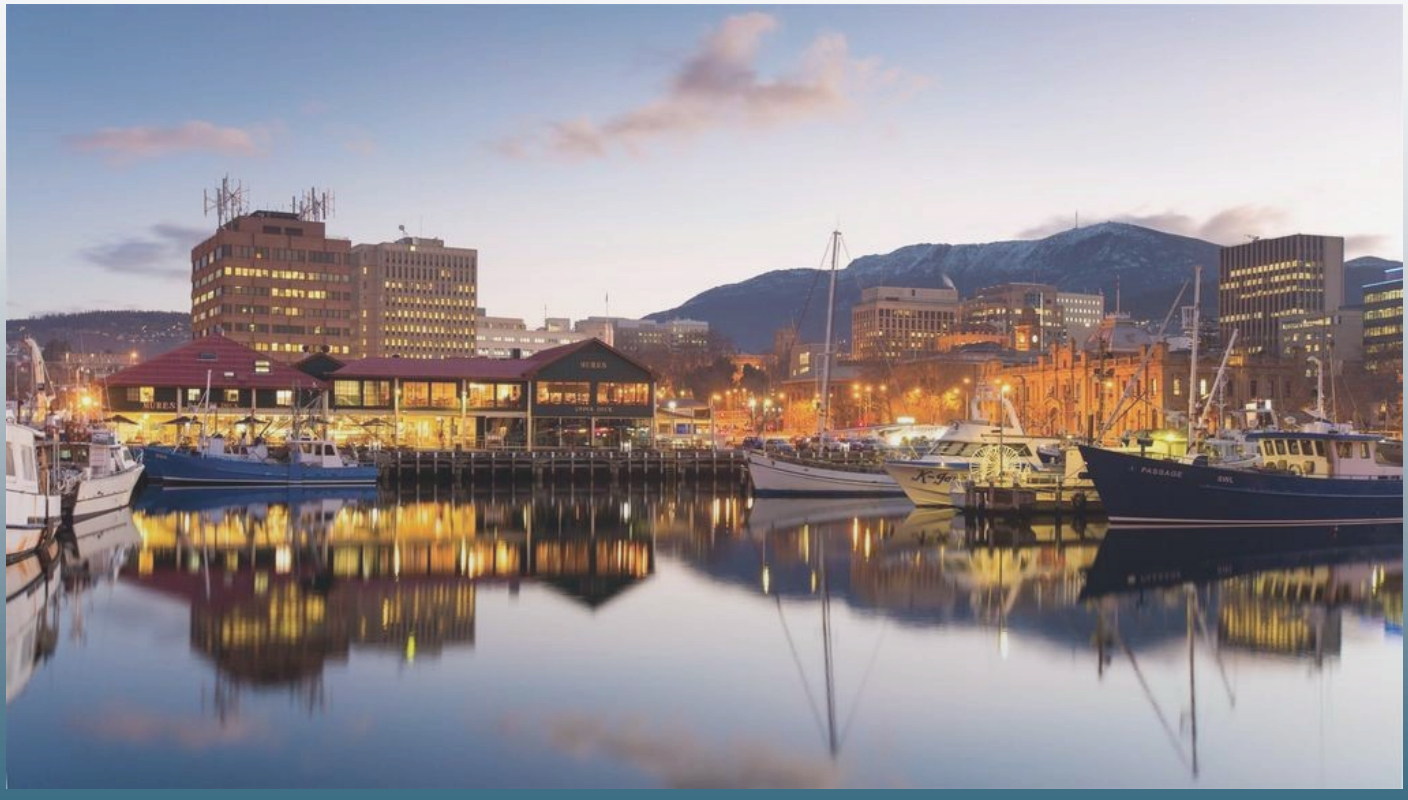
ANZIAM 2018

54th Meeting

4-8 February, 2018

Hotel Grand Chancellor

Hobart, Tasmania



The abstracts of the talks in this handbook were provided individually by the 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 John Banks for his software allowing abstract submission and generation of LaTeX files.

We also thank the organisers of the ANZIAM 2017 conference for providing their LaTeX template files.

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1 Conference Details and History

1.1 Organising Committee

- Larry Forbes (University of Tasmania) — Director
- Karen Bradford (University of Tasmania)
- Andrew Bassom (University of Tasmania)
- Michael Brideson (University of Tasmania)

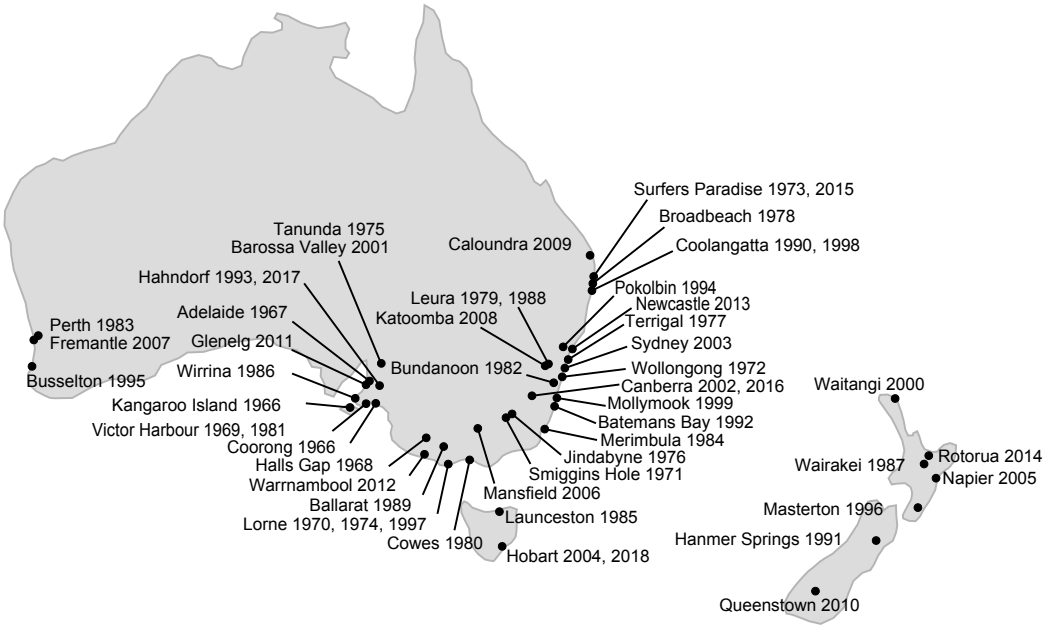
1.2 Invited Speakers Committee

- Tammy Lynch (Massey University) — Chair
- Andrew Bassom (University of Tasmania)
- Sophie Hautphenne (University of Melbourne)
- Alex James (University of Canterbury)
- Carlo Laing (Massey University)
- Michael Small (University of Western Australia)
- Sharon Stephen (University of Sydney)
- Ian Turner (Queensland University of Technology)

1.3 Invited Speakers

- Snezhana Abarzhi (University of Western Australia)
- Alys Clark (University of Auckland) — 2017 J.H. Michell Medallist
- Michael Plank (Canterbury University)
- Louise Ryan (University of Technology, Sydney)
- Kate Smith-Miles (University of Melbourne) — 2017 E.O. Tuck Medallist
- Mandyam Srinivasan (University of Queensland)
- Nick Trefethen (University of Oxford)

1.4 Past Conference Locations



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

1.5 The T.M. Cherry Student Prize

An annual prize for the best student talk was introduced in 1969 at Victor Harbor. In May 1976 the Division of Applied Mathematics titled it the "T.M. Cherry Student Prize" in honour of Professor Sir Thomas MacFarland Cherry. Past recipients are listed below.

1969	R. Jones	U Adelaide
1970	J. Rickard	UCL
1971	J. Jones	Mount Stromlo
1972	Not awarded	
1973	Not awarded	
1974	R. P. Oertel	U Adelaide
1975	R. E. Robinson	U Sydney
1976	J. P. Abbott	ANU
1977	J. Finnigan	CSIRO
	S. Bhaskaran	U Adelaide
1978	B. Hughes	ANU
	P. Robinson	UQ
1979	J. R. Coleby	U Adelaide
	B. Hughes	ANU
1980	M. Lukas	ANU
1981	A. Plank	UNSW
1982	G. Fulford	UoW
	J. Gear	U Melbourne
1983	P. Kovesi	UWA
1984	A. Kucera	UoW
	S. Wright	UQ
1985	G. Fulford	UoW
	F. Murrell	U Melbourne
1986	A. Becker	Monash U
	K. Thalassoudis	U Adelaide
1988	W. Henry	ANU
1987	M. Rumsewicz	U Adelaide
1989	M. Myerscough	U Oxford
	J. Roberts	U Melbourne
1990	J. Best	UoW
1991	S. K. Lucas	U Sydney
1992	S. F. Brown	UoW
1993	D. Standingford	U Adelaide
1994	B. Barnes	Monash U
1995	A. Buryak	ANU
1996	A. Gore	U Newcastle
	D. Scullen	U Adelaide
1997	S. Cummins	Monash U
1998	J. Clark	U Sydney
	T. Gourlay	U Adelaide
1999	E. Ostrovskaya	ANU
2000	C. Reid	Massey U
2001	M. Haese	U Adelaide
2002	V. Gubernov	ADFA
	W. Megill	UBC/UoW
2003	Not awarded	
2004	K. Mustapha	UNSW
2005	J. Looker	U Melbourne
2006	C. Fricke	U Melbourne
2007	S. Harper	Massey U
2008	E. Button	U Melbourne
	M. Haythorpe	UniSA
2009	S. Cohen	U Adelaide
2010	L. Mitchell	U Sydney
2011	S. Butler	U Sydney
	J. Caffrey	U Melbourne
2012	J. Nassios	U Melbourne
2013	D. Khoury	UNSW
	T. Vo	U Sydney
2014	M. Chan	U Sydney
2015	H. Tronnolone	U Adelaide
2016	D. Arnold	U Adelaide
	A. Jenner	U Sydney
2017	C. Miller	U Melbourne
	E. Hester	U Sydney

1.6 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

1.7 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	2009	Scott McCue	QUT
2000	Antoinette Tordesillas	U Melbourne	2011	Frances Kuo	UNSW
2001	Nigel Bean	U Adelaide	2012	Matthew Simpson	QUT
2002	Stephen Lucas	UniSA	2013	Terence O'Kane	CMAR CSIRO
2004	Mark Nelson	UoW	2014	Ngamta Thamwattana	UoW
2006	Sanjeeva Balasuriya	U Sydney	2015	Barry Cox	U Adelaide
2007	Yvonne Stokes	U Adelaide	2016	Joshua Ross	U Adelaide
2008	Carlo Laing	Massey U	2017	Alys Clark	U Auckland

1.8 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 EO Tuck Medals were presented at ANZIAM 2013.

