a natural notion of compartment extinction, providing a solution to Atto-type problems.

In this talk, I present JSF (an open-source package implementing this approximation) and demonstrate, through a simulation study of an epidemiological SIRS model with demography, that it reproduces much of the behaviour of current gold standard exact simulation techniques, while being substantially faster. I will also show, using synthetic data as a toy example, how JSF lets us discuss elimination scenarios under intervention. Finally, using clinical data of SARS-CoV-2 infections, I will demonstrate how JSF enables the analysis of within-host processes, while accounting for viral clearance.

Simple wood, complex challenges: modelling moisture migration and swelling in timber boards

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

Timber is an excellent and widespread construction material used worldwide for small to midrise building construction. Moisture ingress in the timber can cause swelling, which affects the structural performance of the board. In species such as Pinus radiata (radiata pine) the density and material properties can vary greatly within the span of a few millimetres across the growth rings, however many previous transport and mechanical models treat the timber boards as a homogeneous material. In this work, we simulate the complex heat and mass transfer processes in a fully coupled manner using a heterogeneous formulation, and then compute the stress and strain fields using a decoupled, post-processing approach based on the finite element analysis software ABAQUS. We rely on previous work to generate the three-dimensional computational mesh using images of the end grain pattern, together with an anatomical image of the cellular structure of radiata pine. The mesh is comprised of triangular prismatic elements where the nodes lie along the growth rings as to ensure that sharp change in density is captured with the mesh structure. We then use the TransPore model to simulate moisture migration under representative climatic conditions similar to those experienced in Brisbane, Australia. The stress and strain model is then used to compute the swelling (strain) and internal generated during the wetting process.

Right place, right time, right activation

Catheryn W Gray and Adelle C F Coster
University of New South Wales

Akt/PKB is a crucial crosstalk node that coordinates multiple cellular processes such as growth, proliferation, and metabolism in the mammalian cell. As a key player in the regulation of glucose metabolism, Akt is recruited to the plasma membrane by insulin and activated via a process of double phosphorylation that is thought to take place exclusively at the plasma membrane. Following phosphorylation, the activated Akt is redistributed to a variety of cellular locations where it phosphorylates a plethora of downstream effectors. However, the precise nature of post-activation events in this important signalling cascade remains unclear.

In order to investigate some of the competing theories concerning post-activation events in the Akt signalling cascade, we present and analyse a deterministic ordinary differential equation model of the activation of Akt in response to insulin. This model explicitly tracks the initial translocation of Akt from cytosol to plasma membrane, phosphorylation at the plasma membrane, and the subsequent return of activated Akt to the cytosol. We present insights gained from the mathematical analysis of the model and discuss the implications of this for the understanding of the underlying biological system.

Data-driven prediction of the El Niño–Southern Oscillation using entropy-optimal Scalable Probabilistic Approximations

Michael Groom, Davide Bassetti, Illia Horenko and Terence O'Kane
CSIRO

This talk will present an application of novel data-driven methods to the prediction of the El Niño-Southern Oscillation (ENSO). Prediction of ENSO is formulated as a classification task, where the Nino3.4 index is coarse-grained to take a value of 1 if it exceeds $+0.4°C$ in n months time, -1 if it exceeds $-0.4°C$ and 0 otherwise. For lead times ranging from 3 months to 24 months, a classifier is trained to predict the labelled data based on a set of features derived from observational and resimulated datasets over the period of 1948 to 2018.

The labels for n-month ahead prediction are determined using the Nino3.4 index calculated from the HadISST observational dataset. The features used for prediction are the first 100 principal components (PCs) from an empirical orthogonal function (EOF) analysis of global sea surface temperatures (SST), along with the first 100 PCs from an EOF analysis of the vertical derivative of water temperature at the equator (dT/dz) as a proxy for thermocline variability. EOF analyses are performed for two resimulated datasets; the ACCESS-O model, which uses CORE.v2 interannual forcing over a period of 1948-2007 as well as data assimilation from 1990-2007, along with the ACCESS-OM2 model, which uses JRA55-do interannual forcing over a period of 1958-2018.

This classification task represents an example of supervised machine learning in the small data regime, since the number of features used is of similar size to the number of data instances available for training. The recently proposed entropy-optimal Scalable Probabilistic Approximation (eSPA) classifier has been shown to avoid overfitting in this regime. eSPA simultaneously performs clustering, feature selection and classification and is physically interpretable. Results are shown for in-sample and out-of-sample predictions for lead times of up to 24 months. In particular, the interpretability of the method is highlighted by generating composite images of the cluster centroids (by recombining the PCs with their corresponding EOFs) and demonstrating that the obtained cluster affiliation sequences follow known ENSO dynamics.

Switching near heteroclinic networks as a piecewise-smooth dynamical system

David Groothuizen Dijkema, Vivien Kirk and Claire Postlethwaite
University of Auckland

A heteroclinic cycle is an invariant structure in a dynamical system composed of a sequence of equilibria and orbits connecting them in a cyclic manner. Near an attracting heteroclinic cycle, trajectories will asymptote onto the cycle and visit each equilibrium in turn. As time evolves, trajectories spend increasingly longer periods of time near each equilibrium, before making a rapid switch to the next one. Systems with heteroclinic cycles can be used to model intransitive interactions and intermittent phenomena.

A heteroclinic network is the connected union of a collection of heteroclinic cycles. Near a heteroclinic network, trajectories may asymptote onto one component cycle, possibly making a finite number of switches between cycles before doing so. Trajectories may also asymptote onto a larger subset of the network by cycling between cycles in regular or irregular sequences. The stability regions of different asymptotic behaviour can form complicated structures in parameter space with complicated patterns, including Farey-like concatenation and arbitrarily long, sometimes infinite, chains of sequences of cycling between cycles. In this talk, we will discuss how we can use piecewise-smooth maps to investigate switching near heteroclinic networks and these patterns and structures.

Transient waiting time distributions in call centres with skills-based routing

Hritika Gupta
The University of Melbourne

We present a method to calculate the time-dependent waiting time distributions for call centres that employ skills-based routing. Many call centres are subject to service level agreements that stipulate that they must achieve targets such as that 90% of calls are answered within 20 seconds. In order to manage a centre so that targets like these are met, there is a need to calculate the waiting time distributions experienced by customers. We model the call centre system as a continuous-time Markov chain and then make use of the Laplace transformation to calculate the relevant quantities. We also demonstrate the use of this method to find the optimal routing policy in a certain class of policies.

Self-reinforcing persistent random walks

Daniel Han
UNSW Sydney

I will introduce a persistent random walk model with finite velocity and self-reinforcing directionality, which explains how exponentially distributed runs self-organize into truncated Lévy walks observed in active intracellular transport. This random walk is described by a nonhomogeneous in space and time, hyperbolic partial differential equation for the probability density function (PDF) of particle position. This PDF exhibits a bimodal density (aggregation phenomena) in the superdiffusive regime, which is not observed in classical linear hyperbolic and Lévy walk models. Finally, I will find the exact solutions for the first and second moments and criteria for the transition to superdiffusion.

Mechanisms of plateau formation for oscillations in lymphatic muscle cells

Edward J Hancock
The University of Sydney

Failures of the lymphatic system can cause cardiovascular disease, neurological disorders, and a range of other diseases. A critical function of the lymphatic vascular system is the active pumping of fluid from around cells back into the blood circulation - driven by periodic contractions of lymphatic muscle cells (LMCs). These periodic contractions occur due to linked pacemaker oscillations in the membrane potential (M-clock) and the calcium concentration (C clock) of LMCs. Previously, we proposed and analysed a minimal model of synchronized dual-clock-driven oscillations in the M-clock and C clock. However, while this model qualitatively replicated the period of oscillations under different conditions, it did not replicate the shape of the oscillations. Here, we modify calcium release in the C-clock components of the model to replicate the plateau behaviour. We also qualitatively analyse the different mechanisms for plateau formation using phase-plane analysis. The model has the potential to help determine opportunities for pharmacological treatment of lymphatic system pumping defects.

Fluid flow through an involute spiral

Brendan Harding
Victoria University of Wellington

Steady viscous fluid flow through spiral duct geometries is often assumed to be well approximated by the fluid flow through a circular curved geometry. This is especially the case for fluid flows through micro-scale devices. In this presentation I will discuss some recent efforts to quantify the difference between fluid flows through spiral and circular duct geometries. Involute spiral curves lead to a natural orthogonal coordinate system, unlike Archimedean spirals, and thereby provide an ideal setting for performing such a comparison.

Near optimal selection of sites for mosquito surveillance of Japanese encephalitis virus in Australia

Lucinda Harrison, David Duncan, Jennifer Flegg, David Price, Nick Golding and Freya Shearer
The University of Melbourne

Japanese encephalitis virus is a leading cause of viral encephalitis worldwide, causing life-changing disability and death in humans. Before 2021, the disease had only been detected in Australia in small outbreaks in the Torres Strait and Far North Queensland. However, since early 2022, the disease has been identified in at least 36 people and 85 piggeries across the Australian mainland, as far south as Victoria. The transmission cycle of the mosquito-borne virus is complex, with many species implicated as potential reservoir hosts. In this work, we draw on predictions of the geographic distributions of wildlife host and vector species, modelled using environmental data: the intersection of host and vector distributions constitutes the potential extent of virus transmission. We combine this modelling output with a dataset of locations of virus surveillance and detection to estimate the realised extent of virus transmission. We then consider site selection for mosquito surveillance: given the modelled potential extent of virus transmission and defined stakeholder priorities, what is the optimal set of sites for surveillance of Japanese encephalitis virus in mosquitoes? To avoid evaluating the utility of all possible surveillance designs, we apply methods of simulation-based optimal design, to explore design space and find near-optimal designs for Japanese encephalitis virus surveillance.

Determining the crossing numbers of certain graph products

Michael Haythorpe
Flinders University

The *crossing number problem* (CNP) is concerned with the following question: what is the fewest number of edge crossings required in a 2D drawing of a graph (or network). For planar graphs the answer is zero, and this can be detected efficiently, however for non-planar graphs CNP is an extremely difficult problem to solve. Indeed, despite significant computational effort, the crossing number of K_{13} (complete graph on 13 vertices) is unknown to this day. Instead, researchers in this area have focused on determining the crossing numbers for infinite graph families, typically resulting from graph products involving a small fixed graph, and arbitrarily large graphs such as paths. Dozens of papers have been published along these lines, where the small fixed graph has 6 or fewer vertices. There are 141 such families, and as of a 2019 survey, around 60 of these remained unresolved in the literature. We present a new method which can be applied to any such small fixed graph, and show that it settles all but one of the outstanding cases, and is also applicable to larger graphs which have not yet been seriously considered in the literature.

Winning with chaos in soccer: entropy-based analysis for team performance evaluation

Ishara Bandara, Sergiy Shelyag, Sutharshan Rajasegarar, Daniel B. Dwyer, Eun-jin Kim, Maia Angelova
Deakin University

Modern soccer values team performance over individual performance. However, assessing team performance in soccer is challenging, considering its low-scoring and unpredictable nature. Recent literature has revolved around space creation and space utilization in soccer, evaluating on and off runs by the players. Yet, the role of randomness in team ball movements and its impact on success is unexplored. This work introduces an entropy-based time-series performance evaluation metric for analyzing spatiotemporal event distribution at regular intervals to quantify chaos in team ball movements using a novel cumulative ball possession matrix. We found a correlation between match-winning performances and the randomness in the spatial distribution of ball movement events. This work demonstrates the proposed metric's significance with 80% accuracy for match-winning performance classification. Statistically, significant relationships were observed between the extracted temporal features and match-winning performances based on the GLM p-values and coefficients. In general, the match winners have employed a dispersed chaotic event distribution in the first half of the game, suggesting an offensive approach, followed by a compact, cautious approach toward the end. This work also revealed that first-half performances are more critical for match-winning performances. Despite soccer's unpredictable nature, this work provides a valuable time-series metric to evaluate performance differences between stronger and weaker team's performances.

Buzz off! Suppressing the neglected mosquitoes transmitting neglected diseases

Roslyn Hickson, Matthew Ryan, Dan Pagendam and Brendan Trewin
CSIRO and James Cook University

Aedes albopictus mosquitoes are competent vectors for the spread of at least 24 different arboviruses, including dengue fever, Ross River virus, and Japanese encephalitis, but remain relatively less studied than their more urban cousins, *Aedes aegypti.* We model an Incompatible Insect Technique (IIT) based intervention for mosquito control, with bidirectional incompatibility between two (or more) strains of *Wolbachia.* We explore the expected time until population suppression and a proxy for cost (numbers of mosquitoes released) of such an intervention. We further explore for a single locale how immigration and emigration of mosquitoes between areas might affect these factors, and reversibility of the intervention – an important consideration in modern *Wolbachia*-based mosquito control programs.

Starting vortices generated at the sharp edges of an arbitrary body

Edward M. Hinton, Wei Hou, Anthony Leonard, Tim Colonius, Dale I. Pullin and John E. Sader
The University of Melbourne

The unsteady 'starting vortex' that is generated at the trailing edge of an impulsively translated flat plate is a longstanding problem in fluid dynamics of fundamental importance. Here, we present a novel formulation that describes the starting vortex at any sharp and straight edge of an arbitrary body under general time-dependent two-dimensional translation and rotation. This inviscid theory identifies that three self-similar vortex types can arise depending on the flow structure local to the edge. The vortex evolution is entirely characterized via the first two terms in the Laurent series of the complex potential. The two terms are associated with the local flow components perpendicular and parallel to the edge, respectively. The formulation unifies a range of starting vortices reported in the literature from seemingly different contexts. The predictions of the theory are compared favourably with high-fidelity direct numerical simulations of the Navier-Stokes equations.

Putting the eggs before the chickens: a model of chicken farming in Ethiopia

Graeme Hocking and Hanan Omar
Murdoch University

Chickens are a vital part of the agriculture and food supply in Ethiopia, yet the behaviour of farmers varies widely across the country. Here we discuss a simple model of chicken production and include the effects of disease and different farming practices to estimate the efficiency of different approaches. This is part of an international research project on food production.

The value of information paradox

Matthew Holden, Morenikeji D. Akinlotan, Allison Binley, Frankie Cho, Kate Helmstedt and Iadine Chadès
The University of Queensland

Value of Information analysis is a method for quantifying how additional information may improve management decisions, with applications ranging from biodiversity conservation to fisheries. However, VoI studies often suggest that collecting more data will not substantially improve management outcomes. This often contradicts the intuition of ecologists and managers who often believe new information is critical for management. This inconsistency is exacerbated by the perception that Value of Information is a black-box method. A lack of understanding of why Value of Information is usually lower than ecologists expect is hampering on-ground uptake. There is a need to identify the factors that drive VoI methodology to produce low values. Here, we use mathematics to explain why Value of Information is often low. We first derive analytic solutions and upper bounds for a Value of Information problem with two uncertain states, two actions, and four management outcomes. We then apply our formulation to a published frog population management case study and extend the results numerically to ten million randomly generated larger-sized problems. Our simple analysis provides insight into the important factors that drive Value of Information analysis and is a stepping stone towards increasing the interpretability of Value of Information analysis in more complex settings.

When to invest in conservation with climate uncertainty

Jordan Holdorf, Melanie Roberts, Ivan Diaz-Rainey and Chris Brown
Griffith University

Interest in nature markets is steadily growing with strong interest in the emerging carbon and biodiversity markets. This promotes the need to make investment decisions in a financial framework, which allows restoration projects to benefit from these emerging markets. Currently, most funding for restoration comes from philanthropic and/or grants, which means that traditional methods such as Marxan aim to minimise the cost of the project rather than focusing on the financial markets the project can produce revenue through. This leads to the demand for a financial framework that focuses on restoration projects utilising these emerging markets and maximising the overall revenue of the project. We must also consider climate change as it is a major risk to ecological investments. Therefore, not only do models need to include emerging natural capital markets, but also need to account for climatic uncertainty, so informed decisions can be made.

This results in a need to optimize investment into conservation from a financial perspective accounting for climate risks. One prominent area of interest is determining when to invest in conservation projects over time when there is both financial and climate risk and profit. Here we present results from a study using stochastic dynamic programming as a tool to determine the optimal investment strategy into restoration projects generating revenue through nature markets.

Improved short-term Antarctic sea ice extent predictions with machine learning and remote sensing data

Jacinta Holloway-Brown, Elizabeth Shine, Ariaan Purich and Ryan Heneghan
The University of Adelaide

Antarctic sea ice has been reaching record lows in recent years, despite cyclical and expected shifts in known environmental relationships. These unprecedented changes indicate that:

- Climate change signals are emerging more clearly
- Differences in sea ice extent cannot always be reliably predicted based on these known, related environmental variables

It is important to model and understand short-term, regional Antarctic sea ice changes as uncertainty continues to increase in this system. While physics based Earth System Models (ESMs) can produce accurate long term projections, their performance is poor at local and short-term scales. Statistical models are similarly suited to predicting long term overall trends rather than accurate short term predictions. Statistical models also provide predictions of a total or average over a large area e.g. total extent over all of Antarctica. This can smooth over more significant, regional changes.

Recently, machine learning (ML) methods offer an alternative approach to producing these local and short-term predictions. We explore whether observations based ML predictions are more accurate than environmental based ones, given the loss of connection between known environmental system and sea ice dynamics due to the emergence of climate signals. We also produce spatially explicit predictions of Antarctic sea ice extent, identifying regional variability and varying levels of uncertainty.