2013	Shaun Hendy	VUW and Callaghan Innovation
	Geoffry Mercer	ANU
2015	Troy Farrell	QUT
2017	Kate Smith-Miles	Monash U

1.9 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

1.10 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

1.11 Acknowledgements

The Organising Committee gratefully acknowledges the financial support of Professor Nalini Joshi's Georgina Sweet Australian Laureate Fellowship.

The Organising Committee gratefully acknowledges John Banks for providing the conference registration and abstract submission software, `register!`.

The Organising Committee is thankful for funding received from the ANZIAM Student Support Scheme to assist the following students to attend the ANZIAM 2018 conference:

Rosemary Aogo
Sarah Belet
Chantelle Blachut
Calum Braham
Alexander Browning
Hilary Hunt
Claudio Ibarra
Adrianne Jenner
Matthew King
Maria Kleshnina
Tiffany Leung
Sha Lin
Meirian Lovelace-Tozer
Michael Lydeamore
Benjamin Maldon
Sean McInerney
Claire Miller
Liam Morrow
Samson Ogunlade
Pantea Pooladvand
James Reoch
Joseph Teague
Eloise Tredenick
Lachlan Tyrrell
Demival Vasques
Sean Vittadello
Collin Zheng

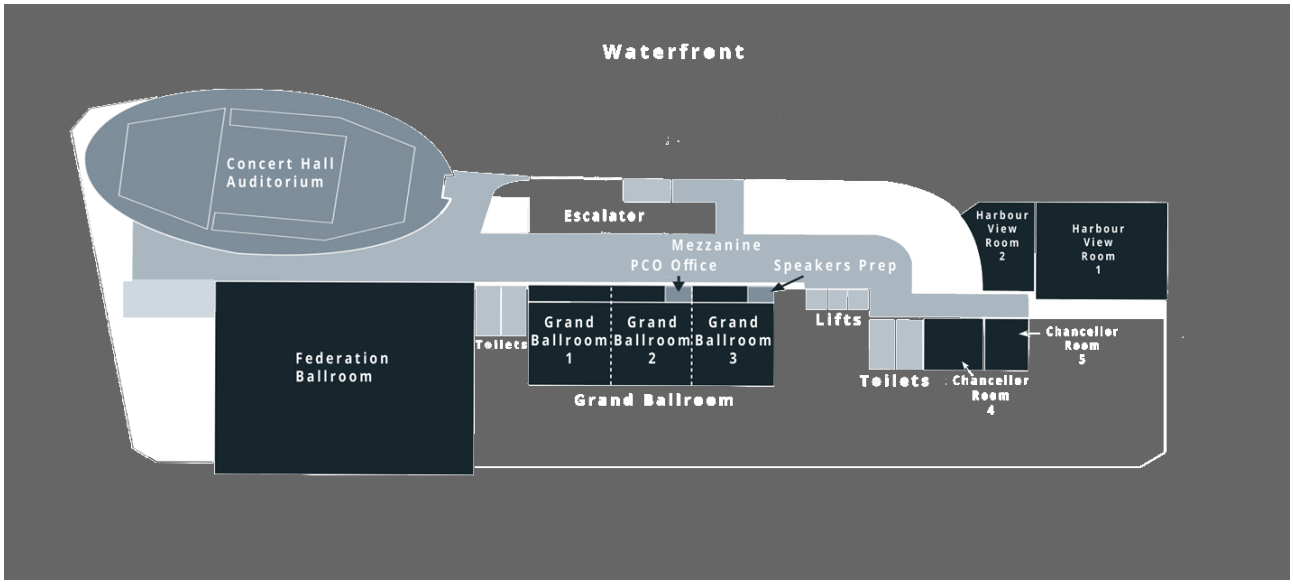
2 Conference Events, Venues and Facilities

2.1 Conference Venue

The conference is being held at the Hotel Grand Chancellor (HGC) in Hobart, Tasmania. The HGC is at 1 Davey Street, overlooking Hobart Harbour and Constitution Dock.

The HGC is convenient to the Tasmanian Travel and Information Centre (corner of Elizabeth St and Davey St), Elizabeth St Mall, and the historic regions of Battery Point and Salamanca Place.

All conference rooms are located on Level 1 of the HGC; the floor plan is shown below. The five meeting rooms are the Grand Ballrooms 1, 2 and 3; Harbour View Room 2; and Chancellor Room 4. Grand Ballrooms 2 and 3 will combine for the conference opening, closing, and plenary sessions.



2.2 Conference Welcome Reception

The welcome reception will be held from 6–8 pm on Sunday, February 4 in Harbour View Room 1. All conference delegates and registered guests are invited.

2.3 Conference Banquet

The Conference Banquet will be held in the Grand Ballroom on Wednesday, February 7. Pre-dinner drinks will be served on the Mezzanine from 6:30 pm, for a 7 pm start to the banquet.

2.4 Refreshment Breaks and Lunches

Arrival tea and coffee will be available on the Mezzanine prior to the Conference Opening on Monday and 9 am invited Talks on the remaining days. Morning teas, afternoon teas and lunches will also be set up on the Mezzanine. Lunches are included in the registration fee for delegates and their registered guests.

2.5 Internet Access

Delegates will be provided with WiFi internet access throughout the conference. Connection details will be provided at the conference.

2.6 Invited Lectures and Contributed Talks

All invited lectures will take place in Grand Ballroom 2–3 and are scheduled for 50 minutes, inclusive of questions.

Contributed talks will be held in parallel sessions in Grand Ballroom 1, Grand Ballroom 2, Grand Ballroom 3, Harbour View 2 and Chancellor 4. The duration of each contributed talk will be fifteen minutes with an additional five minutes for questions and room change over.

2.7 Student Evening

All students are invited to BarCelona in Salamanca Square from 6:30 pm on Monday, February 5 for the Student Evening. The Evening 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 Laura Karantgis.

2.8 Women in Mathematical Sciences Lunch

The 2018 Women in Mathematical Sciences ANZIAM Lunch will be held on Tuesday, February 6. This event is being held under the umbrella of the Women in Mathematics Special Interest Group (WIMSIG) of the Australian Mathematical Society. It is free to all registrants at ANZIAM 2018 who wish to attend and is funded and supported by Prof. Nalini Joshi's Georgina Sweet Australian Laureate Fellowship. It is open to people of any gender.

The purpose of the lunch is to support women, and particularly early career researchers, to enter and establish careers in mathematics. Come along and hear about the careers of the ANZIAM 2018 female plenary speakers, to discuss issues concerning women in mathematics in Australia, and to network with fellow WIMSIG members and supporters. Check out the WIMSIG website (austms.org.au/WIMSIG-QA) for information on/advice from the female plenary speakers at this and past ANZIAM and AustMS conferences.

Please collect your lunch from the Mezzanine and then convene in Grand Ballroom 2.

2.9 Tuesday Afternoon - Explore Hobart

The Tuesday afternoon of ANZIAM conferences is traditionally set aside for free time. We encourage you to use this time to explore some of the wonderful attractions in the Greater Hobart region.

The hotel foyer has a pamphlet display area for local attractions. More information can be obtained from the Tasmanian Travel and Information Centre on the corner of Elizabeth St and Davey St (approximately 150 m from the HGC).

Here are some suggestions for activities:

Across the road from the HGC is the Tasmanian Museum and Art Gallery.

One block further along is the Maritime Museum of Tasmania.

MONA, the Museum of Old and New Art is the largest privately funded museum in Australia. The building is carved into the landscape and the displayed art is often reviewed anywhere on the scale from disgusting to wonderful. A trip to the museum on the MONA ferry is an attraction in itself. Unfortunately, the museum is **closed** on Tuesdays.

The historic regions of Salamanca Place and Battery Point are wonderful places to explore on foot, as is the Hobart Rivulet track which takes you into the foothills of kunanyi / Mount Wellington.

The World Heritage listed Female Factory Historic Site is also beside the Hobart Rivulet and just downstream from the Cascade Brewery.

Sightseeing tours around Hobart are available on the Red Decker bus. Alternatively, see Hobart from the river with Hobart Historic Cruises.

3 Conference Programme

The program is shown on the following pages. Contributed talks should be no more than 15 minutes and speakers will be provided a warning after 12 minutes. Talks must stop after 15 minutes to allow 3 minutes for questions and 2 minutes for room changes.