To produce posterior estimates of sea ice extent with associated uncertainty we use the ML method Stochastic Spatial Random Forest (SS-RF). This is a peer reviewed, open source machine learning method which is accurate and effective for monitoring land cover change in satellite images. It is fast, non-parametric and generalisable to many types of big data. Importantly, it quantifies uncertainty by producing posterior probabilities of land cover. This is highly valuable when modelling sea ice extent change which is inherently uncertain, and increasingly so, as the signal of climate change impacts becomes more evident.

Improving stability of covariant BSSN formulation of the Einstein equations against homogeneous and isotropic spacetime background

Hidetomo Hoshino, Takuya Tsuchiya and Gen Yoneda
Waseda University

In solving the Einstein equations numerically, the BSSN formulation is more widely used due to its numerical stability. However, constraint violation cannot be avoided even with the BSSN formulation, depending on the background spacetime. We consider the constraint stability of the Einstein equations against homogeneous and isotropic spacetime background with the covariant form of the BSSN formulation. We propose that adjusting the time evolution equation with constraints contributes to improving the constraint stability.

Compounded Sibuya random walks and the fractional graph Laplacian

Boris Huang
UNSW Sydney

Models for anomalous super diffusion, with mean squared displacement scaling faster than linearly in time, often involve non-local operators, such as the fractional order Laplacian. The generalisation of these ideas to graphs naturally leads to considerations of fractional order graph Laplacians. These graph Laplacians can be used in models of large networks such as the world wide web.

I will show how fractional order graph Laplacians can arise by considering a compound (continuous time) random walk on a graph. This surprisingly neat result arises from a connection between the generalised binomial theorem and the Sibuya distribution, a heavy tailed discrete distribution. I will address some of the computational challenges in simulating these random walks as well as generalisations.

Chemical gardens: the origin of life?

Herbert Huppert

We will start by describing the initial investigations of the growth of chemical gardens by Johann Glauber (1604-1670), said to be the first chemical engineer, and by Newton in about 1680. We will then describe how they grow easily around deep-sea vents or black smokers. The question will then be raised if life started in surface waters or at hydrothermal vents. Recent experiments and associated theory will then be described of the growth of chemical gardens in Hele-Shaw cells.

Modelling light presented to the human fetus using Monte Carlo simulations

Zac Isaac
The University of Waikato

The extent to which external light sources illuminate the uterine environment is unknown. Recent experimental work indicates that the human fetus responds to external visual stimuli such as laser diodes, and initial modeling work suggests the fetus may not develop in a completely dark environment as previously assumed. Development of the human visual system begins within the womb, and there is motivation in fields such as developmental psychology, transabdominal oximetry, and photoacoustics to explore the extent to which light penetrates maternal abdominal tissue and how this varies temporally and across individuals. In this talk, we outline a purpose-built Monte Carlo model that uses histological properties of maternal tissue in simulating transdermal light sources applied to the maternal abdomen. We use the results of this modeling to determine approximate levels of uterine illumination from point source stimuli, as used in experimental applications, and consider the extensions of this work to natural light and the ambient illuminance of the womb.

Hydrodynamics of filter feeders

Tasawar Iqbal, Catherine Penington, Christian Thomas and Lyndon Koens
Macquarie University

Taylor's swimming sheet is one of the simplest, most revealing models for microscopic swimming. Since its development, it has been extended in many ways, like improving the series convergence, exploring peristaltic pumping, and swimming in non-Newtonian fluids. In this paper, we consider a two-dimensional Taylor swimming sheet with a finite Brinkman layer over it. This could represent a swimmer within a confined, porous boundary. We observe that the far-field velocity and flux reduce as we increase the Brinkman constant, the thickness, or the lower boundary of the Brinkman region. The maximum pressure drop across the layer increases with the Brinkman constant and the filter thickness but decreases with increasing filter thickness. We observe that the maximum pressure drop has a non-linear dependence on the geometry of the filter feeders compared to when it is far away, where the dependence is more linear. These results could be useful in investigating the flows around the cilia in the lung and microscopic filter feeders.

Geometrical design and mechanical properties of origami-inspired cylindrical honeycomb cores

Sachiko Ishida
Meiji University

Origami, the Japanese art of paper folding, encompasses traditional art, culture, and hobbies. Beyond its artistic aspects, origami is employed in designing core structures based on space-filling polyhedra, such as honeycomb cores. This presentation delves into the geometrical design and mechanical properties of cylindrical honeycomb cores. Cylindrical honeycomb cores were developed from conventional flat honeycomb cores using a mapping technique. In this study, the prototyping of cylindrical honeycomb cores involved folding sheets of craft paper, drawing inspiration from origami techniques. Static compression tests revealed that the cylindrical honeycomb cores exhibited high compression strength in the radial direction. This finding suggests that these cores are well-suited for mechanical components such as vehicle tires, robotic rovers, bearings, and liquid containers.

Agent-based modelling of Plasmodium vivax under treatment with radical cure

Elizabeth Ivory
The University of Melbourne

Plasmodium vivax is the most geographically widespread malaria-causing parasite. It can produce latent, liver-stage parasites (hypnozoites) which may cause multiple malaria relapses from a single new infection. In order to kill these hypnozoites and prevent *Plasmodium vivax* relapses, a liver-stage treatment such as primaquine or tafenoquine is required. When paired with a blood-stage treatment to treat the active infection, it is termed "radical cure". However, those with a G6PD enzyme deficiency (up to 30% of a population) are at high risk of adverse reactions to radical cure treatment, such as haemolysis (red blood cell death).

This work extends an agent-based stochastic transmission model to incorporate individual G6PD enzyme levels and testing, allowing modelling of different treatment regimens for individuals based on a current quantitative G6PD test. Additionally, we adapt existing hypnozoite models in order to stochastically model the number of hypnozoites and the corresponding relapse rate for each person within a tropical setting, within this agent-based and stochastic transmission model framework.

Tractability of biochemical signalling models

Chathranee Jayathilaka, Robyn Araujo, Lan Nguyen and Mark Flegg
Monash University

Complex biochemical networks are often described mathematically with the use of many nonlinear coupled ODEs. However, dissecting these models to explain underlying behaviour is difficult using rigorous classical analysis. Instead, often a scientist will propose the qualitative behaviour of the system by looking at the underlying general relationships between components in the network. The reason why this is considered acceptable is because common network topological features are often associated with specific behaviour (for example, oscillation). We will take a mathematical perspective towards the question of how acceptable is it to make simplistic reductions of a network into a qualitatively comparable network with the same features. We explore specifically how these networks can be simplified as their topological complexity increases as well as important properties, which we will define, are varied in the underlying mathematical model.

Efficient modelling of heterogeneous cell populations

Stuart Johnston
The University of Melbourne

The biological world is highly heterogeneous. This heterogeneity is implicated in, amongst other, embryonic development and drug resistance in tumours. Even within nominally identical cell populations, both cell behaviour and characteristics, such as morphology and gene expression, are heterogeneous. In mathematical models of cell populations, heterogeneity is typically either neglected, or is limited to one or two characteristics. However, we know that heterogeneity manifests in myriad characteristics that can each impact cell behaviour. Here we present an approach for modelling heterogeneous cell populations.

We first model a population of individual cells. A cell's behaviour is dictated by its individual characteristics and is modelled via a lattice-based random walk. The evolution of the individual characteristics is governed by a different random walk model. From this underlying model, we derive a corresponding partial differential equation (PDE) model that describes the evolution of the heterogeneity across the cell population. The dimension of the PDE corresponds to the number of heterogeneous characteristics. To keep the computation tractable, we employ distribution approximation techniques. We demonstrate that the resulting system of PDEs accurately captures both the behaviour in the random walk model and the heterogeneity in the cell population, while providing a methodology that scales efficiently with the number of heterogeneous characteristics.

Dynamics through the lens of cryptography

Nalini Joshi
The University of Sydney

Elliptic curves first arose from Newton's study of planetary motion and Bernoulli and Euler's studies of integrals. Elliptic curve cryptography relies on addition on an elliptic curve and gives a discrete dynamical system on the curve. More than two centuries after Newton, it became clear that similar discrete dynamics mapping one elliptic curve to another can also be defined. In this talk, I describe how the resulting integrable maps fit into the framework of cryptography. This suggests the possible existence of new algorithms for post-quantum cryptography.

A truss structure with mechanical optimality, integrability and artisiticity

Kenji Kajiwara, Yoshiki Jikumaru, Kazuki Hayashi, Kentaro Hayakawa and Yohei Yokosuka
Kyushu University

We report that a class of integrable discrete holomorphic functions can generate planar truss structures with a certain mechanical optimality called the Michell structure, well-known in the area of architecture. Further, the discrete planar curves formed by the edges are nothing but the discrete analogue of the logarithmic spiral which is a special case of the discrete log-aesthetic curves. Discrete log-aesthetic curves are integrable discrete analogue of the log-aesthetic curves, which is known as a class of planar curves with built-in aesthetic nature, and those curves are invariant curves with respect to integrable deformation of planar curves in similarity geometry.

Managing peak power demand for a fleet of trains

Maria Kapsis, Peter Pudney, Phil Howlett, Amie Albrecht and Peng Zhou
University of South Australia

Electric trains are an efficient means of transport but can impose significant power demands on national electricity supply systems. There are regular peaks in demand for relatively short periods of time in the early morning and early evening when public transport usage and household consumption are both high. The cost of electricity increases dramatically when there is a high demand for electricity from consumers. Railway operators are offered financial incentives to reduce their energy consumption during times of high electricity demand.

What is the best way to reduce electricity demand for a fleet of trains during multiple peak demand intervals?

Enzyme kinetics simulation at the scale of individual particles

Taylor Kearney and Mark B. Flegg
Monash University

Enzyme-catalysed reactions involve two distinct timescales. There is a short timescale on which the enzyme binds to a substrate, and a comparatively long timescale over which the resulting bound complex is transformed into a product. The rate at which the substrate is converted into product is characteristically non-linear and is traditionally derived by applying singular perturbation theory to the system's governing equations. This analysis assumes that the enzyme and substrate bind effectively instantaneously when viewed on the long timescale. Many particle-based simulations of reaction-diffusion systems are unable to accurately model this behaviour owing to their use of proximity-based reaction conditions that do not correctly model fast reactions. I will present a new reaction condition that correctly incorporates the fast reactions that occur on the short timescale for a specific enzymatic system, and demonstrate that non-linear reaction rates can be reproduced using proximity-based reaction conditions.

Self-similarity in non-Newtonian thin films

Steven Kedda, Michael Dallaston and Scott McCue
Queensland University of Technology

Thin film equations are a class of nonlinear partial differential equations, which have numerous physical applications in the industry. In the last few decades, much work has been done investigating the self-similar dynamics of thin films evolving towards singularities under various physical effects and how they interact with surface tension, including normal stresses like van der Waals (vdW) force and tangential stresses like thermocapillarity. More recent works have considered non-Newtonian rheologies of these fluids and how this might influence the qualitative behaviour of thin film rupture. Power-law fluids are a ubiquitous example of such non-Newtonian fluids. However this fluid model leads to a degenerate PDE in the context of thin film models, as the viscous stress is non-analytic with zero strain rates, possibly resulting in a non-differentiable flux. The Carreau model is a regularised version of a power-law fluid, allowing a smooth transition between Newtonian and power-law regimes for vanishing strain rates, avoiding the singular nature of modelling a power-law fluid. For vdW rupture, the long-term behaviour of the Carreau model is virtually identical to a power-law regime. In this talk we present results discussing the use of the Carreau model as a substitute for modelling power-law thin films and discuss the implications for self-similar analysis.

Complex-valued neural networks

Jamie Keegan-Treloar
Flinders University

Real-valued neural networks are hugely influential and are used across many fields, however, their convergence to the global minima is not guaranteed. By embedding neural networks into higher dimensional number systems, such as complex numbers, many limitations are alleviated. The size of the network is reduced while retaining the same functionality. A consequence of the hierarchial network structure of complex-valued neural networks is that the critical points are all saddle points with only one minimum. The capabilities of real-valued neural networks is well understood via the universal approximation theorem, however, the approximation capabilities of complex-valued neural networks is poorly understood. This presentation will introduce the mathematics of neural networks with the necessary conditions for extending to complex-values before examining the approximation capabilities of complex-valued neural networks.

Voronoi cell-based model of epithelial carcinogenesis evolution

Mst Shanta Khatun, J. Guy Lyons and Peter S. Kim
The University of Sydney

Epithelial carcinogenesis progresses from a series of genetic mutations caused during cell division. These successive mutations trigger unregulated cell growth through excessive cell division, migration, and invasion of the underlying extracellular matrix (ECM) of the tissue. In epithelial carcinogenesis, mutations accumulating in a cell play a critical role by giving rise to heterogeneous cell populations that interact and cooperate with each other and with their microenvironment, such as the ECM. In fact, the interaction and cooperation among heterogenous cells results in a cooperative tumour causing massive invasion of ECM. To model cancer, it is crucial to investigate its evolutionary characteristics and behaviours. In this study, we build a Voronoi Cell-Based Model (VCBM) of cancer evolution. Building on this model, we consider four mutations such as faster cell-cycling, impaired apoptosis, hyperproliferation, and more invasiveness (possible examples of these mutations are NOTCH, TP53, Hras and Sna2, respectively) that epithelial cells successively acquire to progress to a malignant tumour. These mutations reduce a cell's death rate, increase proliferation, and increase invasion. In addition, we consider two variations of these mutations: cell-autonomous, meaning cells only modify their own behaviour without benefitting other cells around them, and microenvironmental, meaning cells assist other cells by modifying their microenvironment. In the VCBM model, we focus on the microenvironmental interactions of the cells arising through these mutations in forming a tumour. After exploration, we found that cells acquiring microenvironmental cooperative mutations, in contrast to non-cooperative cell-autonomous mutations, can give rise to a faster-growing tumour by extensively invading the ECM.

Mathematical model of corneal epithelial cell behaviour

Neda Khodabakhsh
The University of Sydney

The cornea is the outermost transparent layer of the eye arranged in several layers. Unlike many epithelial tissues that only have one layer, the corneal epithelium, which is the cornea's exterior surface, is composed of 5-7 stratified layers. This stratification occurs through a process known as cell delamination whereby cells from one layer move upwards to the layer above. Furthermore, the corneal epithelium is preserved by migration of new basal cells from the periphery, where they are produced by stem cells, to the centre of the cornea. In 2016, Lobo et al., used mathematical and biological models to show that corneal epithelial cells in the basal layer have a centripetal growth pattern. However, given that corneal epithelium is multilayered, there are some open questions: What regulates this stratification and how are the layers organized?

In this talk, we present an agent-based model including biological forces and feedback to describe cell behavior in the basal layer. Additionally, we propose an approach to capture the dynamics of cell delamination from the basal layer.

Data-driven and physics-constrained reduced order model of the global oceans

Vassili Kitsios, **Laurent Cordier and Terence O'Kane**
CSIRO

A reduced order model (ROM) of the global oceans is developed by projecting the hydrostatic Boussinesq equations of motion onto a proper orthogonal decomposition (POD) basis. The ROM is hence constrained to the physical that the equations of motion can support. This approach also drastically reduces the complexity of the model, from a system of partial differential equations governing the spatio-temporal evolution of a three-dimensional fluid, to a system of ordinary differential equations governing the contribution of each POD mode in time. The basis of three-dimensional POD modes is calculated from the volumetric ocean fields of an ensemble climate reanalysis dataset. The coefficients in the POD ROM are calculated using a data-driven optimisation approach. The performance of various POD ROM configurations are assessed. Each configuration is derived from an alternate sea-water equation of state, linking the density and temperature fields. POD ROMs incorporating an equation of state in which density is a quadratic function of temperature, are able to reproduce the statistics of the large-scale structures at a fraction of the computational cost required to numerically simulate this flow. Due to the speed and efficiency of calculation, such ROMs of the global geophysical system may enable researchers and policy makers to assess the physical risk for a broader range of potential future climate scenarios.

Heterogeneity in network structure switches the dominant transmission mode of infectious diseases

Pratyush K Kollepara, **Rebecca H Chisholm and Joel C Miller**
La Trobe University

Several recent emerging diseases have exhibited both sexual and nonsexual transmission modes (Ebola, Zika, and mpox). In the recent mpox outbreaks, transmission through sexual contacts appears to be the dominant mode of transmission. Motivated by this, we use an SIR-like model to argue that an initially dominant sexual transmission mode can be overtaken by casual transmission at later stages, even if the basic casual reproduction number is less than one. Our results highlight the risk of intervention designs which are informed only by the early dynamics of the disease.

A reinforcement learning method for optimizing the omnichannel retail problems

Mary Kolyaei, Lele Zhang and Hamideh Anjomshoa
The University of Melbourne

We study the fulfillment and inventory operations faced by an omnichannel retailer selling multiple products to customers in different customer zones. The retailer serves its customers through both online and physical channels, offering a seamless shopping experience. To formulate this problem we consider a sequential stochastic programming model over the planning horizon. The retailer should balance between fulfilling current orders and proactively replenishing inventory to meet future demands. State-of-the-art Deep Reinforcement Learning (DRL) algorithms such as PPO and A3C are evaluated and compared using numerical examples. Besides, the experimental design is formulated and executed, encompassing variations in supply chain structures and costs. We also applied (s,Q) policy as a foundational reference for evaluating the efficacy of more advanced agents. Consequently, DRL emerges as a practical and effective choice for addressing real-world problems.