	Monday Morning *student talk				
8:00–8:30	Registration — Mezzanine				
8:30–9:00	Conference Opening, Grand Ballroom 2–3				
9:00–9:50	**Invited: Nick Trefethen, (University of Oxford)**, Grand Ballroom 2–3 **Title:** Mathematics of the Faraday Cage (#186, p. 120) *Chair: Larry Forbes*				
	Grand Ballroom 1	Grand Ballroom 2	Grand Ballroom 3	Harbour View 2	Chancellor 4
	Chair: Roslyn Hickson	*Chair:* Jerome Droniou	*Chair:* Mark Flegg	*Chair:* Carlo Laing	*Chair:* Tony Roberts
10:00–10:20	**Rebecca Chisholm** Understanding how immunity, strain diversity and prevalence interact in multi-strain pathogens using agent-based modelling (#29, p. 41)	**Peter Johnston** Evaluating singular integrals for fun and profit (#85, p. 68)	**Jennifer Flegg** A mathematical model of the use of supplemental oxygen to combat surgical site infection (#51, p. 51)	**Bernd Krauskopf** Robust chaos: blenders in a Hénon-like family (#95, p. 73)	**Jim Denier** New results in the instability of compressible boundary layers (#38, p. 45)
10:20–10:40	**Sarah Belet*** Models for the spread of Wolbachia in mosquito populations as a means of suppressing dengue fever transmission (#16, p. 34)	**Robert Scott Anderssen** Modelling causality: integral equations versus ODEs (#6, p. 29)	**Anand Rampadarath*** A Distribution-Moment approximation for coupled airway dynamics of the airway wall and airway smooth muscle (#147, p. 100)	**Andrus Giraldo** Shilnikov-like chaos in two nonlinear coupled photonic nanocavities (#60, p. 56)	**Lidong Cui*** Resonance, symmetry and pattern selection in Langmuir circulation (#36, p. 44)
10:40–11:00	**Saber Dini*** Investigating the efficacy of antimalarial drugs using a mathematical model (#39, p. 46)	**Barbara Johnston** The 'sinh' transformation method for evaluating nearly singular boundary element integrals (#84, p. 68)	**Adel Ahmed Almalki*** An analysis of the first order growth fragmentation equation for special division kernels (#5, p. 28)	**Elle Musoke*** The geometry of a three-dimensional invariant manifold in a four-dimensional slow-fast system (#124, p. 88)	**Suha Al Ali*** Withdrawal of water from within a sand column (#4, p. 28)
11:00–11:20	Morning tea - Mezzanine				

	Monday morning continued *student talk				
	Grand Ballroom 1	Grand Ballroom 2	Grand Ballroom 3	Harbour View 2	Chancellor 4
	Chair: Mick Roberts	*Chair:* Linda Stals	*Chair:* Matthew Simpson	*Chair:* Michael Small	*Chair:* Scott McCue
11:20–11:40	**Samson Ogunlade*** Modelling malaria parasites' survivability the dry season (#132, p. 92)	**Frank de Hoog** Iterative Deconvolution (#37, p. 45)	**Edward Green** Can the left ventricle get enough oxygen? (#66, p. 59)	**Martin Wechselberger** Two-stroke relaxation oscillators (#203, p. 128)	**John Harper** A Volterra equation with a physically but not mathematically unique solution: a bubble rising in a liquid with negative surface activity (#71, p. 61)
11:40–12:00	**Robert Cope** Multi-strain epidemic models for transmission and evolution of drug resistant pathogens (#32, p. 42)	**Graeme Wake** Geometric Optimisation (#198, p. 126)	**Elias Vera Siguenza*** A mathematical model supports a key role for anion exchanger Ae4 (Slc4a9) in salivary gland fluid secretion (#195, p. 124)	**Andrew Keane** State-dependent delays in the El Niño Southern Oscillation system (#89, p. 70)	**Liam Morrow*** A level set based numerical scheme for doubly connected Hele-Shaw flow (#123, p. 87)
12:00–12:20	**Stuart Johnston** An analytical approach for quantifying the influence of nanoparticle polydispersity on cellular delivered dose (#86, p. 69)	**Ian Sloan** Needlet approximation on the sphere (#164, p. 108)	**Ngamta Thamwattana** Modelling phagocytosis (#182, p. 117)	**Chantelle Blachut*** Detecting and characterising coherent structures and their evolution in non-autonomous dynamical systems (#18, p. 35)	**Lachlan Tyrrell*** Viscous fingering patterns driven by heterogeneous substrate wettability (#190, p. 122)

	Monday morning continued *student talk				
	Grand Ballroom 1	Grand Ballroom 2	Grand Ballroom 3	Harbour View 2	Chancellor 4
12:20–12:40	**David Khoury** Correctly assessing drug efficacy in malaria relies on understand parasite kinetics before treatment (#90, p. 71)	**Jeremy Sumner** Lie-Markov models derived from finite semigroups (#172, p. 112)	**Nathan Pages*** A model of calcium dynamics in anatomically accurate parotid acinar cells (#137, p. 95)	**Soizic Terrien** Pulsing dynamics in an excitable laser subject to delayed optical feedback (#181, p. 117)	**Khanh Pham*** On the evaluation of Landau constants in amplitude equations away from a critical point. Part 1: supercritical regimes (#140, p. 96)
12:40–1:00	**Rosemary Aogo*** Modelling malaria parasite development before and after drug treatment (#8, p. 30)	**Tony Roberts** Projective integration of multiscale ODEs via Dynamic Mode Decomposition (#155, p. 104)	**Sean Trinity Vittadello*** Mathematical models for cell migration with real-time cell cycle dynamics (#197, p. 125)	**Robert Nawiekang Otupiri*** Numerical modelling and characterisation of an all-fibre laser with saturable absorber (#135, p. 94)	**Sergey Suslov** On the evaluation of Landau constants in amplitude equations away from a critical point. Part 2: subcritical regimes and a physical example (#173, p. 113)
1:00–2:00	Lunch - Mezzanine				

	Monday afternoon *student talk				
2:00–2:50	**Invited: Louise Ryan, (University of Technology, Sydney)**, Grand Ballroom 2–3 **Title:** But I'm a data scientist too, aren't I? (#159, p. 106) *Chair: Barbara Holland*				
	Grand Ballroom 1	Grand Ballroom 2	Grand Ballroom 3	Harbour View 2	Chancellor 4
	Chair: Ngamta Thamwattana	*Chair:* Geetika Verma	*Chair:* Amie Albrecht	*Chair:* Elliot Carr	*Chair:* Yvonne Stokes
3:00–3:20	**Bronwyn Hajek** Analytic solutions for a reaction diffusion model of calcium waves on the surface of an egg (#69, p. 60)	**Andrew Black** Importance sampling for partially observed Markov models (#19, p. 36)	**Meirian Sara Lovelace-Tozer*** Modelling donor flow (#106, p. 79)	**Tim Moroney** A modern linear algebra library for C++17 (#122, p. 87)	**Stephen Walters** Viscous Rayleigh-Taylor flows in two and three dimensions using GPU acceleration (#200, p. 127)
3:20–3:40	**Wang Jin** The role of initial geometry in experimental models of wound closing (#83, p. 67)	**Benjamin David Kaehler** Full reconstruction of a hidden variable model with just two observed variables (#87, p. 69)	**Erika Rana Gabriela Belchamber*** Stochastic optimal control of a solar-powered car (#15, p. 34)	**Atsushi Minamihata** Accurate error bounds for linear systems using H-matrices (#121, p. 86)	**Mohamed Nasser** A fast numerical method for ideal fluid flow in domains with multiple stirrers (#126, p. 89)
3:40–4:00	Afternoon tea - Mezzanine				

	Monday afternoon continued *student talk				
	Grand Ballroom 1	Grand Ballroom 2	Grand Ballroom 3	Harbour View 2	Chancellor 4
	Chair: Edward Green	*Chair:* Andrew Black	*Chair:* Peter Taylor	*Chair:* Ian Sloan	*Chair:* Larry Forbes
4:00–4:20	**Tertius Ralph*** Hard-core interactions in one-dimensional velocity jump models (#146, p. 99)	**Jessica Penfold*** Using Approximate Bayesian Computation to understand the impact of climate in seasonal influenza in Australia (#138, p. 95)	**Adelle Coster** Fat and muscle glucose regulation same-same or different? (#34, p. 43)	**Linda Stals** Domain Decomposition applied to the thin-plate spline saddle point problem (#169, p. 111)	**Yvonne Stokes** Why oversized holes in microstructured optical fibres? (#171, p. 112)
4:20–4:40	**Alexander Tam*** Investigating the effect of nutrient-limited growth on floral pattern formation in yeast biofilms (#177, p. 115)	**Ashwani Kumar*** A sequential stochastic mixed integer programming model for elective surgery scheduling (#97, p. 74)	**Mark Fackrell** A timely solution to the nurse rostering problem: an operations research approach (#46, p. 49)	**Craig Douglas** Solving high condition number systems (#41, p. 47)	**Matthew James Hopwood*** Extensional flow of an axisymmetric transversely isotropic fluid thread (#78, p. 65)
4:40–5:00	**Anna McGann*** Anomalous Diffusion on a Growing Domain (#117, p. 84)	**Demival Vasques Filho*** Look who's talking: bipartite networks as representations of a topic model of New Zealand parliamentary speeches (#194, p. 124)	**Ryan Loxton** Switching time optimization for switched systems with time-dependent and state-dependent switching conditions (#107, p. 79)	**Robert Lodder** The BEST Approach to the Search for Extraterrestrial Intelligence (SETI) (#104, p. 78)	**James Reoch*** Thin-film multiphase modelling of collagen gel mechanics (#149, p. 101)
5:00–5:20	**Vijay Rajagopal** The Cardiac Cell under the Mathematical Microscope (#145, p. 99)	**Calum Braham*** Logarithmically-discretised population balance models of aggregation and fragmentation (#21, p. 37)	**Ali Tirdad** Improving health benefits of in-home care for chronic patients through optimal service timing (#184, p. 118)	**Sebastián Elías Graiff Zurita*** Discrete mechanical systems: existence of trajectories (#62, p. 57)	**Sophie Calabretto** Objective detection of rotationally coherent vortices (#25, p. 39)
6:30	ANZIAM Student Evening - BarCelona, Salamanca Square				