Mathematical assessment of the role of intervention programs for malaria control

Maame Akua Korsah, Stuart T. Johnston, Kathryn Tiedje, Karen Day, Jennifer A. Flegg and Camelia R. Walker
The University of Melbourne

Malaria remains a global health problem despite the many attempts to control and eradicate it. There is an urgent need to understand the current transmission dynamics of malaria and to determine the interventions necessary to control malaria. In this paper, we seek to develop a fit-for-purpose mathematical model to assess the interventions needed to control malaria in an endemic setting. To achieve this, we formulate a malaria transmission model to analyse the spread of malaria in the presence of interventions. A sensitivity analysis of the model is performed to determine the relative impact of the model parameters on disease transmission. We explore how existing variations in the recruitment and management of intervention strategies affect malaria transmission. Results obtained from the study imply that the discontinuation of existing interventions has a significant effect on malaria prevalence. Thus, the maintenance of interventions is imperative for malaria elimination and eradication. In a scenario study aimed at assessing the impact of long-lasting insecticidal nets (LLINs), indoor residual spraying (IRS), and localized individual measures, our findings indicate that increased LLINs utilization and extended IRS coverage(with longer-lasting insecticides) cause a more pronounced reduction in symptomatic malaria prevalence compared to a reduced LLINs utilization and shorter IRS coverage. Additionally, our study demonstrates the impact of localized preventive measures in mitigating the spread of malaria when compared to the absence of interventions.

Emergence of a blender: weaving a carpet from one-dimensional global manifolds

Dana C'Julio, Bernd Krauskopf and Hinke M Osinga
University of Auckland

A blender is a tool for constructing a new type of 'wild' chaotic dynamics in invertible maps of dimension three and vector fields of dimension four. We study a family of 3D Hnon-like maps and make precise statements about how a blender emerges when parameters are changed. To this end, we employ advanced numerical techniques to determine when the one-dimensional stable manifolds of relevant saddle points weave through phase space to form an impenetrable carpet, which is the characterising property of a blender. The exact mechanism of how a blender emerges depends on the orientability of the map.

Incorporating cell mechanics into a model of biological tissue growth within confined spaces

Shahak Kuba, Pascal Buenzli and Matthew Simpson
QUT

During biological tissue growth, cells proliferate and embed into the extra-cellular matrix that they produce to form new tissue. This growth typically occurs in confined spaces, such as porous spaces in bone and in tissue engineering scaffolds. As new tissue material is only deposited in available space, the growth process is highly regulated by local geometry, resulting in what is called geometric control of tissue growth. While the effects of geometry during tissue growth are established, empirical observations also suggest cellular mechanics significantly influence the growth process. To explore the relationship between these two influences (on where and how fast tissue grows), we develop a cell-based mathematical model of tissue growth that includes cell-cell mechanical interactions. Operating under the assumption that the active cell proliferation and embedment of tissue production occurs solely at the leading edge, our discrete cell-based model simulates the evolution of the leading edge through mechanical interactions and the production of an extra-cellular matrix. Our numerical simulations align with the findings of existing continuum models of tissue growth. We also show that in an appropriate continuum limit in which spacings between cells tend towards zero, the evolution of cell density is governed by a reaction-diffusion-advection equation on the moving tissue boundary, where tissue-scale diffusivity is related to the mechanical relaxation parameters of the discrete cell-based model.

Solution of Fisher's and Burger's-Fisher equation using septic Hermite collocation method

Archna Kumari and Vijay Kumar Kukreja

In this paper sixth-order Hermite scheme for the numerical solution of Fishers and Burgers'-Fisher equations is developed. This scheme is a combination of orthogonal collocation on finite element method and septic Hermite base function. The septic Hermite ensures continuity of dependent variable and its first three derivatives throughout the solution range and are applied for space discretization, whereas Crank-Nicolson scheme is used for time discretization. A system of (6N+2)X(6N+2) equations is obtained, which is solved using MATLAB software. The stability and convergence analysis of the scheme are also discussed. Peano theorem is used to estimate the error bounds for septic Hermites and the calculations are performed using Mathematica software. Number of examples are considered to demonstrate the accuracy of the scheme and compare the results with the exact solution or the data available in literature. Overall, the scheme is found to be easy to implement and gives better results than the existing ones.

A multiple time scale analysis of an immunogenic tumour model

Timothy Earl Figueroa Lapuz
The University of Sydney

In 1994, Kuznetsov et. al. presented a model of a tumour population that is cell-mediated by effector cells e.g. cytotoxic T lymphocyte cells. In 2020, Osojnik et. al. revisits the model to discuss aspects of its excitable behaviour. In this talk, we present the model through the lens of geometric singular perturbation theory (GSPT).

A bifurcation analysis under the variation of the basal effector supply rate is shown. The oscillatory regime is of particular interest as there are segments where it appears the tumour is dormant, but can quickly resurge. The model is then nondimensionalised with this in mind.

In our analysis, coordinate-independent (i.e. nonstandard) GSPT methods are used to find the leading-order approximations of the flow on multiple time-scales, which differs from Osojnik et. al., where a coordinate transformation was made so that it is amenable to standard GSPT methods. In our present case, it turns out that higher-order terms of the 2D slow manifolds underlying the system and its corresponding slow flows are required and so the parametrisation method is employed. This then leads us to a discussion of the observed relaxation oscillation.

Synchronization of two coupled quadcopters using contraction theory

Jagdeep Singh Lather and **Arpit Sharma**
National Institute of Technology Kurukshetra

This paper investigates the synchronization of two coupled quadcopters via contraction theory. The aim to achieve synchronization in the roll and pitch angles of two quadcopter models. The mathematical modelling and synchronization procedures have been developed and simulated on Matlab respectively. Supplement to the identical characteristics of the quadcopters, intentional variations in their initial conditions were introduced. The inherent nonlinearities of quadcopters renders them highly responsive to even the slightest deviations in initial conditions, resulting in abrupt trajectory variations. The application of contraction theory is shown to emerge as a valuable and effective solution to mitigate these challenges, ensuring stability and coherence in the synchronized behavior of the quadcopters.

Grandmother care and the origin of menopause

Anthia Le
The University of Queensland

The image of a grandmother is widely associated with a little old woman, lovingly caring for her grandchildren by providing them with freshly baked goods. However, although humans and other great apes share a common ancestor, this image of older females providing care for kin is surprisingly only synonymous to older human females. Even if older female great apes had the propensity to provide care for kin, they do not live past their reproductive years. This deviation in life history could shed light on how human females evolved to have a post-fertile life stage. In particular, the Grandmother Hypothesis suggests that environmental changes encouraged postmenopausal females to aid in caring for dependants and ensure the survival of their kin.

I will present a system of ordinary differential equations (ODEs) to examine whether the Grandmother Hypothesis could allow for traits associated with menopause, a long lifespan and old-age infertility to evolve. We find that regardless of whether the birth rate is dependent on mother or offspring longevity, grandmother care can cause a shift in our ancestral lineage from one without a post-fertile life stage to one that does.

Agent-based modelling in the post-Omicron era of COVID-19 management

<u>Thao P Le</u>, Eamon Conway, Edifofon Akpan et al.
The University of Melbourne

In the post-Omicron era of COVID-19, populations worldwide now have complex immune landscapes with unique exposure and vaccination histories. Going forward, optimal, sustainable, and cost-effective vaccine use is required to manage COVID-19 disease burdenall of which is country-context specific. Here, we use agent-based modelling to simulate a range of prior immune landscapes and population demographics. The agent-based modelling framework allows us to simulate individuals with unique neutralising antibodies, age, and history of vaccination and infection exposure, which in turn affects each individual's contacts, probability of transmission, infection and severity of disease. Using this model, we can assess the subsequent impact of different types of vaccine programs across the different population demographics and income levels to determine which strategies are more cost-effective than others. Across different population demographics and income levels, we consistently find that boosting strategies targeting older age groups (representing populations at risk) are most likely to be cost-effective, with paediatric programs unlikely to be cost-effective regardless of country income.

The effect of calcium influx on calcium signalling

<u>Lloyd Lee</u>, Ryan Yoast, Scott Emrich, Mohamed Trebak, Vivien Kirk and James Sneyd
University of Auckland

Cells utilize the changes in the calcium ion concentration inside them as a signal to perform all sorts of cellular functions. The calcium signal is governed by a complex set of interactions, and one of the major pathways is through calcium influx. Recent experimental data for HEK293 cells shows that two rather different types of oscillation can occur when a cell is stimulated with agonist: narrow-spike oscillations (whereby calcium concentration decreases quickly after a sharp increase) and, for cells with a low amount of calcium influx, broad-spike oscillations (whereby calcium concentration decreases in a prolonged manner after a sharp increase).

In this talk, a mathematical model that exhibits both broad- and narrow-spike oscillations, depending on the amount of calcium influx, is proposed. Bifurcation analysis of the proposed model shows that broad-spike oscillations are only observed for cells with a low calcium influx, agreeing with the experimental results.

Mathematical models of therapeutic intervention in robust chemical reaction networks

Noa Levi, Robyn Araujo and Adrianne Jenner
Queensland University of Technology

A recurrent feature of biological systems is their capacity for adaptation. This allows systems to process changes in the external environment and robustly adjust themselves to maintain a fixed output, or setpoint'. The propensity for biological systems to exhibit adaptation is thought to play an important role in many treatment failures, especially in the context of cancer, since the underlying signalling networks are frequently able to adapt to the therapy. Here we investigate a range of pharmaceutical drugs, specifically enzyme inhibitors, and create novel mathematical models of therapeutic intervention in robustly adapting biological networks. Analysis of these models unveils the specific requirements of a candidate drug to disturb RPA in adaptation-capable systems, which is believed will have profound consequences for the future of drug development against a wide range of human diseases.

Forecasting climate change impacts on the production of crops key to food security

Dan Li, Terence J. O'Kane and Vassili Kitsios
CSIRO

Climate change poses a serious threat to the agricultural industry, making it highly vulnerable. This susceptibility could potentially result in reduced crop production, which in turn, could have substantial repercussions on policies related to food security. Forecasting the prospective impacts of climate change on crop production necessitates a comprehensive model outlining how crops could respond to potential future conditions. This study introduces a multivariate autoregressive econometrics model aimed at capturing the relationships between climate variables and the annual growth rate in crop yield across the world's producing regions. Utilizing historical national production data for crops key to food security and climate variables spanning from 1961 to 2018, the developed model demonstrates superior accuracy as compared to previously published traditional panel regression methods. The projected future impacts of climate change on crop production growth, concerning temperature and precipitation, are estimated using the proposed econometric model. These future estimates are derived for a wide range of potential carbon emissions scenarios. The required climate responses to these emissions scenarios are calculated using QuickClim, a recently published, highly computationally efficient machine learning approach to climate projections.

Modelling of cylindrical yeast colony growth

Kai Li, Anthony Gallo, Benjamin Binder and Edward Green
The University of Adelaide

Experimental studies on yeast growth are of fundamental importance in modern-day microbiology because yeasts are model organisms used to understand how cells function, with application to disease research such as cancer and pathogenic infections. In this talk, we will investigate and provide a mathematical framework to identify and analyse the key mechanisms that drive cylindrical yeast colony expansion. This growth mode is in the uniaxial direction where we derive and solve a system of reaction-diffusion-advection equations for cell density, pressure, and nutrient concentration.

Pan-Antarctic assessment of ocean wave induced flexural stresses on ice shelves

Jie Liang, Jordan Pitt and Luke Bennetts
The University of Adelaide

There has been rising interest in ice shelf flexure produced by ocean waves due to a combination of recent theoretical studies and observed calving events. Current mathematical models that explore the flexure of ice shelves induced by ocean waves often employ a simplified uniform geometry, consisting of constant shelf thickness and seabed. Bennetts et al (2022, Geophysical Research Letters, doi.org/10.1029/2022GL100868) introduced an efficient mathematical model of the wave-induced shelf flexure for the non-uniform geometry of the Ross Ice Shelf taken from the BEDMAP2 dataset. The results showed significant impact of shelf geometry and wave period on flexural strain.

The presented study further investigates the impact of geometrical variations on shelf flexure. It extends the work of Bennetts et al (2022) to multiple ice shelves, providing statistical relationships between shelf flexure and ice shelf thickness and seabed variation across the range of wave periods (swell, infra-gravity, and extremely long period waves).

Generating synthetic contact matrices using open-source data

Michael Lydeamore, Nick Tierney, Aarathy Babu and Nick Golding
Monash University

Contact matrices describe the degree of contact between individuals of given age groups. These matrices are commonly used to model how diseases such as COVID-19 spread in a population through social contact. There are pre-existing statistical methodologies to project empirical contact matrices to new countries. These projections have been demonstrated by Prem et al., and the resulting matrices have been extensively applied across infectious diseases applications.

However, the social contact assumptions from Prem et al. do not match observations in many countries, and only provide outputs of the contact matrices for each country at the whole of country level. This is limiting, as the age population distribution of many countries, including Australia, is quite heterogeneous, and assuming it is homogeneous would result in inaccurate representation of community infection in many regions.

In this talk we demonstrate new methods and a new free and open source software solution to compute synthetic contact matrices using population demographics, and present a comparison with established methods.

Bifurcation analysis of a two-delay model for the Atlantic Meridional Overturning Circulation

Renzo Mancini, Tra Dinh and Bernd Krauskopf
The University of Auckland

We perform a bifurcation study of a conceptual model for the Atlantic Meridional Overturning Circulation (AMOC) in the form of a scalar delay differential equation (DDE) with two time delays. The time delays are associated with the negative salinity feedback between the Equator and the North Pole, and the density exchange between the surface and deep water at the Pole. After rescaling, the delays are the only parameters of the model.

Our findings are presented as a two-dimensional bifurcation diagram in the plane of the two delays. The system exhibits complex oscillatory behavior, which we analyze with the software package DDE-Biftool for Matlab. This enables the identification and characterization of fascinating dynamics, including codimension-two Belyakov and Shilnikov-Hopf global bifurcations, which act as organizing centers for nearby dynamics. In particular, we discover previously unknown limiting periodic oscillations with rational ratios between the delays and the associated period, which we refer to as *locking orbits*. Moreover, we show where in the parameter space the nontrivial oscillations are stable and, hence, observable in the context of the AMOC.

Unsteady solutions of the forced Korteweg–de Vries equation with negative forcing and weak dispersion

Kholod Mandoora
Monash University

Among many applications the forced Korteweg–de Vries (fKdV) equation models the transcritical flow of stratified fluids over topography, where the forcing can be classified as positive or negative dependent on the particular stratification. The hydraulic approximation is essential in analysing transcritical flow for positive forcing. However, the hydraulic approximation fails for negative forcing when the dispersion is weak, mainly due to the unsteady shock waves over the topography. Here we analyse the types of solutions that exist for the fKdV equation with zero initial condition for negative forcing and small dispersion. Numerical simulations are obtained using the pseudospectral method for spatial discretisation and the fourth-order linearly implicit Runge–Kutta method with a variable step-size approach for time discretisation. We use the wave resistance to classify the types of solution regimes and the wave resistance power spectrum to identify the dominant frequencies of solutions. We identify three main regimes, supercritical, transcritical, and subcritical, that each contain classical, intermediate, and weak dispersion subregimes. Moreover, we discuss the nature of instabilities over the topography for weak dispersion.

Modelling of dispersal of hydrogen in the retina: Axisymmetric solution

Wafaa Faisal Mansoor and Graeme Hocking
Murdoch University

A simple mathematical model of advection and diffusion of hydrogen within the retina is discussed to assist in interpretation of the hydrogen clearance technique that is used to estimate blood flow. The model assumes the retina consists of two, well-mixed layers with different thickness, assuming flow is radially outwards from the centre of the retina. Solutions to the governing equations are obtained by employing Laplace transform and convolution integral theory, respectively. The model results show that the velocity of the peak in hydrogen concentration is not the same as blood flow velocity. The effect of the diffusion across the avascular layer is to redistribute the hydro- gen so it takes a slower path along the retina. This research contributes to understanding the dispersal of hydrogen in the retina and in particular the blood flow in the vascular retina. Accurate measurement of retinal blood flow can be used to detect early signs of disease such as diabetes.

Stability of asymptotic waves in the Fisher-Stefan equation

T. Bui, P v Heijster and R. Marangell
The University of Sydney

This talk will discuss spectral, linear, and nonlinear stability of the vanishing and slow-moving travelling waves that arise as time asymptotic solutions to the Fisher-Stefan equation. All stability is in terms of the limiting equations that the asymptotic waves satisfy.

Mathematical modelling of solute pathways and residence in human stratum corneum

Rory Marriott, Yuri Anissimov, Tim Gould and Owen Jepps
Griffith University

Solute transport phenomena in the stratum corneum is a vitally important field of study for the development of transdermal drug delivery systems and risk assessment of toxicological exposure of chemicals to the skin. Mathematical models have been built to investigate the contributions of different stratum corneum transport pathways and reservoir formation to transdermal drug delivery. A finite element model was developed in Python to investigate the role of various microscopic phenomena on reservoir formation and transdermal penetration. A compartmental model was developed to investigate the macroscopic effects of slow binding and epidermal turnover on drug delivery and elimination. Using the finite element model, the effects of various lipid layer structures on transdermal penetration pathways were elucidated, showing that intercellular pathways may be more prevalent than is often thought. Evidence was found that both limited cornified envelope permeability and anisotropic lipid regions can independently explain experimental observations of permeation pathways. The compartmental model showed that significant amounts of solute sequestered by reservoir formation can be lost from the skin's surface due to epidermal turnover. This may be a source of discrepancy between in vitro and in vivo experiments of transdermal penetration. It was shown that the true extent of this effect is not captured under the assumption of instantaneous binding, and that slow equilibration events are an essential aspect of modelling in vivo transport.

A unified characterization of blow-up solutions for ODEs through dynamics at infinity

Kaname Matsue
Kyushu University

A characterization of blow-up solutions for ODEs is provided. Through embeddings (compactifications) of phase spaces and time-scale transformations, vector fields are transformed into appropriate ones, called desingularized vector fields, which "dynamics at infinity" makes sense. Local (center-)stable manifolds of invariant sets at infinity then characterize blow-up solutions with their asymptotic behavior, the blow-up rates and geometric morphology. In this talk, I'll talk about an overview of results involving this issue as far as the time permits, the basic characterization and various generalizations such as "type-II blow-ups", "asymptotic expansions", "computer-assisted analysis" and extension to "nonautonomous systems".

Balancing the privacy and utility with margin-consistent noise

Harry McArthur, Joseph Chien, Chris Mann, Kate Smith-Miles and Peter Taylor
The University of Melbourne

One of the central goals of data-dissemination organisations around the world is to collect and publish information about individuals in a population to inform important policy decisions and research objectives. Can we ensure the privacy of the individuals is maintained while retaining the utility of the data? One of the most fundamental ways information about a population is released is via a collection of statistics called counting queries. These statistics essentially count the number of records in a population meeting a specific criteria. The current techniques used to make inference about an individual difficult or uncertain rely on injecting a controlled amount of noise into the statistics — effectively meaning the published counts are close to the true values but intentionally different. In order to quantify the level of unintended disclosure of sensitive information a given technique has, we can consider what an attacker can learn from the released information, or equivalently what they can reconstruct about the underlying database. Anything that can be learned about an individual is a potential violation of privacy. We discuss the design of different reconstruction methods for the purpose of informing the decision on how best to inject this noise, or implement other privacy preserving techniques — optimising the utility of the data subject to certain privacy constraints. A natural property of the published statistics is to be margin-consistent, meaning the published marginals (or total counts) are consistent with the corresponding interior cell counts across any choice of contingency table. Generally, this property is not imposed due to tractability issues when simultaneously satisfying privacy constraints. We believe enforcing this property can provide significantly improved protection guarantees for the same amount of added noise, and consequently propose a novel and efficient method for generating margin-consistent noise based on Markov-Chain Monte-Carlo techniques. Using existing database reconstruction attacks in the literature, we use our proposed algorithm to generate statistics with margin-consistent noise and validate its privacy-preserving properties by comparing it to identically and independently distributed (IID) noise through a series of computational experiments.

Three-dimensional linear gravity-capillary wave patterns

Scott W. McCue, Ravindra Pethiyagoda, Nicholas R. Buttle and Timothy J. Moroney
Queensland University of Technology

For a disturbance travelling steadily in a straight line, fully three-dimensional gravity-capillary wakes are complicated patterns that depend heavily on the speed of the disturbance, with potentially three wave components: transverse waves propagating predominately in the direction of travel behind the disturbance; divergent waves propagating away from the path behind the disturbance; and capillary waves propagating ahead of the disturbance. A well-known result within the linear water wave framework is that no periodic gravity-capillary waves will be produced if a steadily moving disturbance is travelling slower than the critical speed $c_{\min} = \sqrt[4]{4g\gamma/\rho} \approx 0.23\text{ms}^{-1}$, where g is acceleration due to gravity, γ is surface tension, and ρ is the fluid density for water. We shall discuss two less-studied scenarios. First, three-dimensional gravity-capillary waves are still possible for speeds less than $c_{\min}$, although, such wave patterns necessarily involve exponentially decaying amplitudes along the sailing line. And second, for an accelerating disturbance or a disturbance travelling along an arbitrary path, an additional type of spiral wave can appear, which is especially interesting when the speed of the disturbance is less than $c_{\min}$.

Modal error analysis and prediction compensation for Earth system models

Sean McGowan, Sanjeeva Balasuriya, Will Robertson and Nicole Jones
The University of Adelaide

Predicting Earth systems is an important yet challenging problem resulting from the dimensionality, chaotic behaviour, and coupled dynamics of the ocean, atmosphere, and other subsystems of the Earth. The numerical models derived to predict these systems will ultimately contain model error due to limited knowledge and capabilities of representation. Hybrid modeling by pairing a model with a data-driven component has shown promise in outperforming both purely model and data-driven approaches in predicting complex systems. This talk presents two hybrid approaches that may be used to give insight into model error, or to compensate a model during prediction. The effectiveness of this technique is demonstrated on two Earth system variables: tides and sea surface temperature.

Bauxite moisture measurement using microwaves

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

A key uncertainty when delivering bauxite ore to an alumina factory is the moisture content in the shipment. A microwave analyser measures phase shift and attenuation in real time, of microwaves passing through the ore while it is entering the factory on a conveyor belt. These measurements are used to infer the moisture content of the ore, which affects its weight, and directly impacts the price paid per tonne. Our study is motivated by data provided to a Study Group with Industry that was collected from a number of shipments of bauxite ore.

A single-layer model based on Maxwell's differential equations for electromagnetic wave propagation in bauxite underlies the regression that the microwave analyser uses to infer moisture content. This model predicts a linear dependence of data on ore height, and fails to explain the highly nonlinear dependence on bauxite height that is seen in attenuation data.

We develop and solve a four-layer model that allows reflections of electromagnetic waves at interfaces between ore and air. Our model solution features highly nonlinear attenuation as a function of ore height, providing convincing matches to analyser data. It explains how the interference effects of multiple internal reflections cause data to be sensitive to setup geometry and ore height. It provides some hope of improving real-time measurement of ore moisture content using microwaves on a conveyor belt, while also sounding a cautionary note about the possibilities of non-invertibility of the data.

Theory of piezolectric and other hydroleastic wave energy converters

Mike Meylan
The University of Newcastle

Hydroelasticity is the combination of fluid motion and elasticity. Recently, there have been numerous suggestions for wave energy conversion that are based on elastic motions. Some of these proposals involve the use of elastic motion to generate mechanical energy, while others take advantage of the piezoelectric effect. In this presentation, I will provide an overview of the fundamental modelling for these devices and examine various experimental and theoretical studies.

The effect of bump height and length on the free-surface in open channel flows

Hugh Michalski
The University of Adelaide

In this talk, we examine the effect of bump height and length on the air-water interface in two-dimensional open channel flow, using a weakly nonlinear Korteweg-De Vries model with a rectangular bump (boxcar function). Analysis in the weakly nonlinear phase plane provides a way to understand the behaviour of wave amplitude downstream of the bump. It is shown that there is an infinite set of discrete bump lengths with zero-amplitude waves downstream of the bump, for a fixed bump height. This result is compared to Horace Lamb's linear approximation of flow past a semi-ellipse. The research has practical application in reducing the destructive force of large amplitude waves on waterway infrastructure, such as sluice gates and weirs, and minimising wave-drag past submerged obstacles (e.g. a submarine).

Modelling immune cell interactions with endometrial cells in endometriosis

Claire Miller
The University of Auckland

Endometriosis is a chronic condition in which cells similar to those that line the uterus (endometrial cells) grow lesions outside the uterus, commonly in the pelvis. This condition affects one in nine people with a uterus. The predominant hypothesis for onset of the disease is retrograde menstruation, where menstrual debris enters the pelvic region via the fallopian tubes.

There are likely complex interactions between the endometrial cells and the immune system when the cells enter the pelvic region—altered immune environments have been observed in endometriosis patients compared to controls. However, we do not know if the observed altered immune state is abnormal or simply a result of the endometrial cells' presence.

In this talk, I will present a compartmental model of endometrial cell and the immune cell interactions, specifically macrophages and natural killer cells. I will discuss the effect of endometrial cell influx amount, immune escape, and immune cell killing efficacy on lesion size and immune state in the model.

Shock positions for regularized reaction-diffusion equations with negative diffusivity

Thomas Miller, Bronwyn Hajek, Alex Tam, Robert Marangell, Phil Broadbridge
University of South Australia

Reaction diffusion equations describe how the density or concentration of a substance varies in space and time. They have many applications including in chemical physics, population dynamics and biomedical processes. Usually the diffusivity 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.

Reaction diffusion equations with a region of negative diffusivity may give rise to shock solutions and may need regularisation terms in order to be solved numerically. However, imposing a regularisation term can also impose a certain shock position, for instance the regularisation term $\epsilon^2 u_{xxxx}$ is associated with a shock position that satisfies an equal area rule and the regularisation term ϵu_{xxt} is associated with a shock position that jumps to or from a zero of the diffusivity.

One possible shock position we may consider is one that conserves the diffusivity across the shock. For a symmetric diffusivity this coincides with the equal area rule shock position, but for a non-symmetric diffusivity the shock positions for equal area and equal diffusion they no longer coincide. We investigate whether it is possible to construct a regularisation that gives rise to the equal diffusion shock position for both symmetric and non-symmetric diffusivities and find that a nonlinear (rather than linear) fourth order term can achieve this.

A generalised sigmoid population growth model with energy dependence: application to quantify the tipping point for Antarctic shallow seabed algae

Elise Mills, Graeme Clark, Matthew Simpson, Mark Baird and Matthew Adams
Queensland University of Technology

Sigmoid growth models are commonly used to study population dynamics. The size of a population at equilibrium common depends explicitly on the availability of resources, such as an energy or nutrient source, which is not present in standard sigmoid growth models. We introduce a simple generalised extension of sigmoid growth models that can explicitly account for this resource-dependence and demonstrate three examples of this family of models of increasing mathematical complexity. We calibrate and compare each model to observed data for algae under sea-ice in Antarctic coastal waters. We found that through careful construction, models satisfying our framework can estimate key properties of a sea-ice break-out controlled tipping point for the algae, which cannot be estimated using standard sigmoid growth models. Our proposed broader family of energy-dependent sigmoid growth models likely has usage in many population growth contexts where resources limit population size.

Complex systems and networks approaches to modelling atrial fibrillation

Lewis Mitchell
The University of Adelaide

Complexity – the emergence of large-scale phenomena from simple, local rules – arises in numerous natural systems from the micro-scale to macro social systems. Closely related is the study of complex networks and network science, which brings a mathematical and computational toolkit to analyse such systems. In this talk we will look at the application of complex systems approaches to a problem in mathematical biology. We will explore how stochastic modelling approaches to characterise atrial fibrillation (AF) in cardiac research, and suggest clinical treatment approaches. We will further discuss how complex network methods may be deployed to understand the emergence of AF at a more granular level.

Understanding the active metabolic oscillatory subsystem in pancreatic beta cells using geometric singular perturbation techniques.

Prannath Moolchand and Martin Wechselberger
The University of Sydney

Insulin secretion by pancreatic beta cells in response to blood sugar level is fundamental to vital life functions, and is modulated by the tight bidirectional coupling of electrical and metabolic oscillators. Bertram et. al (2023) have recently presented such an Integrator Oscillator Model, whereby the slower metabolic oscillations are mediated by two mechanisms, namely: glycolytic oscillations, also referred to as the active metabolic oscillators (AMO) and calcium effects on ATP consumption, the passive metabolic oscillators (PMO). Our study focuses on the AMO where we employ dimensional analysis (Kosiuk and Szmolyan, 2011) to define appropriate reference scales and non-dimensionalise the model to identify small parameters and processes evolving on different timescales. We proceed to identify the oscillatory regime of this model and show that such metabolic oscillations can be recast as relaxation oscillations (Jelbart et al., 2022), a more general class of multiple timescale problem involving oscillation cycles comprising fast and slow segments. Using the machinery of geometric singular perturbation theory developed for such relaxation oscillators (Wechselberger, 2020), we aim to rigorously explain the observed metabolic oscillations and their contribution to bursting.

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Computation of random time-shift distributions for stochastic population models

Dylan Morris
The University of Adelaide

Even in large systems, the effect of noise arising from when populations are initially small can persist to be measurable on the macroscale. A simple example of such behaviour is estimating the peak timing in models of epidemics, which is influenced by the amount of time it takes to reach the exponential growth phase. A deterministic approximation to a stochastic model will fail to capture the effect of the noise, but it can be accurately approximated by including an additional random time-shift to the initial conditions. In this talk I will present an efficient numerical method for computing the distribution of the time-shift for a large class of stochastic models. The explicit computation of the time-shift distribution can be used to build a practical tool for the efficient generation of macroscopic trajectories of stochastic population models, without the need for costly stochastic simulations. I will provide an example of using such methods to simulate a simple within-host viral dynamics model where accurately capturing the effect of the early-time dynamics are critical in providing a more accurate realisations compared to using traditional mean-field approximations.

Hyperbolic special functions and the projection-slice theorem

Peter Morrison

The projection-slice theorem is ubiquitous across many areas of applied mathematics, known for giving a formula that brings together the Fourier, Abel and Hankel transforms. This talk will cover a generalised form of this theorem which brings together a number of different special functions, including those related to functions of Mehler-Fock, Macdonald and Whittaker type. We show how this analysis can be extended to give a number of interesting results that can be loosely terms as index transforms. We then proceed to develop an understanding from this perspective of the different representations of the hyperbolic plane, and show how they all related to the hyperbolic heat kernel. We close with some discussion of more advanced topics related to spectral traces, zeta functions and addition formulae related to relativistic systems.

Quantifying biological heterogeneity in nanoparticle-cell interaction experiments

Ryan J. Murphy, Matthew Faria, James M. Osborne and Stuart T. Johnston
The University of Melbourne

Nanoparticles are a promising tool for targeted drug delivery. However, many nanoparticles that demonstrate high efficacy in preclinical experiments perform poorly in clinical trials. Here, we examine in vitro nanoparticle-cell interaction experiments designed to assess nanoparticle efficacy. These experiments are summarised by the nanoparticle-cell association rate. Previous studies focus on point estimates of this rate and overlook the measured heterogeneity present in cell-only and particle-only control samples. In this study, we go beyond previously employed methods, such as the method of least squares, and use approximate Bayesian computation methods and a hierarchical ODE-based mathematical model to explore a range of experimental designs. By exploiting previously overlooked heterogeneity in control samples, we reveal heterogeneity in nanoparticle-cell association rates and generate predictions for quantities that cannot be observed by experimentation alone such as the time-evolution of the number of associated nanoparticles. These findings suggest that it is important to consider heterogeneity even when interpreting the simplest of controlled in vitro nanoparticle-cell interaction experiments.

Mathematical tools for science students—a context-driven applied mathematics service unit

Mary Myerscough and Nathan Duignan
The University of Sydney

The BSc degree at the University of Sydney has always had a compulsory mathematics and/or statistics core component in first year. Prior to 2018, this was essentially "mathematicians' maths" taught at various levels of depth and complexity: Fundamental, Mainstream and Advanced. (The purpose of these multiple levels was to allow for the diversity of students' choices in high school mathematics study.) Mathematics and Statistics majors, Engineering students, students studying mathematics for an Education degree and students taking mathematics as part of their BSc core were all taught in the same units. For all of these units, we assumed that students had studied calculus at some level before starting university.

In 2017 our School introduced a new unit "Introduction to Data Science" where statistics was taught using a practical, contextual approach. This raised the possibility of a complementary new unit for Science students which would replace the Fundamental level units and where mathematics was taught in a contextual setting, where students were encouraged to use numerical and algebraic software and where the focus was on the type of mathematical thinking that students would need for science, particularly chemistry and the life and medical sciences, rather than on mathematical theory alone.

This new unit, "Mathematics Toolbox for Science" was introduced in Semester 1, 2023, following extensive consultation both within the School of Mathematics and Statistics and with colleagues in other Schools in the Faculty of Science.

In this presentation, we will describe some of the features of this new unit and what we have learnt from designing and teaching it.

Path integral approach to universal dynamics of reservoir computers

Naoto Nakano
Meiji University

We study a characterization of the reservoir computer (RC) by the probability distribution of coupling constants of the random network. Utilising the path integral method, we elucidate random network dynamics, leading to a classification of networks based on the coupling constant distribution function and the eigenvalue distribution of the matrix of the coupling constant. The findings suggest a correlation between the RC's computational capacity and network parameters across universality classes. Numerical simulations reveal superior computational performance near phase transitions. This work provides novel insights for designing RCs.

A mathematical model for the role of smooth muscle cells phenotype switching in atherosclerotic plaque

Joseph P. Ndenda, Michael G. Watson and Mary R. Myerscough
The University of Sydney

Vascular smooth muscle cells (VSMCs) play a fundamental role in the pathophysiology of atherosclerosis. VSMCs form a cap over the mid-stage atherosclerotic plaque. These VSMCs in the cap may ingest lipids, in a similar way to plaque macrophages. This stimulates a switch, cells triggered by internal lipid accumulation, of SMCs to a macrophage-like phenotype. However, these SMC-derived macrophages (SDMs) are ineffective in clearing lipids and apoptotic cells from the lesion microenvironment, and they have a reduced phagocytic capacity compared with classical monocytes, macrophages, or dendritic cells. Failure to remove lipids and apoptotic cells from the atherosclerotic plaque leads to secondary necrosis and an inflammatory necrotic core. The fibrous cap has a critical role in plaque maintenance, and the number of SMCs in fibrous caps is directly correlated with plaque stability. A thin fibrous cap, where the VSMC population has been depleted, increases rupture risk. Plaque rupture releases thrombogenic material and causes thrombus formation, leading to clinical complications such as heart attack and stroke. The mechanisms of phenotypic switching, cap formation, and plaque stability remain poorly understood in the pathogenesis of atherosclerosis.