Tuesday morning

*student talk

9:00–9:50	**Invited: Mandyam Srinivasan, (The University of Queensland)**, Grand Ballroom 2–3 **Title:** From birds and bees to flying machines (#168, p. 110) *Chair: Mary Myerscough*				
	Grand Ballroom 1	Grand Ballroom 2	Grand Ballroom 3	Harbour View 2	Chancellor 4
	Chair: Peter Kim	*Chair:* Mark Nelson	*Chair:* Catherine Penington	*Chair:* Hinke Osinga	*Chair:* Elliot Carr
10:00–10:20	**Roslyn Hickson** A history-based multi-outbreak influenza model (#75, p. 63)	**Jim Byrnes** Active sonar remote identification of materials (#24, p. 38)	**Zoltan Neufeld** Modelling collective cell migration in a channel (#128, p. 90)	**Cris Hasan*** Saddle slow manifolds and canard orbits in the Hodgkin–Huxley model (#72, p. 61)	**Silvestru Sever Dragomir** Approximation of f-Divergence Measure in Information Theory and Applications (#42, p. 47)
10:20–10:40	**James Nicholas Walker*** A sequential approach to data-augmented MCMC (#199, p. 126)	**Troy Farrell** Towards accurate real-time control of lithium ion batteries (#48, p. 50)	**Alexander Paul Browning*** A Bayesian computational approach to explore the optimal duration of a cell proliferation assay (#23, p. 38)	**Naoto Nakano** Revisiting delay-embedding by using Hilbert-Schmidt integral operator theory for dynamical reconstruction (#125, p. 88)	**Caitlin Gray*** Generating connected spatially embedded graphs (#63, p. 57)
10:40–11:00	**Tiffany Ngo Nam Leung*** Infection-acquired versus vaccine-acquired immunity in an SIRWS model (#101, p. 76)	**Joseph Alex Teague*** Experimental feature driven development for mathematical models of LiFePO4 batteries (#180, p. 116)	**Oleksii Matsiaka*** Continuum approximations for lattice-free multi-species models of collective cell migration (#115, p. 83)	**Debora Cristina Correa** On system behaviour using complex networks of a compression algorithm (#33, p. 43)	**Caleb Gemmell*** Social network analysis from obsidian artefacts (#59, p. 55)
11:00–11:20	Morning tea - Mezzanine				

	Tuesday morning continued *student talk				
	Grand Ballroom 1	Grand Ballroom 2	Grand Ballroom 3	Harbour View 2	Chancellor 4
	Chair: Tammy Lynch	*Chair:* Melanie Roberts	*Chair:* Adelle Coster	*Chair:* Martin Wechselberger	*Chair:* Tim Moroney
11:20–11:40	**Michael Lydeamore*** Investigating the dynamics of coupled models with applications to Group A Streptococcus and Scabies (#110, p. 81)	**Nabil Fadai*** Asymptotic analysis of a multiphase drying model motivated by coffee bean roasting (#47, p. 49)	**Catheryn Gray*** Tracking the location of metabolic controllers: Akt as a harmonic oscillator (#64, p. 58)	**Maria Kleshnina*** Nonlinear learning in games with incompetence (#93, p. 72)	**Siegfried Rump** Linear systems in Matlab with zero residual (#158, p. 105)
11:40–12:00	**Mick Roberts** Is your family pet a source of antibiotic resistance? (#153, p. 103)	**Eloise Tredenick*** Mathematical modelling of hydrophilic agrochemical penetration in astomatous plant cuticles: surfactant and hygroscopic effects (#185, p. 119)	**Adarsh Kumbhari*** Modelling the impact of T-cell avidity on cancer vaccines (#98, p. 75)	**Cecilia Gonzalez-Tokman** Optimal mixing enhancement by local perturbation (#61, p. 56)	**Takuya Tsuchiya** Error analysis of Crouzeix-Raviart and Raviart-Thomas finite element methods (#189, p. 121)
12:10–1:00	**Invited: Michael Plank, (University of Canterbury)**, Grand Ballroom 2–3 **Title:** The other end of the spectrum: size-based models of marine ecosystems and fishing (#142, p. 97) *Chair: Bronwyn Hajek*				

	Tuesday afternoon and evening
1:00–2:00	Lunch - Mezzanine Women in Mathematical Sciences Lunch - Grand Ballroom 2
2:00–7:30	Free time
7:30–9:30	ANZIAM AGM, Grand Ballroom 2
9:30–11:30	ANZIAM Executive Meeting, Chancellor 5

	Wednesday morning *student talk				
9:00–9:50	**Invited: Alys Rachel Clark - 2017 J.H. Michell Medal Winner, (The University of Auckland)**, Grand Ballroom 2–3 **Title:** Pregnancy and beyond: how mathematical modelling could improve early life health (#30, p. 41) *Chair: Matthew Simpson*				
	Grand Ballroom 1	Grand Ballroom 2	Grand Ballroom 3	Harbour View 2	Chancellor 4
	Chair: Philip Broadbridge	*Chair:* Murk Bottema	*Chair:* Noel Barton	*Chair:* Frank de Hoog	*Chair:* Song-Ping Zhu
10:00–10:20	**Kenji Kajiwara** Log-Aesthetic curves in industrial design as similarity geometric analogue of Euler's elastic curves (#88, p. 70)	**Hilary Hunt*** Mixed Signals: Interaction between RyR and IP3R mediated calcium release shapes the calcium transient for hypertrophic signalling in cardiomyocytes (#79, p. 65)	**Mark Nelson** Nitrogen removal in the activated sludge process (#127, p. 89)	**Elliot Joseph Carr** Calculating how long it takes for diffusive processes to effectively reach steady state without computing the transient solution: application to groundwater flow (#26, p. 39)	**Anna Aksamit** Additional information in robust approach to mathematical finance (#3, p. 27)
10:20–10:40	**Guido Baardink*** Localizing softness and stress in topological metamaterials (#10, p. 31)	**Claire Miller*** The impact of stem cell division models in epithelial multi-cellular tissue modelling (#120, p. 86)	**Melanie Roberts** Fine-grained multi-factor hail damage modelling (#152, p. 102)	**Scott McCue** Steady free-surface flow over a bottom obstruction in three dimensions (#116, p. 84)	**Guiyuan Ma** An analytical solution for the HJB equation arising from the Merton problem (#112, p. 82)
10:40–11:00	**Matthew King*** Chaos and fluctuations in a modified Ehrernfest wind-tree model (#92, p. 72)	**Kengo Fujita*** Construction of a mathematical model that reproduces the mechanism of classification and memory of information using timeshift and phase states of brain waves (#56, p. 54)	**Benjamin Ganim*** Forecasting maximum power demand in NSW with SARIMA-regression model (#58, p. 55)	**Sheehan Shakiban Olver** Sparse spectral methods for PDEs on triangles with multivariate orthogonal polynomials (#133, p. 93)	**Xiaoping Lu** Finite margin call stock loan evaluation (#108, p. 80)
11:00–11:20	Morning tea - Mezzanine				

Wednesday morning continued

*student talk

	Grand Ballroom 1	Grand Ballroom 2	Grand Ballroom 3	Harbour View 2	Chancellor 4
	Chair: Christopher Lustri	*Chair:* Hayden Tronnolone	*Chair:* Troy Farrell	*Chair:* Peter Johnston	*Chair:* Anna Aksamit
11:20–11:40	**Nathan Paul Duignan*** On a conjecture about the simultaneous binary collision (#44, p. 48)	**Arnold Reynaldi** Age-specific heterogeneity in CD8+ T-Cell homeostasis (#151, p. 102)	**Steve Taylor** Preserving quality of milk powder shipments (#179, p. 116)	**Dimetre Triadis** An integrable discrete model for soil-water infiltration (#187, p. 120)	**Angus Hamilton Lewis*** Modelling South Australia's electricity prices (#102, p. 77)
11:40–12:00	**Khongorzul Dorjgotov*** Exact invariant solutions of time fractional evolution systems with variable coefficient (#40, p. 46)	**Adrianne Jenner*** The effect of tumour heterogeneity on cancer treatments: the ninja virus (#81, p. 66)	**Mark Joseph McGuinness** MMM, Microwaves Measure Moisture (#118, p. 85)	**Eric William Hester*** Fluid-Structure interaction in pseudospectral codes: The smooth volume penalty method (#74, p. 62)	**Sha Lin*** Pricing puttable convertible bonds with integral equation approaches (#103, p. 77)
12:00–12:20	**Joe O'Leary*** The energy integral in the first post-Newtonian approximation for general relativity (#130, p. 91)	**David Waters*** Calcium Signalling in T-Cells (#201, p. 127)	**Kenta Kobayashi** The relation between Crouzeix-Raviart and Raviart-Thomas finite element methods (#94, p. 73)	**Arthur George Suvorov*** The information geometry of sensor management (#174, p. 113)	**Xin-Jiang He** How should a local regime-switching model be calibrated? (#73, p. 62)
12:20–12:40	**Winston Sweatman** Symmetrical few-body orbits (#175, p. 114)	**Pantea Pooladvand*** Do T-cells compete for antigen? (#143, p. 98)	**Benjamin Maldon*** Pressing charges: analytical solutions to the diffusion model charge carriers in dye-sensitized solar cells (#113, p. 82)	**Marko Lange** Rigorous results in electronic structure calculation (#100, p. 76)	**Song-Ping Zhu** American-style Parisian options and their fair price (#209, p. 132)
12:40–1:00	**James Murray Hill** Relating elasticity and graphene folding conformation (#76, p. 63)	**Ielyaas Cloete*** Calcium oscillations in hepatocytes: how are they shaped? (#31, p. 42)	**Jamilatuzzahro Abdul Fatah*** The determination of Open Science, Open Innovation paddy production in Indonesia using geographically weighted regression (#2, p. 26)	**Jerome Droniou** Low order or high order? Wisdom may be in the middle... (#43, p. 47)	**Sue Ann Chen** Compliance for Personal Financial Advice (#28, p. 40)
1:00–2:00	Lunch - Mezzanine				

	Wednesday afternoon *student talk				
2:00–2:50	**Invited: Kate Smith-Miles - 2017 E.O. Tuck Medal Winner, (The University of Melbourne)**, Grand Ballroom 2–3 **Title:** Optimization in the Darkness of Uncertainty: when you don't know what you don't know, and what you do know isn't much! (#167, p. 110) *Chair: Troy Farrell*				
	Grand Ballroom 1	Grand Ballroom 2	Grand Ballroom 3	Harbour View 2	Chancellor 4
	Chair: Arnold Reynaldi	*Chair:* Robert Cope	*Chair:* Andrew Keane	*Chair:* Boris Baeumer	*Chair:* Phil Howlett
3:00–3:20	**Xueshan Yang*** Dynamics of a coupled calcium system (#206, p. 130)	**Alexey Martyushev** Mathematical modelling of HIV dynamics in humanized mice (#114, p. 83)	**Caroline Wormell*** Linear response in weakly-coupled systems (#205, p. 130)	**Philip Broadbridge** Quantum mechanics from a classical fluids perspective (#22, p. 37)	**Geetika Verma** The replicator equation in discrete time (#196, p. 125)
3:20–3:40	**Mythreye Krishnan*** Network using Michaelis-Menton kinetics: an algorithm to find target genes from expression data (#96, p. 74)	**Nick Beeton** Modelling mange in the common wombat (#14, p. 33)	**Sam Jelbart*** Why there might be more slow-fast systems than you thought there were (#80, p. 66)	**Balazs Sandor*** Topographical uniqueness condition for the weak form of a linear depth-averaged vorticity model (#161, p. 107)	**Florian Wechsung*** Shape optimization with geometric constraints using Moreau-Yosida regularization (#204, p. 129)
3:40–4:00	Afternoon tea - Mezzanine				

Wednesday afternoon continued

*student talk

	Grand Ballroom 1	Grand Ballroom 2	Grand Ballroom 3	Harbour View 2	Chancellor 4
	Chair: Rebecca Chisholm	*Chair:* Mary Myerscough	*Chair:* Gary Froyland	*Chair:* Mark McGuinness	*Chair:* Bruce van Brunt
4:00–4:20	**Ishraq Uddin*** A multiphase model for HDL-assisted stabilisation of early atherosclerotic plaques (#192, p. 123)	**Claudio Arancibia*** The Holling-Tanner predator-prey model with strong Allee effect on prey (#9, p. 30)	**Timothy Roberts*** Neurons, temperature and timescales: what GSPT might tell us about temperature regulation? (#154, p. 103)	**Emma Greenbank*** Modelling Surtseyan Ejecta (#67, p. 59)	**Polwaththa Dilruk Darshana Gallage*** Solving nonlinear PDEs for phase boundaries (#57, p. 54)
4:20–4:40	**Sara Li-Yen Loo*** The evolution of hunting effort in hunter-gatherer populations (#105, p. 78)	**Jonathan Eade*** An ODE model for the transmission of the disease Nosema ceranae in honey bee colonies with demographic structure (#45, p. 48)	**Joshua Ross** Demography determines gene drives success in eradicating pests (#157, p. 105)	**Owen Jepps** Modelling density-dependent collective diffusion in microporous Knudsen flows (#82, p. 67)	**Saima Gul*** A cell growth model adapted for minimum cell size division (#68, p. 60)
4:40–5:00	**Mykola Pinkevych** Dynamics of reactivation from latency in macaques infected with simian immunodeficiency virus (#141, p. 97)	**Zeaiter Zeaiter*** The effect of thermoregulation on honey bee colony health and survival (#207, p. 131)	**Hinke Osinga** Global manifolds parametrised by isochrons (#134, p. 93)	**Sean McInerney*** Evaluating burn damage and exploring first aid treatment with partial differential equations and *in vivo* Porcine experiments (#119, p. 85)	**Lisa Reischmann*** A multiscale approximation of a Cahn–Larché system with phase-separation on the microscale (#148, p. 100)
5:00–5:20				**Graeme Hocking** Plumes generated by desalination outfalls (#77, p. 64)	**Terry O'Kane** Non-stationary nonparametric and regularised time series analysis of observed atmospheric dynamics (#129, p. 90)
6:30–11:00	Conference Banquet 6:30 Pre-dinner drinks - Mezzanine 7:00 Banquet - Grand Ballroom				

	Thursday morning *student talk				
9:00–9:50	**Invited: Snezhana I. Abarzhi, (The University of Western Australia)**, Grand Ballroom 2–3 **Title:** On the fundamental of Rayleigh-Taylor instability and Rayleigh-Taylor interfacial mixing (#1, p. 26) *Chair: Larry Forbes*				
	Grand Ballroom 1	Grand Ballroom 2	Grand Ballroom 3	Harbour View 2	Chancellor 4
	Chair: Nick Beeton	*Chair:* Andrew Bassom	*Chair:* Bernd Krauskopf	*Chair:* Julia Piantadosi	*Chair:* Barbara Holland
10:00–10:20	**Catherine Penington** Modelling cell proliferation times (#139, p. 96)	**Sharon Stephen** Stability of the non-Newtonian asymptotic suction boundary layer (#170, p. 111)	**Carlo Laing** Chimeras on spheres (#99, p. 75)	**Jerzy Filar** Ordered field property in stochastic games (#50, p. 51)	**Dion O'Neale** Real beards & real networks: a spin-glass model of interacting individuals (#131, p. 92)
10:20–10:40	**Christopher Angstmann** Guessing how triangles will split in half: Laplacians and cell division (#7, p. 29)	**Duncan Farrow** Gravity current generated by saline groundwater inflow (#49, p. 50)	**Gary Froyland** FEM-based numerics for approximating the dynamic Laplacian and extracting coherent sets (#55, p. 53)	**Peter Gerrard Taylor** Sampling without replacement: a story of noncentral hypergeometric distributions (#178, p. 115)	**Rowena Ball** The fundamental equation of life (#12, p. 32)
10:40–11:00	**Matthew Simpson** Optimal quantification of contact inhibition in cell populations (#163, p. 108)	**Daisuke Tagami** Some remarks on a time-explicit particle methods for flow problems (#176, p. 114)	**Michael Small** Hunting for a moving target on a graph and building dynamical systems from complex networks (#165, p. 109)	**Justin Tzou** Mean first passage time problems and localised pattern formation - analysis, results, and surprising connections (#191, p. 122)	**Brendan Florio** Tailings dewatering by flocculation (#53, p. 52)
11:00–11:20	Morning tea - Mezzanine				

	Thursday morning and afternoon *student talk				
	Grand Ballroom 1	Grand Ballroom 2	Grand Ballroom 3	Harbour View 2	Chancellor 4
	Chair: David Khoury	*Chair:* Graeme Hocking	*Chair:* Jennifer Flegg	*Chair:* Winston Sweatman	*Chair:* Graeme Wake
11:20–11:40	**Tammy Lynch** Microbial co-existence and selection in enteric fermentation (#111, p. 81)	**Boris Baeumer** Maximal regularity for stochastic Volterra integral equations (#11, p. 31)	**Danya Rose** Who gets the girl? On the operational sex ratio as an index for male strategy (#156, p. 104)	**Christopher Green** Using the Schottky-Klein prime function to compute harmonic measure distribution functions of a class of multiply connected planar domains (#65, p. 58)	**Andrey Pototsky** Shaping liquid drops by vibration (#144, p. 98)
11:40–12:00	**Hayden Tronnolone** Diffusion-limited growth limits in microbial colonies (#188, p. 121)	**Ozge Ozcakir** Nonlinear exact coherent structures in pipe flow (#136, p. 94)	**Michael Greg Watson** Multiphase modelling of early fibrous cap formation in atherosclerosis (#202, p. 128)	**Bruce van Brunt** On a second order PDE that models cell division (#193, p. 123)	**Christopher Lustri** Nonlocal solitary waves in nearest-neighbour particle chains (#109, p. 80)
12:00–12:20	**Josephine Reyes** Modelling HIV latency using distribution of lifespans of infected cells (#150, p. 101)	**Brendan Harding** Inertial force on particles in curved microfluidic ducts (#70, p. 60)	**Peter Kim** Evolution of monogamy in response to human post-menopausal longevity (#91, p. 71)	**Luke Bennetts** Acoustic metamaterial chains involving inertial amplification (#17, p. 35)	**David John Warwick Simpson** The sausage-string structure of mode-locking regions of piecewise-linear maps (#162, p. 107)

	Thursday afternoon continued *student talk				
	Grand Ballroom 1	Grand Ballroom 2	Grand Ballroom 3	Harbour View 2	Chancellor 4
12:20–12:40	**Collin Zheng*** Mathematical models for checkpoint blockade treatments in cancer immunotherapy (#208, p. 131)	**Christian Thomas** Globally unstable behaviour in the rotating-disc boundary layer (#183, p. 118)	**Mark Flegg** Interfacing diffusive particle models between various scales (#52, p. 52)	**Barry Cox** Graphene folding around carbon nanotubes (#35, p. 44)	**Paul Smith** The effect induced in the far-field pattern by the rounding of corners of a scatterer illuminated by a plane wave electromagnetic field (#166, p. 109)
12:40–1:00	**Murk Bottema** Cows and largest connected sets (#20, p. 36)	**Larry Forbes** Fluid mechanics and the gentle art of viscometry (#54, p. 53)0	**Mike Chen** Multiscale modelling of fibre-reinforced hydrogels for tissue engineering (#27, p. 40)	**John Elie Sader** Why does an inverted-flag flap in a uniform steady flow? (#160, p. 106)	**Peter Ballard** The impact of time-dependent transmission rate on the probability of epidemic fade-out (#13, p. 32)
1:10–1:30	Closing remarks, Grand Ballroom 2–3				
1:30–2:30	Lunch - Mezzanine				

4 Conference Abstracts

1 On the fundamental of Rayleigh-Taylor instability and Rayleigh-Taylor interfacial mixing

Snezhana I. Abarzhi
The University of Western Australia
Timetable: p. 23

Rayleigh-Taylor instability (RTI) develops when fluids of different densities are accelerated against their density gradient. Extensive interfacial mixing of the fluids ensues with time. The Rayleigh-Taylor (RT) mixing controls a broad range of processes in nature and technology. Examples include the RTI that quenches ignition in inertial confinement fusion; blast wave induced RT mixing in core-collapse supernova that creates conditions for synthesis of heavy mass elements; RT unstable plasma irregularities in the Earth's ionosphere that result in climate change on regional scales; RT mixing of water and oil bounding efficiency of fossil fuel recovery; the RTI that governs material transformation of under impact in nano-electronics. Our ability to reliably model RT mixing with variable acceleration can advance knowledge of fundamentals of nature and have a major positive impact on energy and environment.

Traditionally, it was presumed that the RTI leads to uncontrolled growth of small-scale perturbations, single-scale nonlinear dynamics, and extensive turbulent mixing that is similar to canonical turbulence. The recent success of the theory and experiments suggests an alternative scenario of RTI evolution. It finds that the RT dynamics is multi-scale, well correlated and sensitive to the initial conditions, and the laminarization of RT mixing can occur due to the effects of acceleration, interfaces, and accelerated shear.