In this study, we present a simple ordinary differential equation model that examines the role of phenotypic switching of vascular smooth muscle cells on atherosclerotic plaque progression. The model includes cell populations and the total lipid content of each cell population because this lipid load determines VSMC phenotypic switching. Through analysis and numerical simulations, we explore the balance between VSMC populations and macrophage populations when there is phenotypic switching. Sensitivity analysis was performed to determine model biological parameters associated with plaque stability. These observations are vital for understanding the factors and mechanisms on phenotypic switching of vascular smooth muscle cells for atherosclerotic plaque progression and stability.

On solving a class of graph theoretic nonconvex optimization problems

Samir Kumar Neogy
Indian Statistical Institute Delhi Centre

In this talk we consider a special class of optimization problems involving distances in trees and the resistance distance of a connected graph with n vertices. These problems are non-convex quadratic programming problems. Besides the graph theory literature there are at least three other areas where these problems have been considered. These areas are: (i) a generalized notion of diameter of a finite metric space (ii) maximizing weighted average distance in graphs and (iii) Nash equilibria of symmetric bimatrix games. We describe these connections in this talk and show that these problems can be converted into a quadratic programming problem with a positive definite matrix and hence can be processed by Lemke's algorithm.

A model for accidental and regulated cell death during the expansion of yeast biofilms

Daniel J Netherwood, Alexander Tam, Edward Green, Jennifer Gardner, Campbell Gourlay, Vladimir Jiranek and Benjamin Binder
The University of Adelaide

The yeast species *Saccharomyces cerevisiae* (the budding yeast) is one of the most intensively studied fungal organisms on the planet due to being an excellent eukaryotic model organism in molecular and cell biology. The expansion of yeast biofilms, where proliferating yeast cells reside within a self-produced extracellular matrix, has garnered significant scientific interest due to its applicability in the biological and biomedical industries. A central feature of the expansion of yeast biofilms is cellular demise, which is onset by one of two independent mechanisms: either accidental cell death (ACD) or regulated cell death (RCD). In this talk, we expand on a recently developed continuum model for the nutrient-limited growth of a yeast biofilm to include the effects of ACD and RCD. The model consists of a coupled system of four non-linear reaction-diffusion equations for the yeast cell density, the essential nutrient concentration, and two species of dead cells. Numerical solutions of the spatially one and two-dimensional governing equations reveal that cells that die by the mechanism of RCD do so in a localised annular region, which propagates with the biofilm as it expands. We find that cells that die by the mechanism of ACD do so in a circular region, which follows the expanding annular region of RCD cells. We conclude by comparing our numerical predictions with our own experiments, where we observe good qualitative agreement.

Travelling wave model of competitive cell invasion

Zoltan Neufeld, Leo Clark, Chenhao Zhang and Joseph Wilson
The University of Queensland

We investigate the competition of two cell types in an epithelial layer due to differences in their mechanical properties. A simple one-dimensional model of a cell layer is represented as a chain of connected overdamped elastic springs with turnover of cells described as stochastic birth and death events. The main focus of our study is to investigate the effects of cell size-dependence of the cell division probability in establishing equilibrium density of a single cell type, and in the competition of mechanically different cells as a model of invasive cancer. We show that the equilibrium density is dependent on the cell stiffness and is different from the biological equilibrium when there is a sharp size threshold for cell division. We derive an analytical approximation for travelling wave speed of competing cells and show that the competitive advantage of hard vs soft cells is determined by the relationship between the mechanical and biological equilibrium density.

Implementation aspects of passive geolocation

Alex Newcombe
Flinders University

I discuss some implementation aspects of passive geolocation from the perspective of a researcher newly entering the field. The cross ambiguity function is discussed and its feasibility for capturing multiple sources and moving sources. Then, we consider fusing angle of arrival information using a cross-entropy algorithm. This talk will be at a level suitable for undergraduates.

Absolute and convective instability of a radial jet with swirl

Muhammad Nisar, Christian Thomas, Sophie Calabretto and Jim Denier
Macquarie University

We undertake linear stability of a radial jet with swirl. Here, swirl is quantified by the parameter ε. The radial jet emerges due to a boundary-layer collision at the equators of an impulsively rotated sphere. Calabretto et al. [1] demonstrated that the radial jet exhibits the distinctive features originally proposed by Riley [2]. Notably, the jet manifests the rapid development of a self-similar structure, characterised by a thickness scaling inversely with the square root of the flow Reynolds number. Thus, using the similarity solution due to Riley as the base flow, we undertake a local linear stability analysis, including both convective and absolute instabilities. For the inviscid stability analysis, two cases are considered. For case-I, the azimuthal velocity, $\bar{w}$, is disregarded, while for case-II, the azimuthal velocity is retained by assuming swirl $\varepsilon \sim O(Re)$. Results suggest that case I adheres to Squire's theorem. For case II, increasing swirl destabilises the flow for a fixed azimuthal wavenumber, β. However, an increase in the azimuthal wavenumber, β, for weak swirl, ε, stabilises the flow, whereas, for strong swirl, destabilises the flow. Regarding the viscous stability of the radial jet, swirl destabilises the flow except for negative-valued azimuthal mode numbers, n. The azimuthal mode $n = 1$ is the most unstable mode. We concluded that the region of convective instability expands with increasing swirl, ε, for azimuthal mode numbers $n \geq 0$, and shrinks with ε for $n < 0$. For the absolute instability, we concluded that swirl, ε, induces flow destabilisation, leading to an expansion of the region of absolute instability. The azimuthal mode $n = 1$ is the most unstable mode, and increasing or decreasing the azimuthal mode number, n, stabilises the flow. Finally, similar to the case of Bickley jet, the radial jet is more unstable to symmetric modes than to antisymmetric modes, and the antisymmetric mode has a shorter wavelength than the symmetric mode.

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Modelling the impact of infectious disease introduced to Australia through European contact

Cody Nitschke
Flinders University

The diffusion of European-introduced infectious diseases–brought to Australia through the process of colonisation–was responsible for high mortality rates among a population never before exposed to such pathogens. We aim to understand the origin, spread and impact of these diseases within the pre-colonial population. In this talk, I will discuss a metapopulation model that we use to explore these issues. This work is supported by the Australian Research Council Centre of Excellence for Australian Biodiversity and Heritage (CABAH).

Bayesian structure learning for climate model evaluation

Terence O'Kane, Dylan Harries and Mark Collier
CSIRO

A Bayesian structure learning approach is employed to compare and contrast interactions between the major climate teleconnections over the recent past as revealed in reanalyses and climate model simulations from leading Meteorological Centers. In a previous study, the authors demonstrated a general framework using homogeneous Dynamic Bayesian Network (DBN) models constructed from reanalyzed time series of empirical climate indices to compare probabilistic graphical models. Reversible jump Markov Chain Monte Carlo (RJMCMC) is used to provide uncertainty quantification for selecting the respective network structures. The incorporation of confidence measures in structural features provided by the Bayesian approach is key to yielding informative measures of the differences between products if network-based approaches are to be used for model evaluation, particularly as point estimates alone may understate the relevant uncertainties. Here we compare models fitted from the NCEP/NCAR and JRA-55 reanalyses and CMIP5 historical simulations in terms of associations for which there is high posterior confidence. Examination of differences in the posterior probabilities assigned to edges of the directed acyclic graph (DAG) provides a quantitative summary of departures in the CMIP5 models from reanalyses. In general terms the climate model simulations are in better agreement with reanalyses where tropical processes dominate, and autocorrelation time scales are long. Seasonal effects are shown to be important when examining tropical-extratropical interactions with the greatest discrepancies and largest uncertainties present for the Southern Hemisphere teleconnections.

Realizable Markovian closures for anisotropic and inhomogeneous turbulent flows

Terence O'Kane and Jorgen Frederiksen
CSIRO

Realizable Eddy Damped Markovian Closures are presented for the interaction of two-dimensional turbulence and transient waves such as Rossby waves. The structure of the closures ensures that they are computationally efficient and guaranteed to be realizable in the presence of transient waves. Here we advance strong interaction fluid turbulence theory and discuss some of the relationships between theoretical approaches employed in statistical classical and quantum field theories, and their overlap. In particular propagator and frequency renormalized closures are presented where the triad interaction times are modified by a generalized eddy damping term. Results are compared to ensemble averaged direct numerical simulations for well resolved inertial ranges.

Emergence of asymmetry in Hydra spheroids

Dietmar Oelz
The University of Queensland

Tissue morphogenesis involves the self-organized creation of patterns and shapes. In many cases details of underlying mechanisms are elusive, yet an increasing amount of experimental data suggests that chemical morphogens and mechanical processes are strongly coupled.

Here, we develop and simulate a minimal model for the emergence of asymmetry in aggregates of the Hydra polyp based on the mechanochemical coupling of surface stiffness and morphogen concentration. We contrast this model with the classical morphogen patterning mechanisms based on Turing-type reaction–diffusion systems. In analogy to this classical mechanism, we carry out the stability analysis of the lower dimensional toy model and identify minimal conditions for symmetry breaking. Our results suggest that mechanochemical pattern formation underlies symmetry breaking in Hydra.

Packing theory derived from phyllotaxis and products of linear forms

Ryoko Oishi-Tomiyasu
Kyushu University

Parastichies are spiral patterns observed in plants and numerical patterns generated using golden angle method. We generalize this method by using Markoff theory and the theory of product of linear forms, to obtain a theory for packing of Riemannian manifolds of general dimensions with a locally diagonalizable metric, including the Euclidean spaces. Using this method, we prove that it is possible to generate almost uniformly distributed point sets on any smooth Riemannian surfaces. The packing density is bounded below by 0.702 on surfaces, by 0.389 on 3-manifolds. This research was conducted with Ph.D student S. E. Graiff-Zurita under the support of the Kyushu University SENTAN-Q program in 2020.

Dual-grid mapping method for the advection-diffusion-reaction equation in a heterogeneous medium

Dylan Oliver, Elliot Carr and Ian Turner
Queensland University of Technology

Models describing heat and mass transport in geometrically complex media are often highly complex and not amenable to analytical solution techniques. It is often required to determine solutions using numerical and computational methods which are frequently accompanied by a significant computational cost, especially in two or three spatial dimensions where the number of nodes required to capture geometric detail can be exorbitant. In this talk, I will describe an adaptive dual-grid mapping method for the accurate solution of the linear heterogeneous advection-diffusion-reaction equation on 2D structured and unstructured grids containing many nodes, and briefly demonstrate some results related to extension of the same method to 3D structured and unstructured grids. Expanding on prior research, a novel mapping is developed allowing accurate solutions to be developed on a grid containing a small number of nodes and subsequent recovery of accurate solutions on a much finer grid containing many nodes.

A dynamical systems approach to low-damage seismic design

Ruisong Xue and Hinke M. Osinga
The University of Auckland

An example of low-damage seismic design is the post-tensioned moment-resisting frame, which exhibits geometric nonlinearity under large deformations. Whether the tilt angle of the frame exceeds a prescribed maximum depends on the forcing properties. We show that this failure boundary is organised by so-called grazing orbits, which reach but do not move beyond the design limit of the frame. We consider both harmonic and aperiodic waves with a broader frequency content.

Applying modern portfolio theory to marine spatial management

Owen Stewart and Michael Bode
Queensland University of Technology

Larval dispersal is the process with which a large portion of marine life reproduce, and involves the transport of larvae by oceanographic flow and locomotive movement. Marine species often exist in metapopulation structures, underpinned by the exchange of offspring via larval dispersal. These dispersal dynamics exhibit significant temporal variability, evident in both empirical genetic data and biophysical simulations of dispersal.

The temporal variability of larval dispersal is often crucial to successful conservation action in marine contexts. Despite this fact, existing conservation planning tools fail to appropriately consider this temporal variability. We propose that the financial technique of modern portfolio theory (MPT) can fill this gap – albeit adjusted to fit a marine conservation context.

MPT is a technique originally used to guide investment in groups of financial assets, known as portfolios. Specifically, MPT aims to maximise the expected value of portfolio returns, while reducing their variance. Through both illustrative models and data analysis of connectivity dynamics, we identify key alterations required to modify MPT for marine population management.

We apply this knowledge to a case study regarding the establishment of marine protected area (MPA) networks, over three distinct regions across the Great Barrier Reef. The conservation goal is to increase coral trout biomass across each region, while reducing its variance from year-to-year. We demonstrate that our adjusted MPT approach can construct MPA networks capable of significantly reducing the variance of biomass, with minimal compromises to its expected value.

Modelling resource limitation and competition in gene regulatory networks

Michael Pan, Peter Gawthrop, Matthew Faria and Stuart Johnston
The University of Melbourne

Synthetic biology aims to artificially engineer cells to exhibit novel behaviours, such as detecting the presence of a specific chemical or producing oscillations. While synthetic biology aims to construct complex cellular "devices" by coupling together various genes (the "parts") in a modular fashion, this approach often fails in practice. A well-known issue in synthetic circuits is that cellular resources such as energy and biomolecules need to be distributed between genes, leading to competition. Existing mathematical models of gene expression often ignore energy entirely, and are thus unsuitable for exploring such phenomena.

In this presentation, I introduce a new kinetic model of gene transcription and translation that accounts for energy consumption and ribosome sequestration. I show that the model can be considerably simplified through quasi-steady-state approximations, and that energy consistency can be enforced through the bond graph approach. By incorporating known parameter values, I show that this model of gene expression is consistent with experimentally observed relationships between energy availability and protein synthesis rate. Finally, I illustrate the utility of this approach in modelling fundamental networks in synthetic biology and discuss how these models could be incorporated into agent-based models of cell populations.

When to stop investing in technology development for ecosystem management?

Luz Pascal, Matthew Adams, Iadine Chades and Kate Helmstedt
Queensland University of Technology

Technology development is becoming an essential investment to address the unprecedented crises our world faces. However, it remains unclear how best to allocate resources for technology development and deployment because of the uncertainties induced by Research and development (R&D): the outcomes of R&D and the effects of technology deployment are uncertain. We present a new approach to solve this problem using Partially Observable Markov Decision Processes. Our model is innovative because it simultaneously plans the development and deployment of a new technology and dynamically adapts to possible technology development or deployment failures. Our analysis reveals it is optimal to invest in technology development for a predetermined time-period before surrender. This is a key finding because it implies that decision-makers do not necessarily need to evaluate the feasibility of the R&D program every year to decide to pursue development. If the new technology is ready at any time during that optimal time-period, our model undertakes an adaptive deployment process to dynamically learn the best way to deploy that new technology. We find that this optimal time-period depends on the dynamics of the system under current management, the initial belief in technology feasibility and costs of technology development and deployment. We provide user-friendly guidelines building on an analytical approximation, which allows decision-makers to use our model without requiring expertise on how to solve a POMDP. We present our results with a case study inspired by the management of a collapsing ecosystem: the Great Barrier Reef, Australia.

Spatial dynamics of inflammation-causing and commensal bacteria in the gastrointestinal tract

Rosemary Aogo, Mark Tanaka and Catherine Penington
Macquarie University

It is important to understand how resident bacteria interact with their hosts and pathogens, and how they play a protective role. We developed a new spatial model of microbial populations in the gut to explore pathogen invasion conditions. Pathogen invasion is usually eliminated by the host immune response but can persist. The most important factor in pathogen persistence is faster decay in the host immune response. Spatial structure allows persistence to occur by creating moving refugia for the pathogens. If time allows, we will also discuss how recolonisation after infection is greatly facilitated by inflammation-resistant commensal bacteria.

Identification of microstructural information from macroscopic boundary measurements in linear elasticity

M. A. Peter and T. Lochner
University of Augsburg

We consider the upscaled linear elasticity problem in the context of periodic homogenisation in the regime where the wavelength is much larger that the microstructure. Based on measurements of the deformation of the (macroscopic) boundary of a body for a given forcing, it is the aim to deduce information on the geometry of the microstructure. For a parametrised microstructure, we are able to prove that there exists at least one solution of the associated minimisation problem based on the L^2-difference of the measured deformation and the resulting deformation for a given parameter. To facilitate the use of gradient-based algorithms, we derive the Gâteaux derivatives using the Lagrangian method of Céa, and we present numerical experiments showcasing the functioning of the method.

Forecasting Covid-19 in Aotearoa New Zealand

Michael Plank, Leighton Watson and Oliver Maclaren
University of Canterbury

Near-term forecasting of infectious disease incidence and consequent demand for acute healthcare services can support capacity planning and public health responses. Despite having well-developed scenario modelling to support the Covid-19 response, Aotearoa New Zealand lacks advanced infectious disease forecasting capacity.

We developed a model using Aotearoa New Zealand's unique Covid-19 data streams to predict reported Covid-19 cases, hospital admissions and hospital occupancy. The method combines a semi-mechanistic model for disease transmission to predict cases with Gaussian process regression models to predict the fraction of reported cases that will require hospital treatment.

We evaluate forecast performance against out-of-sample data over the period from October 2022 to July 2023. Our results show that forecast performance is reasonably good over a 1-3 week time horizon, although generally deteriorates as the time horizon is lengthened. The model was used to provide weekly national and regional forecasts in real-time. This study is an important step towards development of more sophisticated situational awareness and infectious disease forecasting tools in Aotearoa New Zealand.

How cultural innovations trigger the emergence of new pathogens

Pantea Pooladvand, Jeremy Kendal and Mark Tanaka
UNSW Sydney

Humans have a unique ability to shape their environment in favourable ways, usually as a result of new cultural practices or innovations. Importantly, these same practices lead to unintended maladaptive consequences. We focus on one of the most serious classes of such effects, the emergence of new infectious diseases. A wide range of behaviours have inadvertently caused disease emergence, for example, by altering land use and proximity to non-human animal vectors of disease, creating built structures and urban infrastructure that harbour disease, and normative practices that facilitate disease transmission.