In this work, we focus on the classical problem RT mixing induced by variable acceleration with power law time dependence. By applying group theory, we find symmetries, invariants, scaling, correlations and spectra of the RT mixing, and quantify its sensitivity to the initial conditions. In a broad range of the acceleration parameters, critical points are identified at which the RT dynamics are ballistics, quasi-Kolmogorov, steady flex, diffusive, and dissipative. For super-ballistics and super-Kolmogorov dynamics, RT mixing has a greater degree of order when compared to canonical turbulence. For up-steady-flex and super-diffusion - larger velocity fluctuations occur at larger scales, whereas for sub-diffusion and dissipation - larger velocities correspond to smaller scales. The properties of RT mixing depart substantially from those of canonical turbulence thus opening new perspectives for better understanding and control of RT dynamics in nature and technology.

2 The determination of Open Science, Open Innovation paddy production in Indonesia using geographically weighted regression

Jamilatuzzahro Abdul Fatah
Bandung Institute of Technology
Timetable: p. 20

Indonesia is an agricultural country with a large proportion of its population living from cultivation or farming, so agriculture is a sector that plays an essential role in the welfare of Indonesians. Rice is one of the leading food crops that have a strategic value and a significant influence in the economic, environmental, and socio-political sectors. The basic premise of Open Innovation is to open the innovation process to all active players so that knowledge can circulate more freely and can be transformed into products and services that create new markets, fostering a stronger entrepreneurial culture. Specific innovations can no longer be seen as a result of established and isolated innovation activities but as a consequence of a complicated joint creation process that involves the flow of knowledge across economic and social environments. Furthermore, Open Science is a new approach to scientific processes based on collaboration and a new way to spread knowledge using new digital technologies. The collaboration between spatial, open science and open innovation can be effective to analyze the potential of planting as well as production. Therefore, it is necessary to have a model for predicting the amount of rice production, especially in Indonesia. The data used is the historical data of paddy production and land area at 34 Province in Indonesia. In a nutshell, we were using Geographically Weighted Regression (GWR) with AIC precision value of 980.3654 and R Square global of 0.9855874. It means that 98.55% of variation occurred in the paddy production was influenced by the included explanatory variables.

3 Additional information in robust approach to mathematical finance

Anna Aksamit
The University of Sydney
Timetable: p. 19

Robust approach to pricing and hedging derivatives has been an active field of research in mathematical finance over the recent years. In this approach, instead of choosing one model for price dynamics, one considers superhedging simultaneously under a family of models, or pathwise on the set of feasible trajectories. Typically dynamic strategy in stocks and static trading in some European options are allowed. Usually in the literature the focus is on the natural filtration $\mathbb{F}$ of the price process S. Here we give an extension to a general filtration $\mathbb{G}$ which includes the natural filtration of the price process $\mathbb{F} \subset \mathbb{G}$. Two filtrations can model asymmetry of information on the market. The larger filtration can be obtained by considering additional market data and analyses. This talk is based on joint work with Zhaoxu Hou and Jan Obłój.

4 Withdrawal of water from within a sand column*

Suha Al Ali
Murdoch University
Co-authors: Graeme Hocking
Timetable: p. 11

We consider a free surface problem of flow in a vertical sand column when water is being withdrawn. The problem is important in managing valuable underground water resources. One powerful method of finding such a solution is to use conformal mapping and spectral techniques. The method is to compute the solution for a line sink in the vertical duct and then use Fourier techniques to correct for the nonlinear surface conditions. The results of the numerical solution for the steady case are compared with the analytic solution to the approximate, linearized equations. It is found that there is an increase in the depth of the dip in the free surface as the sink increases strength, and that no solutions are possible if the flow rate is too large. The effect of the bottom starts to be important if the sink is more than half of the depth. Some unsteady solutions using a similar technique will also be presented.

5 An analysis of the first order growth fragmentation equation for special division kernels

Adel Ahmed Almalki
Massey University
Timetable: p. 11

The growth fragmentation equation is a linear integro-differential equation describing the evolution of cohorts that grow, divide and die over time. In this talk we focus on a special choice of division kernel that models size structured cell cohorts that divide into daughter cells of equal size. This problem reduces to an initial-boundary value type that involves an advanced partial differential equation. There are no general techniques for solving these problems. The constant growth rate case has been studied by a number of researchers. In particular it was shown that the large time solutions converge to a special solution; the separable solution. We look at the case when the growth rate is linear. This problem can be solved analytically for monomial division rates. We show that the large time dynamics for this case differ markedly from the previous case. Specifically, the solutions approach a time-periodic attracting solution.

6 Modelling causality: integral equations versus ODEs

Robert Scott Anderssen
CSIRO
Timetable: p. 11

In the modelling of viscoelasticity, the tradition is to work with the integral equation formulation first proposed by Boltzmann which correspond to first kind Volterra (causal) convolution integral equations. The earlier models proposed by Maxwell, Kelvin and Voigt were differential equation models. The key observation of Boltzmann that led to his integral equation formulation was that, unlike for a perfect elastic material where the reference state is the original state, the reference state for a viscoelastic material has to be the current state, since it is impossible to return to the original state. The advantages of using first kind Volterra integral equations to model causal dynamics, which includes linear viscoelasticity as a special case, rather than ODEs, will be discussed and illustrated. The key is the step strain experiment. The advantage of using causal integral equation models in biology will be illustrated with the modelling of the genetics of vernalization.

7 Guessing how triangles will split in half: Laplacians and cell division

Christopher Angstmann
University of New South Wales
Timetable: p. 23

There is a long history of empirical rules that describe the geometry of dividing cells. In many simple cases, such as rod shaped bacteria like e.coli, the division will occur symmetrically. In more complicated cell shapes it seems more difficult to intuit how exactly they will divide. In this talk I will show how the division plane in many cases relates to the eigenfunctions of a Laplacian operator defined over the surface of the cell. The use of irregularly shaped cells, such as pleomorphic archaea, gives a great example of the robustness of this connection. Whilst there are other possible reasons for this empirical observation to exist, I will show how it naturally arises from a Turing instability in a set of reaction-diffusion equations.

8 Modelling malaria parasite development before and after drug treatment

Rosemary Aogo
University of New South Wales
Timetable: p. 13

The use of antimalarial drugs has significantly reduced mortality due to malaria, however, the emergence of resistance to the most effective and widely used antimalarial drugs (artemisinin derivatives) impedes this progress. Moreover, artesunate has been reported to have high treatment failure when not used in combination with other drugs, and this may be due to a persisting population of parasites that goes into an inert state and recovers later (dormancy). Further, we have observed previously that stress can cause parasites to mature more slowly, which is perhaps a general survival strategy of the parasite, and a similar effect has been observed after drug treatment. More recently artemisinin resistant parasites have been studied and it has been found that they have an altered development pathway, which protects parasites during treatment. Hence, we are interested in studying the development of parasites through their life cycle without treatment and how treatment with different drugs perturb this normal development. Here, using a novel experimental system, we track the progress in life stages of malaria parasites taken from mice grown in culture. We do this by measuring the RNA and DNA content of parasites over time. Our unique experimental set up allows us to track the parasite throughout their life cycle after treatment with different doses of mefloquine and/or artesunate. By formulating an age-structured partial differential equation model of parasite as well as fitting mixture models we attempt to determine whether the action of antimalarial drugs on parasites i) slows down parasite growth, ii) impairs a proportion of parasites which then mature slowly compared to the unaffected fraction, or iii) arrests parasite development at a particular stage in their life cycle.

9 The Holling-Tanner predator-prey model with strong Allee effect on prey

Claudio Arancibia
Queensland University of Technology
Timetable: p. 22

In this work a Holling-Tanner predator-prey model is analysed incorporating a strong Allee effect on prey and with a functional response of Holling type II. The analysis of the model complements results of previous articles that consider the Holling-Tanner model with a weak Allee effect on prey.

We show the existence of significant differences compared with the well-known Holling-Tanner model, since new equilibrium points can appear in the first quadrant. Besides, the model presents rich dynamics for different parameter values and it is possible to prove the existence of:

(i) a separatrix curve in the phase plane dividing the behaviour of the trajectories,

(ii) a homoclinic curve generated by the stable and unstable manifolds of a positive equilibrium point. When this curve breaks it generates a non-infinitesimal limit cycle,

(iii) different kinds of bifurcations, such as: saddle-node, Hopf, Bogadonov-Takens and homoclinic.

The system has solutions highly sensitive to initial conditions. To simplify the calculus, we considered a topologically equivalent system with a small number of parameters. For this new model, we prove that for certain value of parameters the model exhibits multi-stability phenomenon since there exists a stable limit cycle or a stable positive equilibrium point.

10 Localizing softness and stress in topological metamaterials

Guido Baardink
Kyushu University
Timetable: p. 19

The softness and rigidity of certain ball-spring networks can be described by a topologically protected polarization field. By introducing dislocations to such a polarized lattice we can locally manipulate the yield response.

11 Maximal regularity for stochastic Volterra integral equations

Boris Baeumer
University of Otago
Co-authors: Markus Antoni and Petru Cioica-Licht
Timetable: p. 24

We present an approach to obtain maximal regularity estimates for solutions of stochastic Volterra integral equations driven by a multiplicative Gaussian noise. The main part consists of the proof of suitable estimates for deterministic and stochastic convolution operators. Starting with the scalar-valued case, we use functional calculi results to obtain the corresponding estimates for the operator-valued setting. Once maximal regularity estimates for convolutions are obtained, appropriate Lipschitz and linear growth assumptions on the nonlinearities will lead to unique mild solutions with Holder continuous trajectories.

12 The fundamental equation of life

Rowena Ball
Australian National University
Timetable: p. 23

The role of random fluctuations of a non-equilibrium flow in pre-biotic chemistry has received much less attention than the non-equilibrium condition itself. Plausible environments for life's origin were not only strongly driven, to create sustained disequilibria, but temporally messy too, because input flows through an inhomogeneous matrix were subject to fluctuations. But Brownian motions, or normally distributed, random thermal fluctuations, occur regardless of whether a system is at macroscopic equilibrium or not. It is self-evident that life cannot exist in an equilibrium setting.

We have modelled the putative hydrothermal rock pore setting for the origin of life on Earth as a train of continuous flow units coupled in series. Perfusing through the train are reactants that give rise to thermochemical and pH oscillations, which drive the production of monomers and dimers from activated nucleotides. The dynamical equations that model this system are fully thermally self-consistent. Crucially, we built stochasticity of the inputs into the model. Interrogating the computational results, we found (i) that Gaussian perturbations of the inputs to a system do not induce Gaussian fluctuations in the outputs, and (ii) that the output fluctuations must exhibit a left-skewed, right-weighted probability distribution for a prebiotic chemical system to evolve towards a living system. This 'Goldilocks' distribution, when its moments and parameters are characterized, is the fundamental equation of life. It tells us not only that fluctuations are essential for life to originate, but more: that for a prebiotic chemical system to live it must spend enough time at high temperatures to carry out essential high activation energy reactions, but not so much that reactant is totally consumed, or destroyed, or catalytic surfaces degraded.

Our results have placed stochasticity explicitly at centre stage in the origin-of-life drama. They also vindicate the general approach of constructing and running a simple toy model to learn important new information about a complex system.

Ball, R.; Brindley, J. 2017. Toy trains, loaded dice, and the origin of life: Dimerization on mineral surfaces under periodic drive with Gaussian inputs. Royal Society Open Science 4:17014. (doi: 10.1098/rsos.170141).

13 The impact of time-dependent transmission rate on the probability of epidemic fade-out

Peter Ballard
The University of Adelaide
Timetable: p. 25

Epidemic fade-out refers to the situation in which an infection dies out after the first wave of an outbreak. Previous research has assumed constant parameters, but obviously some parameters can

change over time. In particular, the transmission rate parameter is likely to vary over the course of the year, both due to the climate, and due to changes in human behaviour patterns.

For the SIR-with-demography and SIRS infection models, I present a method for the calculation of the probability of epidemic fade-out when the the parameters are not constant. I then present some results for two different scenarios: flu-like parameters with a sinusoidal variation in transmission rate due to the seasons; and measles-like parameters with a step change in transmission rate due to the switch between school vacations and term time.

14 Modelling mange in the common wombat

Nick Beeton
University of Tasmania
Timetable: p. 21

Some Tasmanian populations of the common wombat (Vombatus ursinus) are threatened with extinction by infection with sarcoptic mange, caused by the mite Sarcoptes scabiei. Little is known about why only some populations, such as Narawntapu National Park (NNP) in the state's north, are susceptible whereas others only experience minor, non-threatening outbreaks.

In NNP, treatment of wombats is performed by installing flaps covered with insecticide on the entrance to their burrows, so that they push through and receive a dose when entering or leaving.

In this talk, we describe two compartmental ODE models of the wombat-mite system. The first assumes spatially homogenous, well-mixed populations of susceptible, pre-symptomatic, symptomatic, and recovered wombats as well as fomites: substances (such as burrow soil) that support mites, which can then infect wombats. The second instead assumes that only a proportion of burrows in the landscape are infected with fomites at any given time, which are moved between burrows by infected wombats.

We examine both models, performing dynamical systems analysis as far as analytically possible, and present numerical sensitivity analyses, varying important parameters such as wombat treatment rate, fomite mortality and fecundity.

We find the two models give sometimes complementary, sometimes contradictory and sometimes surprising results, providing ideas for future disease management as well as a cautionary tale about the applicability of results where model assumptions are not necessarily accurate.

15 Stochastic optimal control of a solar-powered car

Erika Rana Gabriela Belchamber
University of South Australia
Timetable: p. 14

The World Solar Challenge (WSC) is a biennial event held in Australia, where solar cars are driven from Darwin to Adelaide. The Australian Technology Network of Universities is designing and building a solar car to compete in 2019. The solar car must travel over 3000 km in only six days. This presentation details work on a driving strategy the ATN team will use with their solar car.

The speed a solar car travels is restricted by the solar energy it collects. If the battery is empty and available solar energy is low, the car will have to drive slowly or stop. The car will then have to wait until there is enough solar energy to power it at a higher speed. This disruption jeopardises the car's ability to complete the WSC. If solar energy is known in advance, an optimal driving strategy can be found so enough energy is collected for the car to travel at a high speed. When solar energy is not known in advance, the driving strategy must cope with an unknown solar energy.

One possible driving strategy is minimax regret, where the maximum regret is minimised. In this presentation, a minimax regret strategy is described and the distance travelled is compared with the distance travelled in the optimal solution. We use historic solar energy data from stations along the WSC route to test the minimax regret strategy and find the distance travelled is within 1% of the optimal distance.

16 Models for the spread of Wolbachia in mosquito populations as a means of suppressing dengue fever transmission

Sarah Belet
Monash University
Timetable: p. 11

Dengue fever poses a major health issue in tropic environments. Particular breeds of mosquitoes, such as the *aedes aegypti* species common to areas including northern Queensland, carry the virus. Humans contract the dengue virus when bitten by a mosquito that carries it and so, historically, attempts at curtailing the spread of dengue have focused on controlling the size and spread of mosquito populations. Several factors make this an astronomically difficult task to accomplish on any reasonable scale, however, and so more novel methods of suppressing dengue outbreaks are being explored. One such method is the introduction of parasitic bacteria called *Wolbachia* into mosquito populations, which prevents mosquitoes from passing on blood-borne viruses to those it bites. A *Wolbachia* invasion has strong potential to completely saturate mosquito populations due to a mechanism called cytoplasmic incompatibility. The mathematical modelling problem here becomes twofold - first, the task of inferring the position of mosquito populations, and then the modelling of *Wolbachia* spreading through these populations. Here, we will be discussing the effects and mechanisms of *Wolbachia* in more detail, including the phenomenon of cytoplasmic incompatibility. Next, recent developments in modelling

mosquito populations such as the use of semi agent-based models will be outlined, within the context of predicting the spread of *Wolbachia* in order to prevent further dengue outbreaks.

17 Acoustic metamaterial chains involving inertial amplification

Luke Bennetts
The University of Adelaide
Timetable: p. 24

A desirable property of acoustic metamaterials is that they have wide and deep low-frequency bandgaps. The standard method for generating low-frequency bandgaps is to use local resonators, but this often requires prohibitively heavy elements. A practical alternative is to induce anti-resonances using inertial amplification, by equipping the structural elements with lightweight attachments that exert inertial forces proportional to the vibrational forces. This presentation will outline the mechanism by which inertial amplification can be used to control the location and depth of bandgaps along infinite mass-spring chains, via geometrical properties only. The theory will be illustrated by direct numerical simulations.

18 Detecting and characterising coherent structures and their evolution in non-autonomous dynamical systems

Chantelle Blachut
The University of Queensland
Timetable: p. 12

Manifestations of coherent structures are evident throughout the physical world. This research aims at understanding and characterising the behaviour of such structures. We develop and implement algorithms for the detection of minimally dispersive regions in a non-autonomous dynamical setting and propose a method to characterise transport features of the underlying system.

Previous authors have shown that the singular value decomposition (SVD) of a transfer operator induced by a dynamical system is useful for identifying the regions of phase space that exhibit minimal dispersion over a time period of interest. Our work considers the SVD of a cocycle of numerically estimated transition matrices for a time-dependent dynamical system, investigates the evolution of singular vectors in association with Oseledets subspaces and develops algorithms to characterise the behaviour of coherent structures in non-autonomous systems. Our results show that this method allows one to retrieve important information about how and when such structures merge and split in the presence of an underlying time-dependent chaotic flow.

19 Importance sampling for partially observed Markov models

Andrew Black
The University of Adelaide
Timetable: p. 14

Particle marginal Metropolis Hastings (pmMH) is a popular method for performing Bayesian inference when it is only possible to simulate from the underlying model. This uses a particle filter to estimate the likelihood, which is then used in a basic Metropolis Hastings algorithm. A well know problem with particle filters is that the more accurate the observations of a system, the worse the filter performs. For models where we observe a single component of the state exactly, the cost of producing simulations becomes very high. In this talk I will discuss some recent work using importance sampling to generate realisations of Markovian models that match observations exactly. When used in a pmMH scheme, the importance of sampling is that it provides a large speed-up in terms of the effective sample size per unit of computational time compared to simple bootstrap sampling.

20 Cows and largest connected sets

Murk Bottema
Flinders University
Timetable: p. 25

Flecks of fat in steaks, called marbling, influence taste and consumer appeal. Marbling in beef is also of interest in understanding fat metabolism. In a previous study, the number of marbling flecks, their size distribution and shape characteristics were associated with levels of vitamin A in the animal's diet. When the study was extended to characterising marbling in three dimensions, the marbling was found to comprise a single giant fleck accounting for roughly 80% of the total marbling, plus thousands of small flecks. Whether this observation reflects the true structure of marbling in beef or whether the observed large connected sets were due to the discretisation into voxels raised the following question:

Given a random binary array with a given density of 'on' voxels, what proportion of such voxels are expected to form the largest connected component of the set of on voxels?

Several studies on the largest connected components in random graphs have appeared but the literature does not report a clear answer to the question above. Indeed, a formula for the expected size of the largest component has proved elusive. Simulations suggest that the size of connected marbling structure observed in the data cannot be due to chance alone. Observations are consistent with marbling forming a single connected structure. As do the cows, we continue to ruminate on the combinatorics question.

21 Logarithmically-discretised population balance models of aggregation and fragmentation

Calum Braham
The University of Western Australia
Co-authors: Neville Fowkes, Brendan J. Florio, David M. Walker and Michael Small
Timetable: p. 15

Many physical systems can be modelled as a set of particles interacting through aggregation and fragmentation. All but the simplest models of such systems are intractable analytically and, as such, simulations of the time evolution of particle size distributions generally require a discretised particle size domain. The logarithmically-discretised aggregation population balance models of Hounslow et al (1988) and Litster et al (1995) are re-derived using a local, collision-based framework. This derivation has advantages in simplicity and tractability, as local conservation of mass can be ensured without the need for correcting factors or the consideration of intra-bin particle distributions. Unlike the original derivation, appropriate evolution of particle numbers and conservation of mass can be demonstrated without assuming size-independent collision kernels or an infinite size domain, showing the model is valid for more general use. The model is also generalised to allow any logarithm base for the particle size discretisation and a framework is developed to treat fragmentation consistently.