It is possible that behind every infectious disease is a cultural change or innovation that precipitated or accelerated the emergence of a pathogen. Conversely, it is possible that every cultural innovation is associated with an unrecognised risk of generating a new disease (infectious or otherwise) in the human population.

Consequently, we argue it is important to study the cultural antecedents of disease emergence and to understand how the dynamics of their cultural evolution is connected to the emergence of disease. In this project, we propose a simple model to shed light on the conditions under which pathogen emergence is an inevitable consequence of human cultural evolution. We investigate circumstances in which emergence can be avoided, and examine how human behaviour, such as rates of adoption and abandonment of antecedent practices affect pathogen emergence.

Electromagnetically driven flow in unsupported electrolyte layers: lubrication theory and linear stability of annular flow

Andrey Pototsky and Sergey Suslov
Swinburne University of Technology

We consider a thin horizontal layer of a non-magnetic electrolyte containing a bulk solution of salt and carrying an electric current. The layer is bounded by two deformable free surfaces loaded with an insoluble surfactant and is placed in a vertical magnetic field. The arising Lorentz force drives the electrolyte in the plane of the layer. We employ the long-wave approximation to derive general two-dimensional hydrodynamic equations describing symmetric pinching-type deformations of the free surfaces. These equations are used to study the azimuthal flow in an annular film spanning the gap between two coaxial cylindrical electrodes. In weakly deformed films, the base azimuthal flow and its linear stability with respect to azimuthally invariant perturbations are studied analytically. For relatively thick layers and weak magnetic fields, the leading mode with the smallest decay rate is found to correspond to a monotonic azimuthal velocity perturbation. The Marangoni effect leads to further stabilisation of the flow while perturbations of the solute concentration in the bulk of the fluid have no influence on the flow stability. In strongly deformed films in the diffusion-dominated regime, the azimuthal flow becomes linearly unstable with respect to an oscillatory mixed mode characterised by the combination of radial and azimuthal velocity perturbations when the voltage applied between electrodes exceeds the critical value.

Utilising machine learning to predict zoonotic spillover risk

Naik Bakht Sania Qureshi, Roslyn Hickson, Maryam Golchin, Anjana Karawita and Andrew Hoskins
CSIRO

According to World Health Organisation, around 75 percent of newly emerging infectious diseases reported globally are zoonotic (transmitted from animals to humans). This highlights the urgent need to maintain and improve preparedness through effective strategies to address potential future threats. Therefore, our project focuses on forecasting zoonotic spillover risks, employing state-of-the-art machine learning techniques. Initially, we implemented the XGBoost (Extreme Gradient Boosting) technique, known for its performance, speed and accuracy in various machine learning applications. Currently, we are exploring other machine learning models such as SVM (Support Vector Machine) and K-Nearest Neighbours to determine the most effective one. We have developed a model that finds common features among various infectious agents. This could help identify pathogens that share similar characteristics to locate potential geographic hotspots for the spread of these diseases.

Linear convergence of tilt-correct DFO proximal bundle method

C. Planiden and T. Rajapaksha
University of Wollongong

In this presentation, we will demonstrate the linear convergence of a derivative-free proximal bundle method called the tilt-correct DFO proximal bundle method. The purpose of this method is to locate an approximate proximal point to minimise a nonsmooth convex objective function. Although we have precise function values, our subgradients are not exact, which means that the value of the model function at the initial iterative point could be higher than the original function value, which is not ideal. To address this issue, we apply a correction to the approximated subgradient at that point. However, since the model function is not always an underestimator of the objective function, we lose the benefit of convexity. To achieve the convergence rate of the algorithm, we establish a suitable framework and use a subdifferential-based error bound on the distance to critical points. The subgradient of the model produced through this process may not be an accurate subgradient of the actual function at any point along iterations. Therefore, we transport model subgradients to a nearby point where they are subgradients of the objective function. Additionally, we describe an application: the DFO VU-algorithm, which employs the DFO proximal bundle to take steps on the nonsmooth space, while on the smooth space, it utilizes quasi-Newton steps to accelerate the convergence towards the minimizer.

Modelling interventions in the MERGE gully erosion model

Melanie E Roberts
Australian Rivers Institute, Griffith University

Gully erosion is the dominant source of sediment impacting the Great Barrier Reef, and as such is the focus of considerable effort to improve water quality on the Reef. The MERGE gully erosion model was developed in collaboration with the Queensland Water Modelling Network and Queensland Government to support on-ground rehabilitation and management activities of smaller channel-like gullies. This talk will introduce a number of common management responses and explore how they can be represented in MERGE, their practical application to support decision making, and highlight opportunities for improvement.

Randomly surreal (numbers)

Matthew Roughan
The University of Adelaide

Surreal numbers are not a class in themselves, but rather an unconventional construction for numbers (including the naturals, rationals, reals and ordinals). Almost all of the literature on surreal numbers views them purely as a theoretical construction. For instance, there is substantial theory demonstrating that surreal operators (addition, multiplication, ...) can be defined consistently. However, the field of surreal numbers has a richness that is not at all evident from the simple descriptions available.

This talk will consider consider a simple, convergent stochastic process that to generate ensembles of random surreal numbers that have non-trivial, but controllable complexity. We implement the process using Julia, a relatively new programming langauge designed for mathematical and scientific programming, and we will disucuss why Julia is a good choice for this problem.

The polylogarithm function in Julia

Matthew Roughan
The University of Adelaide

The polylogarithm function is one of the constellation of important mathematical functions. It has a long history, and many connections to other special functions and series, and many applications, for instance in statistical physics. However, the practical aspects of its numerical evaluation have not received the type of comprehensive treatments lavished on its siblings. Only a handful of formal publications consider the evaluation of the function, and most focus on a specific domain and/or presume arbitrary precision arithmetic will be used. And very little of the literature contains any formal validation of numerical performance. In this paper we present an algorithm for calculating polylogarithms for both complex parameter and argument and evaluate it thoroughly in comparison to the arbitrary precision implementation in Mathematica. The implementation was created in a new scientific computing language Julia, which is ideal for the purpose, but also allows us to write the code in a simple, natural manner so as to make it easy to port the implementation to other such languages.

BaD transmission modelling: Incorporating human behaviour into simple models of disease transmission

Matt Ryan, Emily Brindal, Mick Roberts and Roslyn Hickson
CSIRO

The interactions between human behaviour and the spread of infectious diseases creates complex feedback loops between behaviour and infection transmission. One human's behaviour may affect another human's behaviour, while human behaviour affects infection spread and infection spread affects human behaviour. Despite this, many transmission models either ignore the intricacies of human behaviour or consider it as constant. Here, I introduce our behaviour and disease (BaD) modelling approach for incorporating human behaviour models from behavioural science into infection transmission models. Specifically, I will discuss how to incorporate a visible protective behaviour into the susceptible-infectious-recovered-susceptible (SIRS) transmission model using the socio-psychological Health Belief Model. I will also discuss the transient and long-term dynamics of our BaD SIRS model, and demonstrate how BaD modelling can be used to investigate the effects of non-pharmaceutical intervention strategies that target specific components of the Health Belief Model.

Comprehensive forecasting of emergency cases arrivals for surgical departments: a comparative analysis of existing approaches

Hajar Sadegh Zadeh, Mark Fackrell, Joyce Zhang and Hamideh Anjomshoa
The University of Melbourne

This investigation provides an in-depth comparison of various forecasting models aimed at predicting the number of emergency case arrivals in surgical departments for every weekday of the ensuing week. This critical analysis utilizes a substantial six-year historical data set from a hospital in New South Wales (NSW), leveraging this wealth of information to validate the forecasting techniques. The models under scrutiny include Prophet, ARIMA, SARIMAX, LSTM, and agent-based modelling, each assessed for its predictive accuracy and reliability. Following the determination of the most accurate forecasting model from this robust comparative analysis in the first step, the research progresses to the second step. Here, the Poisson arrival process is employed to refine the prediction of the exact hourly arrivals of emergency cases for each day, offering a granular view of the anticipated demands. This methodological two-pronged forecasting framework is crafted to significantly enhance operational planning and resource management within surgical departments. The study's findings, while rooted in the specific context of a NSW hospital's data, aim to establish a benchmark for forecasting practices that can be further validated and potentially generalized across different healthcare settings, emphasizing the importance of methodological precision and context-specific adaptability in the realm of healthcare forecasting.

Mathematical modelling of empirical correlations and validation of shear strength of high strength steel fibres reinforced concrete beams

Babita Saini, S.M. Gupta and Jagdish Chand
National Institute of Technology Kurukshetra

The current study reveals the effects of incorporation of steel fibres on the shear strength of high strength steel fibres reinforced concrete HSSFRC beams. Research associated with different aspects of concrete demands a comprehensive statistical analysis involving various trial or error and empirical techniques. However, as these techniques are highly dependent on the understanding of the user and lack algorithms specifically for conduction evaluation of concrete based research, the chances of error increases. The empirical relationships between the process parameters that is independent variables and response parameters that is dependent variables of the HSSFRC beams were generated using mathematical modelling. In this regard, the process parameters were defined as, a) longitudinal reinforcement ratio (ρ); b) a by d ratio ; c) steel fibre volume Vf and, d) grade of concrete beams. Similarly, the various response parameters chosen were, a) ultimate shear force and b) maximum shear stress. The empirical relations were developed between the process and response parameters of the HSSFRC beams of different strengths by using the results obtained from the experimental and output of Design expert software. Subsequently, response surface plots were generated to obtain statically verified results.

Optimization of switching frequency and pulse width of buck converter based inverter

Manish Arora and Lalit Mohan Saini
National Institute of Technology Kurukshetra

This paper provides the effect of variation of switching frequency and pulse width of buck converter on Total Harmonic Distortion (THD) of output voltage. Multilevel inverters are preferred; because, they provide lower distortion in output voltage. Also, THD of output voltage should be lower than 5 percent for inverters, in order to conform to IEEE-519 standard. Use of higher switching frequency can provide lower THD for same level inverter. Buck converter based inverter is simulated using MATLAB/SIMULINK Software and the effect of variation of switching frequency on THD has been observed. Genetic Algorithm is used to determine the switching frequency at which minimum value of THD is obtained. It has been observed that this optimization technique gives better power quality of output voltage in comparison with other reported studies.

Weather or not? Exploring the impact of human movement and weather on dengue outbreaks in Pacific Island Countries

Justin Sexton and Roslyn Hickson
CSIRO

Mosquito-borne disease outbreaks such as dengue are on the rise in the Pacific Island region. While weather and climatic drivers have been linked with dengue outbreaks, social events and human mobility are often ignored in such studies. We investigate potential drivers of observed dengue outbreaks in Pacific Island Countries (PICs), with a specific focus on international events and movement (through flight data) into and between Pacific Islands. Random Forest models were used to investigate the importance of these as drivers of dengue outbreaks. By better understanding the drivers of outbreaks we can help decision makers manage the risks.

Ordinal Poincaré sections: reconstructing the first return map from an ordinal segmentation of time series

Zahra Shahriari, Shannon D. Algar, David M. Walker and Michael Small
The University of Western Australia

Nonlinear time series analysis attempts to derive insights about deterministic dynamical systems from observed time series data, which is typically scalar. Various techniques have been developed to create models of the underlying vector field, estimate dynamical invariants, and visualize the geometry of the attractor and its unstable periodic orbits. The first return map, a fundamental representation of a dynamical system's behaviour, is often computed using complex numerical models of the system's flow or heuristic methods.

In our approach, we propose a novel method grounded in the growing interest in the ordinal encoding of dynamics and symbolic dynamics. This method stands out due to its simplicity, robustness, generality, and numerical efficiency in obtaining the first return map for a continuous dynamical system from a scalar time series. We demonstrate the effectiveness of our method in reconstructing the first return map for both simple low-dimensional chaotic systems and infinite-dimensional delay differential systems.

Our method relies on ordinal partitions of the time series, and the first return map is constructed by repeatedly intersecting the data with specific ordinal sequences. This approach allows us to obtain distinct first return maps for various ordinal sequences. We present results for well-known dynamical systems, including the Lorenz, Rössler, and Mackey-Glass systems, in chaotic regimes to showcase the effectiveness of our method.

Uncovering the secrets of cancer: discover how microRNA-17-92 utilises transcriptional and translational time delays to control the gene expression network

Akshay Sharma, Louise Olsen-Kettle and Dr Tonghua Zhang
Swinburne University of Technology

In this paper, we have formulated and analysed a mathematical model with multiple time delays of the genetic regulatory network of the microRNA-17-92 (miR-17-92) cluster. We have focused on the effect of the associated transcriptional and translational time delays of both positive and negative feedback loops on the miR-17-92 regulatory network. To gain better insight, we have explored the role of individual time delay in controlling the transition of the G1/S cell cycle process. We pay particular attention to the concentration of E2F and Myc, which trigger the protein ON and OFF switches. To analyse the situation mathematically, we employ delay-dependent stability analysis and bifurcation analysis using delay differential equations, and a biological study of the time-delayed random transitions between the ON and OFF states for protein synthesis. Based on our study we can conclude that the translational time delay (τ_2) can halt the healthy transition of cells in the G1/S cell cycle phase as the small increase in (τ_2) can destroy bistability of the system. Simulations are carried out to numerically show the solution trajectories under the combined effect of delays. Finally, we summarise the simulation results and the impact of delays on the dual behaviour of miR-17-92 as it can act as an oncogene or as a tumour suppressor gene.

Modelling of decision-making in complex conflict environments

Sergiy Shelyag, Mathew Zuparic, Maia Angelova, Ye Zhu and Alexander Kalloniatis
Flinders University

How do people make and implement decisions? Decisions are based on time-dependent interactions with the environment, which is invariably complex, volatile, and uncertain. This is applicable to any kind of decision-making, including competitive sports, co-operational and competitive organisational structures, military conflicts. Characterising and modelling decision-making processes and designing model-informed strategies for organisational structures with the aim to achieve favourable results, therefore, would be of interest.

In my presentation, I will show a mathematical model of two adversarial populations in the vicinity of a neutral population and will explore the impact of each population pursuing specific decision-making strategies. The model is defined by the archetypal Lanchester, Lotka-Volterra and Kuramoto-Sakaguchi components, which characterise adversarial interaction, population dynamics and decision-making, with feedback between each component adding heterogeneity. In the model, adversaries are capable of drawing support from neutral population by enabling the decision-making initiative.

The model is studied both analytically and numerically, and I will discuss applicability of the model to a variety of real-life scenarios.

A closed queuing model for GLUT4 dynamics: an exploration of mechanisms

Brock Sherlock and Adelle Coster
University of New South Wales

Mammalian cells regulate their glucose levels by redistributing glucose transporter proteins within the cell. The GLUT4 transporter translocates in response to insulin with increased insulin levels causing a higher expression of GLUT4 at the cell surface. Mean-field models of the dynamics of GLUT4 have previously been used to identify dominant processes at the macroscopic scale (J. Biol. Chem., 289(25): 17280-17298). However, these models also do not provide explanatory mechanisms for the response to the insulin signal.

Here, a stochastic model, a closed queuing network, is explored as a feasible mechanistic model of this system. The model mechanisms and parameters will be discussed along with biological interpretations. Experimental data will be used to contextualise model dynamics and demonstrate desired behaviours.

Efficient prediction, estimation and identifiability analysis with mechanistic mathematical models

Matthew Simpson
Queensland University of Technology

Interpreting data using mechanistic mathematical models provides a foundation for discovery and decision-making in all areas of science and engineering. Key steps in using mechanistic mathematical models to interpret data include: (i) identifiability analysis; (ii) parameter estimation; and (iii) model prediction. Here we present a systematic, computationally efficient likelihood-based workflow that addresses all three steps in a unified way. Recently developed methods for constructing profile-wise prediction intervals enable this workflow and provide the central linkage between different workflow components. These methods propagate profile-likelihood-based confidence sets for model parameters to predictions in a way that isolates how different parameter combinations affect model predictions. We show how to extend these profile-wise prediction intervals to two-dimensional interest parameters, and then combine profile-wise prediction confidence sets to give an overall prediction confidence set that approximates the full likelihood-based prediction confidence set well. We apply our methods to a range of synthetic data and real-world ecological data describing re-growth of coral reefs on the Great Barrier Reef after some external disturbance, such as a tropical cyclone or coral bleaching event.

Modelling weapon engagement zones using machine learning

David Skene, Peter Moskvichev, Simon Blaess and Matthew Christie
Defence Science and Technology Group

DSTG conducts research to understand, improve, and extend the capabilities of the Combat Management Systems (CMS) that control and coordinate the warfighting capabilities of Australia's major Surface Ships. A significant component of the CMS is the mathematical calculations that mediate effective and efficient engagement of threats. Part of these calculations involves determining whether the threat is within a region known as the Weapon Engagement Zone' (WEZ), which is defined as the region where an effector can successfully intercept a threat given the threat's tracked kinematics. Ideally, we would run simulations in real-time to check if a threat is within the WEZ. However, the computational demands of these simulations presently prevent this from being done in real-time. Therefore, we require a pre-generated set of a data, and a model to interpret said data, to allow the CMS to continuously perform WEZ checks'. This is non-trivial because the WEZ is at least 5-dimensional and features increasingly complicated topographical features when generated against ever evolving threat sets.

In this presentation we will present our work in modelling the WEZ using a variety of methods. We will show how neural networks come out as the highest quality method to model the complicated hypervolumes that define WEZs and show that using a Recursive Stratified Sampling method is an interesting and novel method for generating the data to train the neural network.

Model reduction for finite networks of coupled oscillators with higher order interactions

Lauren Smith and Penghao Liu
The University of Auckland

Many real world systems can be described as networks of coupled oscillators, such as power grids and the neural dynamics of the brain. Until recently only pairwise interactions between oscillators had been considered, but it has been brought to light that higher order interactions, i.e. interactions between three or more oscillators, exist in real world networks and yield fundamentally different dynamical behaviours. For example, the transition to synchronisation as coupling strengths increase is generically a soft, gradual, transition for pairwise coupling, but can be an abrupt, explosive, transition when higher order interactions are included. Model reduction for these types of systems has been performed under the unphysical assumption that the network is infinite. Here we present model reduction methodology for finite networks, based on the collective coordinate approach. We show that our reduced system is able to capture the macroscopic dynamics of the full system, including both gradual and explosive synchronisation transitions. Our methodology also captures finite size effects such as scaling of critical bifurcation parameters.

Finite element methods for some micromagnetic models at elevated temperature

Agus Soenjaya and Thanh Tran
University of New South Wales

The Landau-Lifshitz equation is a vector-valued nonlinear PDE used in micromagnetics to model the effects of magnetic field on ferromagnetic materials. An important feature of this equation is the conservation of magnitude of the magnetisation vector. Recent advances in spintronics and magnonics showed that this equation is essentially valid only at very low temperature, since it completely ignores contributions from high-frequency spin waves responsible for fluctuation in magnetisation magnitude. To rectify this problem, the Landau-Lifshitz-Baryakhtar (LLBar) and the Landau-Lifshitz-Bloch (LLBloch) equations were proposed in the physics literature. These nonlinear PDEs take into account longitudinal relaxation and are valid at high temperature, which are important for applications in heat-assisted magnetic recording and magnonic devices.

We propose some fully discrete conforming numerical schemes to solve the LLBar and LLBloch equations, including one based on mixed formulation of the equation, in each case obtaining optimal rate of convergence to the exact solution. Some properties of the schemes, including well-posedness, unconditional stability and energy dissipation at discrete level, will be discussed. Numerical simulations corroborate our theoretical results. As a by-product of our analysis, we show the convergence of solution of the LLBar equation to that of the LLBloch equation at high temperature in the limit of vanishing exchange damping parameter.

Optimizing noninvasive ventilation strategies: a comparative study of mathematical models and machine learning approaches

Ayesha Sohail
The University of Sydney

During this presentation, we will discuss two mathematical models for passive and for noninvasive ventilation. The first model employs linear regression techniques while the second utilises nonlinear algorithms, both derived from fundamental pressure balances in the lung-ventilator system. The performance of these models is evaluated and compared against a benchmark physical model using a test lung. The simulations generated by these models indicate that an airway leak proximal to the airway opening during pressure support noninvasive ventilation can lead to dynamic instability.

The machine learning approach is used to optimise a special type of nonpassive ventilation where the total cycle times of the ventilator are adaptive, depending on the inspiratory phases of these cycles. This adaptability is achieved through real-time data processing and feedback mechanisms integrated into the machine learning algorithms. The tools used show promise in optimising noninvasive ventilation strategies and improving patient outcomes.

Translation of the resistance risk for the antimalarial drug cabamiquine across infection models

Eva Stadler, Vandana Thathy, Claudia Demarta-Gatsi, Claude Oeuvray, Marcus C.S. Lee, Laurent Dembl, David A. Fidock, David S. Khoury and Thomas Spangenberg
UNSW Sydney

With the spread of resistance to antimalarials, it remains important to develop new antimalarials and assess their propensity to select for resistant parasites. However, it is not clear how well pre-clinical measures can predict resistance in a human treatment setting. Here, we explore data from in vitro, animal and clinical studies of the candidate antimalarial compound cabamiquine to examine the propensity of this agent to select for resistant Plasmodium falciparum parasites. We first show that in vitro studies of laboratory strains and clinical isolates, humanised mouse models, and volunteer infection studies, provide a wide range of frequencies of resistant mutants. We explored if this variability could be explained due to stochastic differences arising from experiment design choices, such as the number of parasites in an animal at the time of treatment by developing a stochastic mathematical model. We find that simulations of the stochastic model were highly consistent with the frequencies estimated from the data. Thus, much of the observed variability in resistance potency across different preclinical models is predictable based on only the mutation rate, setup of the experiment and fitness cost of resistant mutants. Overall, we show that preclinical infection models were highly predictive of resistance frequency in early human trials with cabamiquine. Thus, this work helps to understand the potential risks for a given drug and suggests that in vitro and animal models are useful for the assessment of resistance risks and predicting performance in human studies.

The effect of internal structure on the stability of fibre drawing

Yvonne Stokes, Jonathan Wylie, Nazmun Papri and Dongdong He
The University of Adelaide

Work by Matovich and Pearson (Industrial & Engineering Chemistry Fundamentals 8, 1969), showed that isothermal drawing of thin solid fibres, where the effect of surface tension is negligible, is unstable above a critical value D_{crit} of the draw ratio, i.e. where the pulling speed exceeds the feed speed by the factor D_{crit} and the cross-sectional area of the final fibre is a factor $1/D_{\text{crit}}$ smaller than the cross-sectional area of the initial preform. In the case of a solid fibre $D_{\text{crit}} \approx 20.21$. Nevertheless, draw ratios well in excess of D_{crit} are necessarily and successfully used in practical fibre drawing, motivating much subsequent research into the effects of other parameters, such as inertia, temperature and surface tension, on stability.

This talk concerns our work on draw stability for a fibre with internal structure, i.e. air channels within it, which shows that stability is less than that of a solid fibre when surface tension is non-negligible. This work solves an open problem posed by Fitt et al. (Journal of Engineering Mathematics 43, 2002).

Rogue bursts as an effect of broken symmetry

P. Subramanian, E. Knobloch and P. G. Kevrekidis
University of Auckland

The formation of rogue waves is of interest, from North sea waves and waves in tanks to waves in nonlinear optics. Most common models used to investigate rogue bursts use the nonlinear Schrödinger (NLS) equation and its variants. However, such integrable settings and analytical solutions are rare in higher dimensions. So we propose to use the model of a dissipative system: which describes interaction between standing waves in domains of moderate aspect ratio. When spatial reflection symmetry is broken, the left and right running waves can interact strongly producing a temporally localised extremely large amplitude event.

We consider a ring of identical, diffusively coupled oscillators where the spatial reflection symmetry is broken in each oscillator. This ring of oscillators with weak coupling are able to demonstrate rogue events occurring at random times and locations. Importantly, this is the case even when the parameters characterising the individual oscillators are chosen to generate periodic oscillations only. We look at different diagnostics ranging from the event amplitude distribution function to studying the precursors to the local emergence of large amplitude events. This work aims to be a starting point for further exploration of alternative mechanisms producing extreme events, and potentially enable their identification in other nonlinear lattice systems in one or more dimensions.

References: P. Subramanian, E. Knobloch and P. G. Kevrekidis, Forced symmetry breaking as a mechanism for rogue bursts in a dissipative nonlinear dynamical lattice, Physical Review E 106, 014212 (2022)

Effective reaction rates in chemical reaction networks

Tomoharu Suda
RIKEN

The chemical reaction theory is a mathematical framework to describe the time evolution of a chemical system. Strong results are known concerning the question of what state the system will take after a long time. However, it is important for the application to consider the actual rate of change or the behaviour in a short time. Here, we discuss the effective rate of compound reaction by considering open systems, where feeding species are converted into product species. We introduce the notion of straight-line solutions of non-autonomous ordinary differential equations to formulate the notion of rate. Special attention is given to first-order networks, where we examine the conditions for the existence and characterisation of overall reaction rates.

Hierarchy of catastrophes in swirling electrolyte

Sergey A. Suslov and John McCloughan
Swinburne University of Technology

In this talk, I will present our new findings from the analysis of a flow of an electrolyte in an annular layer driven by a bulk Lorentz force, a setup used in physical modelling of hurricanes and in various electromagnetic stirring applications. Previously, we demonstrated the existence of a saddle-node bifurcation linking two steady axisymmetric flow solutions for this configuration. However, our recent analysis demonstrated that this seemingly simple setup has a much more diverse underlying structure than what first meets the eye. We discovered that the saddle-node bifurcation is a local feature of a global fold catastrophe that in turn is a part of three-parameter cusp catastrophe. I will discuss both the main features of the analysis that we developed and the intriguing features of physical flows that we found and that bring us one step closer to the answer to the ultimate question: how and why the experimentally observable vortices appear.

Numerical analysis of an incomplete balancing Domain Decomposition Method based on Polytopal Elements

Daisuke Tagami
Kyushu University

A Balancing Domain Decomposition (BDD) method is originally proposed by Mandel (1993), and is regarded as the preconditioner of linear iterative solvers for artificial boundary problems appearing in Domain Decomposition Methods (DDM) based on finite element methods; see, for example, Glowinski, et al. When using a BDD method, we need to set a coarse space, which includes the kernel of the coefficient matrix of resultant linear system derived from a corresponding artificial boundary problem. In case of magnetic field problems, the number of the Degrees Of Freedom (DOF) of the coarse space is equal to the number of nodal points of triangulation. This fact leads BDD methods for magnetic field problems can keep the condition number of the coefficient matrix of resultant linear system, but we cannot expect to reduce their computational costs. Now, to reduce the number of DOF of coarse spaces in BDD methods and their computational costs, Polytopal Element Methods (PEM; see Di Pietro, et al. (2021)) is introduced, and is used for approximations of the coarse space with Domain-by-Domain methods. We call the method "Incomplete BDD". Owing to the approximation of coarse spaces, we can expect to reduce computational costs to solve coarse-space problems as well as to keep the condition number of the coefficient matrix of resultant linear system.

Though the yeasty waves confound

Alex Tam, Ed Green, Ben Binder and Danny Netherwood
University of South Australia

Depending on the environment, colonies of the bakers' yeast can form strikingly different patterns. The 'ASKE Yeast' group studies all forms of yeast colony growth. Understanding and controlling the mechanisms of yeast colony growth could enhance yeasts' impact on humanity, from improving food and drink production to preventing pathogenic infections.

When grown on soft agar, yeasts form biofilms that can colonise entire Petri dishes in 1–2 weeks. I will discuss thin-film extensional flow modelling for biofilm growth, where varying the slip coefficient models changes to agar density. I will include numerical results and comparison with experiments for the speed and shape of the biofilm.

A decentralised algorithms for min-max problems

Matthew Tam
The University of Melbourne

In this talk, we consider a connected network of finitely many agents working cooperatively to solve a min-max problem with convex-concave structure. We propose a decentralised first-order algorithm which can be viewed as combining features of two algorithms: PG-EXTRA for decentralised minimisation problems and the forward reflected backward method for (non-distributed) min-max problems. In each iteration of our algorithm, each agent computes the gradient of the smooth component of its local objective function as well as the proximal operator of its nonsmooth component, following by a round of communication with its neighbours.

Being selfish with your relationships: A selfish agent model for opinion dynamics and echo chamber formation

Eugene Tan, Thomas Stemler and Michael Small
The University of Western Australia

Bounded confidence models (BCM) are extensively used to model continuous opinion dynamics in social networks. Typically, these models are analysed on static networks where edges do not vary over time. Following in the footsteps of adaptive voter models, further research has considered BCMs in the setting where agents are able to dynamically adjust their edges, which subsequently feedback into the opinion dynamics of the network. Several methods of updating connections have been proposed ranging from random rewiring to more sophisticated approaches based on concordant edges, homophily and cognitive dissonance. We present a modified form of the bounded confidence model, termed the selfish agent opinion (SAO) model, where connection updates are evaluated using a game theoretic approach. Agents in the SAO model maintain two classes of relationships, friends and acquaintances, based on which they update their opinions and edges to optimise a payoff function that may include multiple social factors. This research explores the effects, which we describe as "cognitive dissonance" and "introversion" that mimic the corresponding social behaviours, on social network and opinion dynamics. We find that the SAO model is able to produce non-trivial social behaviours using only modest assumptions. Specifically, SAO models naturally produce echo chambers for social networks with increased sensitivity to cognitive dissonance, whilst introversion produces high levels of fragmentation and low social mobility. Additionally, the effect of tolerant agents and inquisitive social encounters is investigated. It is found that both the presence of very small numbers of tolerant agents and inquisitive encounters are able to strongly promote consensus formation.

Using random walks for inference on networks

Aditya Maitra and Peter Taylor
The University of Melbourne

Given a connected network N with node set V and edge set E, we can construct a random walk $\mathcal{R}(N)$ by starting at some node i, choosing an edge (i, j) uniformly from the edges incident to node i and moving to node j. This random walk is an irreducible discrete-time Markov chain with state space V and stationary distribution $\pi(i) = d(i)/2|E|$, where $d(i)$ is the degree of node i.

A general property of discrete-time Markov chains is that the stationary distribution $\pi(i)$ evaluated at state i is equal to $1/E\tau_i$ where τ_i is the expected return time to state i. So one way to estimate $\pi(i)$, and hence the number of edges in N, is to repeatedly simulate $\mathcal{R}(N)$ and observe the return times to derive an estimator for $E\tau_i$.

In this talk, I will discuss some implications and extensions of this observation.

Velocity jump process with volume exclusions in a narrow channel

Steve Taylor, Tertius Ralph and Gayani Tennakoon
University of Auckland

This talk analyses the impact of collisions in a finite system of identical hard-core particles driven according to a velocity jump process. The physical space is essentially a channel in with a probability of occupants being able to pass each other. The system mimics what nature does, where individuals pass one another in a narrow channel while making incidental contact with those moving in the opposite direction. The passing probability may depend on the particles' size and the channel's width. Starting from a particle level model, we systematically derive a nonlinear transport equation based on an asymptotic expansion. Under low-occupied fractions, numerical solutions of both the kinetic model and the stochastic particle system are compared during biased and unbiased random velocity changes. Analysis of the subpopulation motility within a large population exhibits the consequences of volume exclusions and channel confinements on the travelling speeds.

Bio-geochemical clogging in permeable reactive barriers when treating acidic groundwater

Natalie Thamwattana
The University of Newcastle

Acid sulphate soils (ASS) are naturally occurring sediments commonly found along coastal regions of Australia. When exposed to air during flood mitigation drain or upon excavation (e.g. coal mining), pyrite in ASS can rapidly oxidise to form sulphuric acid, leading to acidic groundwater and causing acid drainage in underground coal mines. To treat acidic groundwater, permeable reactive barriers (PRBs) are introduced to neutralize acidity induced by pyrite oxidation in ASS terrain. PRBs (alkaline materials, e.g. crushed recycled concrete, ash, blast-furnace slag and calcitic limestone) are used as an underground filter to eradicate the contaminants through chemical and/or biological processes. However, clogging due to chemical precipitates and bacteria growth can reduce the porosity of PRBs which in turn reduces their longevity and functionality. In this talk, we discuss modelling clogging in PRBs which is due to the accumulation of bacteria and reactive aggregates becoming coated with chemical precipitates, and the effect of the clogging on the performance of PRBs. With the proposed bio-geochemical clogging model, we investigate the variation of hydraulic head of groundwater flow in PBRs and the excess water pore pressure in piezometers installed in PRBs.

Compartmental models of infectious disease dynamics with correlates of immunity

Ruarai Tobin
The University of Melbourne

Typical compartmental models of infection dynamics that incorporate waning immunity assume a susceptible-infected-recovered-susceptible (SIRS) structure. Under this structure, recovered individuals are fully protected against reinfection and then lose immunity after some exponentially distributed period. However, epidemiological studies suggest that immunity at the individual level can be modelled as being dependent on an immunity correlate (often referred to as a "correlate of protection"), such as antibody levels, with subsequent durations of immunity being non-exponential. We utilise an ordinary differential equation framework which stratifies a susceptible-infected-susceptible (SIS) compartmental model across levels of immunity correlate, allowing for the modelling of infection dynamics with flexible immune dynamics. We demonstrate the existence of stable oscillation in infection incidence under realistic parameterisations and provide early results on the implications of the model.

Lévy flight versus Brownian search strategies

Justin Tzou and Leo Tzou
Macquarie University

The Lévy flight foraging hypothesis asserts that biological organisms have evolved to employ (truncated) Lévy flight searches due to such strategies being more efficient than those based on Brownian motion. However, we provide here a counterexample in which Brownian search is more efficient. Our counterexample is based on the framework of the classic narrow escape problem in which a random search is performed for a small target within a confined search domain. Through mathematical analysis supported by Monte Carlo simulations, we give insights into possible reasons for why a Brownian search strategy appears to be more efficient.

Tipping phenomena in inertial focusing and separation of particles

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

Small finite-size particles suspended in fluid flow through an enclosed curved duct can focus to attractors (such as fixed points or limit cycles) in the two-dimensional duct cross-section. This phenomenon has been exploited in various industrial and medical applications to passively separate particles by size using purely hydrodynamic effects. I will present results of our numerical exploration of particle dynamics in spiral duct geometries with slowly varying curvature. We observe rich nonlinear particle dynamics and various types of tipping phenomena, such as bifurcation-induced tipping (B-tipping), rate-induced tipping (R-tipping) and a combination of both. I will discuss implications of these unsteady dynamical behaviours for separating particles by size.

Long-range capillarity theory

Enrico Valdinoci
The University of Western Australia

The classical capillarity theory describes the formation of droplets due to surface tension. We present a new model accounting for long-range interaction forces. In this setting, the contact angle between the liquid and the container is dictated by a nonlocal version of the classical Young's Law. We also discuss regularity properties and asymptotics.

Generalised likelihood profiles for models with intractable likelihoods

David J Warne, Oliver J Maclaren, Elliot J Carr, Matthew J Simpson and Christopher Drovandi
Queensland University of Technology

Likelihood profiling is an efficient and powerful frequentist approach for parameter estimation, uncertainty quantification and practical identifiablity analysis. Unfortunately, these methods cannot be easily applied for stochastic models without a tractable likelihood function. Such models are typical in many fields of science, rendering these classical approaches impractical in these settings. To address this limitation, we develop a new approach to generalising the methods of likelihood profiling for situations when the likelihood cannot be evaluated but stochastic simulations of the assumed data generating process are possible. Our approach is based upon recasting developments from generalised Bayesian inference into a frequentist setting. We derive a method for constructing generalised likelihood profiles and calibrating these profiles to achieve desired frequentist coverage for a given coverage level. We demonstrate the performance of our method on realistic examples from the literature and highlight the capability of our approach for the purpose of practical identifiability analysis for models with intractable likelihoods.

Critical initial conditions in competitive exothermic-endothermic reaction systems

Simon Watt
UNSW Canberra

In exploring the behaviour of many reaction diffusion systems, one of the most common behaviour, particularly in one dimension, is a travelling wave as the fuel is consumed. Depending on the system parameter values, the speed of this wave can be constant, or the speed can vary with time in a periodic way. However, depending on the initial concentration profiles, it is possible that the only behaviour is for extinction to occur. We will look at the boundary between initial profiles that develop into travelling waves and those that lead to extinction.

Tackling the erosion of neurological function: can we restore functional deficits in multiple sclerosis patients?

Georgia R. Weatherley, Robyn P. Araujo and Adrianne L. Jenner
Queensland University of Technology

People with multiple sclerosis (MS) experience diverse neurological symptoms arising from their immune system's mistaken attack on the protective myelin sheaths of nerve fibres. Myelin is a membrane extension of oligodendrocytes, and bouts of heightened immune dysfunction result in the loss of these vital cells and their myelin, leading to functional deficits. Current therapeutics are designed to suppress the levels of harmful immune activity but do little to address the wellbeing of patients with large accumulations of existing myelin and oligodendrocyte loss, motivating recent interest in remyelination therapies. I will discuss our development of an agent-based model of the key disease dynamics for use in understanding the thresholds of immune stress beyond which oligodendrocytes stop myelinating and undergo apoptosis (cell death). Further, our in silica implementation of remyelination therapies targeting oligodendrocyte reintroduction and their preservation suggests the capacity to restore functional deficits. This is an exciting result, given that current clinical interventions are limited to slowing the disease course in a preventative approach, and are only effective for select MS subtypes.

Shock selection rules in composite regularised reaction-nonlinear diffusion models

BH Bradshaw-Hajek, I Lizarraga, R Marangell and M Wechselberger
The University of Sydney

Reaction-nonlinear diffusion (RND) equations have recently been developed as a powerful and flexible modelling tool in order to investigate the emergence of steep fronts in biological and ecological contexts. In this talk, we shall demonstrate the utility and scope of *regularisation* as a technique to investigate the existence and uniqueness of steep-fronted travelling wave solutions in RND models with forward-backward-forward diffusion. Our principal tool is *geometric singular perturbation theory* (GSPT).

In particular, we will show that *composite* regularisations can be used to construct families of monotone shock-fronted travelling waves sweeping out distinct generalised area rules, which smoothly interpolate between two extremal rules for shock selection that are well-known in the shockwave literature. Our analysis blends *Melnikov methods*–including a new variant of the method which can be applied to autonomous *piecewise-smooth* systems–with GSPT techniques applied to the travelling wave problem of the regularised RND model over distinct spatio-temporal scales.

This work extends previous results [1,2] and was funded via an ARC DP20 grant.

[1] Y Li, P van Heijster, MJ Simpson, M Wechselberger. Shock-fronted travelling waves in a reaction–diffusion model with nonlinear forward–backward–forward diffusion. Physica D,423(132916), 2021.

[2] I Lizarraga, R Marangell. Spectral stability of shock-fronted travelling waves under viscous relaxation. Journal of Nonlinear Science, 33(82), 2023.

Level set-based inverse homogenisation of piezoelectric metamaterials

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

In this talk we will discuss the development of computational techniques for level set-based topology optimisation of piezoelectric materials and structures. In the first part of the talk we will introduce piezoelectric materials, the concept of computational homogenisation, and some interesting figures of merit for piezoelectric materials. Following this we will discuss the concept of level set-based topology optimisation. We will use the developed techniques to design piezoelectric materials with enhanced properties towards industrial applications.

An extendable Julia-based set of scalable computational tools for level set-based topology optimisation

Zachary J Wegert, Jordi Manyer, Connor N Mallon, Santiago Badia and Vivien J Challis
Queensland University of Technology

Topology optimisation is a class of PDE-constrained optimisation that seeks to minimise functionals that depend on the underlying domain and possibly the solutions to PDE constraints. Owing to a rich theoretical foundation and wide array of ever-evolving industrial applications, topology optimisation has become an increasingly popular topic in both industry and academia. As a result there is a need for general, extendable, and scalable high performance open-source algorithms that handle general optimisation problems with complicated underlying PDEs.

In this talk we will discuss on-going research and development of high-performance *Julia*-based level-set algorithms that are readily distributed across a HPC cluster via MPI. We use automatic differentiation to enable handling of complex problems without the need to calculate shape derivatives. We demonstrate the generality of the API and underlying algorithms by formulating and solving several optimisation problems of increasing complexity.

Broadband energy capture by an array of heaving buoys

Amy-Rose Westcott, Luke Bennetts, Nataliia Sergiienko and Benjamin Cazzolato
University of Adelaide

Broadband energy capture is sought by grading the resonant properties of an array of heaving buoy-type wave energy converters (WECs) in 2D, thereby extending the work by Wilks et al. (2022) to a WEC-array. Linear potential-flow theory is applied and WEC interactions are modelled using multiple-wave scattering theory in the frequency domain. The resonant properties of WECs are tuned via a linear spring-damper power take-off mechanism.

Bloch-Floquet theory is applied to determine the grading of WEC-resonances (controlled via the PTO spring terms) which prevents transmission on the targeted power capture interval. Near-perfect absorption at individual frequencies is then obtained by manipulating the complex-frequency zeros of the reflection coefficient through the extraction of incident energy (using the PTO damping terms).

The resulting graded array captures near-perfect absorption ($> 98\%$ of incident energy) from a targeted band of wavelengths spanning twice the array's length. Additionally, the grading of the (a) WEC-array can be optimised to achieve near-perfect, broadband absorption. Lastly, forcing by a transient wave packet is considered to demonstrate the temporal behaviour of the array.

Reference: Wilks, B., Montiel, F. and Wakes, S. (2022), 'Rainbow Reflection and Broadband Energy Absorption of Water Waves by Graded Arrays of Vertical Barriers', *J. Fluid Mech.*, **941**, pp. 1–25.

Approximation of stochastic fluid models

Joern Wichmann
Monash University

In this talk we discuss the design of algorithms in the context of stochastic fluid models.

Stochastic fluid models arise from classical deterministic ones, e.g. Stokes and Navier–Stokes, by enriching them with an additional stochastic forcing. This forcing accounts for random effects on micro-scales such as random movement of individual fluid particles. It introduces a particular challenge in the design of algorithms – solutions posses limited regularity. The irregularity prohibits to generalise deterministic algorithms and calls for robust algorithms adapted to the natural regularity of solutions. We present design principles that can cope with irregularities and discuss how to derive a rigorous mathematical error analysis. The talk is based on joint work with Kim-Ngan Le (Monash University).

Incorporating the structure of the lung into models of respiratory viral infections

Thomas Williams and James Osborne
The University of Melbourne

Increasingly, modern models of viral infections have come to recognise the important role of spatial structure in infection dynamics. Almost invariably, spatial models of viral infections make use of a wide, flat computational domain which is assumed to be representative of the entire affected tissue. Implicit in this assumption is that either the tissue being modelled is largely wide and homogeneous, or that the topology of the tissue has little influence on the dynamics of the system. While this assumption may apply to some tissues like the liver, it fails to take into account the distinctive topology of the lung. The lung is characterised by a tubular, highly branching structure, and is moreover directional: deeper regions of the lung are composed of far narrower airways and are associated with more severe infection. In our work, we hone in on two crucial components of the geometry of the lung — the tubular structure of airways, and the branching process between airway generations — and explore the important influences these features have on the dynamics of viral infections. We demonstrate the influence of lung structure in controlling the distribution of infection lineages, and illustrate a key role for directionality of infection spread in the lung.

Temporal trends of hospital transfer networks in Victoria for controlling the spread of antibiotic resistance

David Wu, Michael J Lydeamore, Tjibbe Donker, Claire Gorrie, Daneeta Henessey, Nic C Geard, Ben P. Howden, Ben S Cooper, Charlie Higgs, Andrew Wilson, Anton Y Peleg and Andrew J Stewardson
Monash University

The incidence of carbapenemase-producing Enterobacterales (CPE), a group of gut bacteria resistant to most antibiotics, has steadily increased in Victoria over the past decade, posing a significant health threat requiring careful management and mitigation. The spread of CPE within the Victorian hospital system, facilitated by patient movement between hospitals, has been studied in other healthcare systems through static network analysis. However, changes of the structure of the hospital system over time could affect how CPE can spread. In this research, we use line-listed patient admission data to construct a temporal network depicting patient movements over time between hospitals. Our objective is to assess whether a computationally less expensive aggregated static network can effectively capture the intricacies and dynamics observed in this temporal network. Network analysis of a discretised representation of the temporal network suggests a degree of temporal stability. A further simulation study on various temporal aggregation methods then allows us to quantify the difference in the dynamics of the spread of CPE. This study represents a small yet important step toward evidence-based strategies for mitigating the burden of CPE on Victoria's healthcare system.

Pricing for perishable goods in a queueing system

Chenchen Xing
The University of Melbourne

We introduce a pricing model for a monopoly retailer selling perishable goods to strategic customers. Customers arrive according to a Poisson process, and upon arrival, they decide whether to join the system, purchase non-fresh goods or balk based on a reward-cost structure.

We model the interaction between customers and the retailer as a two-population game and derive Nash equilibrium behaviors of the retailer and customers. Our approach enables optimal values of both fresh goods and non-fresh goods to be identified in a short time.

Characterising brain cell morphology using a sub-diffusion model for MRI

Qianqian Yang, Viktor Vegh and Marco Palombo
Queensland University of Technology

The diffusion-MRI signal in brain tissue can be modelled as a sub-diffusion process. The connection between the sub-diffusion model parameters and the microstructure of brain cells is yet to be explored. This research aims to characterise brain cell morphology using the sub-diffusion model parameters. Diffusion MRI signals for five brain cell types are generated using Monte Carlo simulations. The sub-diffusion model parameters are then fitted to the simulated diffusion MRI data for each cell type. Results reveal that sub-diffusion model parameters are sensitive to the branching order of the cell, with higher values indicating higher branching order. Our findings may provide new opportunities in diffusion MRI, where cell morphology and potentially cell type are of interest.

Escape motility of multicellular magnetotactic prokaryotes

Xinyi Yang and Douglas Brumley
The University of Melbourne

Microorganisms often actively respond to external stimuli to navigate towards their preferred niches. For example, single cell magnetotactic bacteria (MTBs) integrate both oxygen sensory information and the Earth's geomagnetic field to help them migrate towards anoxic conditions, in a process known as magneto-aerotaxis. However, for multicellular magnetotactic prokaryotes (MMPs), the colonial structure of 4-16 cells places fundamental constraints on collective sensing and navigation. In our experiments, colonies near an air-water interface exhibit unusual back and forth excursions called escape motility when the magnetic field directs colony towards oxygen-rich locations. While magneto-aerotaxis is well studied for MTBs, so far no one has emphasized its association with escape motility for MMPs. Through tracking of individual colonies in microfluidic devices, and numerical simulations, we demonstrate that escape motility can arise through a simple magneto-aerotaxis mechanism. Moreover, by including hydrodynamic interactions, we are able to simulate dispersion/condensation of MMPs near the air- water interface controlled by the magnetic field strength, which agrees with a recent experimental observation. Our results shed light on how the most primitive multicellular organisms navigate complex physicochemical landscapes.

Efficient allocation of financial resources to ensure dependable resilience in networks

Wei-Chang Yeh
National Tsing Hua University

In the ever-evolving landscape of network infrastructures, the preservation of resilience within binary-state systems has become a central concern. This research explores optimal strategies for allocating financial resources to ensure that binary-state networks consistently demonstrate reliable recovery capabilities in the face of adversities. Through a comprehensive investigation, we emphasise the importance of resilience that is both robust and dependable. Focusing on binary-state networks, characterised by components in either operational or non-operational states, we elucidate strategic measures to strengthen their inherent recovery mechanisms. Our study introduces a novel perspective on the critical role of intelligent resource allocation in achieving steadfast and trustworthy recovery processes during network disruptions. Additionally, we present an innovative algorithm based on the binary-addition-tree algorithm (BAT) and stepwise vectors to effectively address this challenge.

Construction of Castryck-Decru attack for B-SIDH and its implementation

Ryo Yoshizumi
Kyushu University

In cryptography, SIDH and its variant B-SIDH are key-sharing protocols based on isogeny problem between elliptic curves. A polynomial-time attack on SIDH was given in 2022, which is theoretically applicable to B-SIDH.However, prime factors of degree of the isogeny among the Abelian surfaces used in the attack are larger than those of SIDH, and although a single map has been implemented, an efficient implementation of their composition has not been given. In this study, we constructed an algorithm of the attack on B-SIDH and implemented the attack in the computer algebra system Magma. This work is based on joint research with Hiroshi Onuki (The University of Tokyo), Ryo Ohashi (The University of Tokyo), Momonari Kudo (Fukuoka Institute of Technology), and Koji Nuida (Kyushu University/AIST).

Cell differentiation architectures

Adriana Zanca, Lucy Ham and Michael Stumpf
The University of Melbourne

In multicellular organisms, stem cell differentiation, or specialisation, is critical for biological functions including tissue homeostasis and regeneration, and embryogenesis. Cell differentiation is often a multi-step process, with several intermediate states until a cell becomes fully differentiated. In circumstances such as response to injury, some cells are able to dedifferentiate, in other words move into a less differentiated state in their lineage. At stages throughout differentiation and dedifferentiation, cells may also undergo cell death. The process of differentiation, dedifferentiation and cell death can be modelled as a Markov process. In this talk, we consider the mean extinction times for cells with various differentiation architectures and their biological consequences. Even the simplest models can provide useful biological insight.

Deep learning for genetic epidemiology

Alexander E. Zarebski
The University of Melbourne

Phylodynamics uses genomic data to understand population dynamics, e.g. if a population is growing or shrinking. Phylodynamic methods are increasingly used in infectious disease epidemiology to understand the prevalence of infection. However, for even the simplest models of phylodynamics, likelihood-based inference can be intractable. This difficulty severely limits the utility of phylodynamics to answer critical questions about, for example, the prevalence of infection and the reproduction number of a pathogen, which are vital to enacting an appropriate public health response.

Neural networks have shown great potential for estimating transmission dynamics. However, previous neural network-based approaches have struggled with inferring aspects of historical transmission, such as how a pathogen has spread between locations. In this talk, we describe a method for likelihood-free inference, based on a combination of recurrent and recursive neural networks. With a simulation study, we demonstrate the use of this approach in an epidemiological setting. Using methods developed for multimodal data fusion, we can also draw on multiple data sources to improve estimates. In addition to providing a powerful approach for infectious disease epidemiology, this also suggests novel challenges for deep learning.

Pricing American down-and-out call options with transaction costs

Xinyi Zhang and Xiaoping Lu
University of Wollongong

Barrier options are options that automatically become worthless, or activated when the underlying asset price hits a prescribed price, the barrier. Although barrier options are extensively studied in the literature, the pricing of such options in American style with transaction costs is less investigated. Our project focuses on the pricing of down-and-out call options in American-style with proportional transaction costs. Taking transaction costs into account makes the pricing governing equations much more non-linear, an implicit finite difference scheme is used to obtain the numerical solutions. Our results show the effects of transaction costs on option prices for the holder and the writer, as well as the optimal exercise price for American-style options. Our approach can be extended to price other types of barrier options with transaction costs.

Conference Delegates (as of 4 February 2024)

Name	Affiliation
Isobel Abell	The University of Melbourne
I. David Abrahams	University of Cambridge
Tharindi Amarathunge Achchige	University of South Australia
Ishraq Ahmed	The University of Sydney
Anna Aksamit	The University of Sydney
Suliman Al-Homidan	King Fahd University of Petroleum and Minerals
Alberello Alberto	University of East Anglia
Amie Albrecht	University of South Australia
Afnan Aldosri	The University of Newcastle
Rehab Aljabri	The University of Newcastle
Jabr Aljedani	King Abdulaziz University
Faris Alsubaie	The University of Queensland
Md Nurul Anwar	The University of Melbourne
Zayed Asiri	Flinders University
Andrew Axelsen	University of Tasmania
Boris Baeumer	University of Otago
John Bailie	The University of Auckland
Christopher Baker	The University of Melbourne
Indu Bala	The University of Adelaide
Ishara Bandara	Deakin University
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