22 Quantum mechanics from a classical fluids perspective

Philip Broadbridge
La Trobe University
Timetable: p. 21

As shown by Madelüng in 1927, quantum mechanics can be fully described as a system consisting of a real-valued probability density and a real-valued velocity field that satisfies a forced Burgers' fluid equation. It is envisaged that the coupling of a macroscopic measuring device introduces shear to the fluid. With vorticity, the fluid has a vector potential as well as the single scalar potential that is a function of the Schrödinger wave function. This suggests a classical description of the mysterious decoherence or collapse of the wave packet during which time the Schrödinger equation no longer applies. After the dissipation of vorticity, quantum equilibrium is restored, the Born probability rules again apply, and vorticity collapses to a few isolated point vortices which have long been accepted within angular momentum eigenstates since the time of Bohr and Sommerfeld. It has been suggested also that quantum disequilibrium in the early violent universe may explain some discrepancies in the cosmic microwave spectrum. This is not a usual type of ANZIAM talk but it shows that QM may be open to discussion in the language of fluid mechanics.

23 A Bayesian computational approach to explore the optimal duration of a cell proliferation assay

Alexander Paul Browning
Queensland University of Technology
Timetable: p. 16

Cell proliferation assays are routinely used to explore how a low-density monolayer of cells grows with time. For a typical cell line with a doubling time of 12 hours (or longer), a standard cell proliferation assay conducted over 24 hours provides excellent information about the low-density exponential growth rate, but limited information about crowding effects that occur at higher densities. To explore how we can best detect and quantify crowding effects, we examine a stochastic individual based model where cells proliferate according to a generalised logistic growth model. We then apply approximate Bayesian computation to quantify the decrease in uncertainty in the crowding mechanism as the experimental duration is increased.

24 Active sonar remote identification of materials

Jim Byrnes
Prometheus Inc.
Timetable: p. 16

For sonar detection of submarines the baseline technologies incorporate Doppler and target motion analyses as key parameters. However, these clearly will fail if the submarine is sitting on the bottom, as those of several countries are known to do. To address this and other concerns, at the request of Admiral Tom Eccles (Head of NAVSEA PEO Submarines at the time) Prometheus Inc. adapted its MISAR (Material Identification Synthetic Aperture Radar) technology to the sonar environment. Our demonstrated solution, as recognized by the US DoD[1] is known as MIRK (Material Identification Reflectivity Kernel). As stated there, MIRK 'Provides the warfighter the capability to reliably detect bottomed submarines and mines in real time with fewer false alarms, significantly increasing the fleet's ability to defeat Anti-Access / Area Denial (A2/AD) threats.'

Echo returns from active sonar interrogation of an underwater object contain reflectivity kernel (RK) clues. We discuss our novel time-domain deconvolution technique and additional signal processing tools that yield, in a highly stable and real-time manner, reliable RK estimates. Thus MIRK is able to classify active sonar contacts based on this material discrimination technique.

We further discuss enabling requirements for MIRK, specific real-world examples of its use, environments where it has proven successful, and limitations on its applicability.

[1] http://www.defenseinnovationmarketplace.mil/RIF.html, FY 2011 cell F41

25 Objective detection of rotationally coherent vortices

Sophie Calabretto
Macquarie University
Timetable: p. 15

The detection and forecasting of ocean vortices is important in the field of geophysical fluid dynamics as these eddies tend to play a major role in the underlying flow dynamics of the ocean. We approach the issue of ocean eddy identification from a rotational-coherence basis via the identification of elliptic Lagrangian coherent structures (LCSs), and seek the boundaries of rotationally coherent Lagrangian vortices, which are formed by tubes of deforming fluid elements that complete equal bulk material rotation relative to the mean rotation of the deforming fluid volume.

26 Calculating how long it takes for diffusive processes to effectively reach steady state without computing the transient solution: application to groundwater flow

Elliot Joseph Carr
Queensland University of Technology
Timetable: p. 19

When a diffusive process is disturbed from an initial state of equilibrium by a sudden change in boundary conditions, it takes an infinite amount of time to return to an equilibrium (steady) state. While this is strictly true, because the transient solution of the underlying PDE approaches the steady state solution exponentially, there exists a finite time at which the diffusive process is effectively at steady state (i.e. the difference between the transient and steady state solutions is less than a small specified tolerance). A common measure of this so-called finite transition time is the mean action time, which is the expected time of the process calculated by identifying a cumulative distribution function that tracks the progress of the transient solution towards steady state. In this talk, I extend the concept of mean action time and show how the higher order moments can be used to calculate the finite transition time without computing the transient solution. This approach provides a unique mathematical connection with the heuristic argument that the time required for a one-dimensional linear homogeneous diffusion problem to reach steady state is proportional to L^2/D, where L is the length of the medium and D is the diffusivity. A case study involving flow through heterogeneous porous media, where the saturated hydraulic conductivity varies spatially, confirms the accuracy and efficiency of the method.

27 Multiscale modelling of fibre-reinforced hydrogels for tissue engineering

Mike Chen
The University of Adelaide
Co-authors: Laura Kimpton, Jonathan Whiteley, Miguel Castilho, Jos Malda, Colin Please, Sarah Waters and Helen Byrne
Timetable: p. 25

Tissue engineering aims to grow artificial tissues *in vitro* to replace those in the body that have been damaged through age, trauma or disease. A recent approach to engineer artificial cartilage involves seeding cells within a scaffold consisting of an interconnected three dimensional printed lattice of polymer fibres combined with a cast or printed hydrogel, and subjecting the construct (cell-seeded scaffold) to an applied load in a bioreactor. A key question is to understand how the applied load is distributed throughout the construct to the mechanosensitive cells.

To address this, we employ homogenisation theory to derive macroscale governing equations for the effective material properties of the composite, where we treat the fibres as a linear elastic material and the hydrogel as a poroelastic material and exploit the disparate length scales (small inter-fibre spacing compared with construct dimensions). This description reflects the orthotropic nature of the composite. To validate the model, solutions from finite element simulations of the macroscale, homogenised equations are compared to experimental data describing the unconfined compression of fibre-reinforced hydrogels.

28 Compliance for Personal Financial Advice

Sue Ann Chen
IBM Research Australia
Timetable: p. 20

In recent years, Australian financial advice licencees have had to pay hundreds of millions of dollars in financial penalties and compensation, in addition to having to undertake extensive audit programs due to provision of non-compliant financial advice. Existing procedures to assess the compliance of a Statement of Advice (SoA) document are not only time-consuming, but are also severely limited by sampling issues. By leveraging deep learning and natural language processing techniques, our project aims to automatically identify the at-risk documents, thus allowing for a more efficient and thorough compliance assessment procedure.

29 Understanding how immunity, strain diversity and prevalence interact in multi-strain pathogens using agent-based modelling

Rebecca Chisholm
The University of Melbourne
Co-authors: Nicholas Geard
Timetable: p. 11

Infectious diseases are frequently caused by pathogens that exist in multiple phenotypically distinct strains that may differ in traits including drug resistance, virulence, and by the expression of antigens that trigger different host immune responses. The ability of multi-strain pathogens to trigger strain-specific and cross-strain immune responses poses challenges for understanding their transmission and control. These challenges are amplified for pathogens with very large numbers of circulating strains (high diversity). In this talk I will outline how we are using agent based models to generate new understanding of how strain-specific and cross-strain immunity may interact with strain diversity to sustain the transmission of such multi-strain pathogens. I will discuss our results in the context of understanding the transmission of Group A Streptococcus (GAS), an obligate human pathogen with over 200 molecular types, and a major cause of death and disability globally. Our results indicate that strain-specific immunity and low levels of cross-strain immunity may be a contributing factor to the high endemicity of GAS skin infections that exist in settings of poverty, where there is generally high strain diversity and no predominant strains.

30 Pregnancy and beyond: how mathematical modelling could improve early life health

Alys Rachel Clark
The University of Auckland
Timetable: p. 19

Pregnancy and early life is a time of rapid physiological development: organs form and develop over time periods of weeks and months. It is also one of the most difficult periods of life to observe as many clinical techniques used to examine adults bodies in disease are too risky to use in pregnancy and early childhood. So how do we identify risk of poor outcome in early life with relatively low resolution clinical tools? Data defining risk are acquired across many disciplines (such as medicine and cell biology) and provide only snapshots of development. Mathematical modelling potentially provides the missing link between these diverse data sources to improve metrics of health in early life.

In this talk I will present our strategies to model physiological systems in early life, with a focus on modelling oxygen transport and exchange. I will discuss how we use models to better understand the physiological process of oxygen exchange in health and disease, the development process itself, and the potential of mathematical models to improve clinical decision making.

31 Calcium oscillations in hepatocytes: how are they shaped?

Ielyaas Cloete
The University of Auckland
Timetable: p. 20

Calcium in hepatocytes (liver cells) modulate diverse functions, including bile secretion, glucose and energy metabolism and vesicular trafficking. A major question in the study of calcium signalling in hepatocytes is how these distinct cellular processes are controlled and organised via coordinated spatial and temporal calcium signals.

Downstream cellular responses are controlled via intracellular calcium oscillations but the underlying mechanisms which shape these oscillations have yet to be elucidated. We will determine the effects calcium feedbacks on Phospholipase C (PLC), inositol trisphosphate kinase, as well the feedbacks of protein kinase C (PKC) on the hormone receptor have on the whole-cell calcium signals. The data suggests that hormone-induced calcium oscillations require positive calcium feedback on PLC to generate inositol trisphosphate oscillations, yielding cross-coupling between calcium and inositol trisphosphate. Furthermore, there is also a negative feedback pathway, cross-coupling PLC activation to PKC which serves to terminate calcium spikes.

To show this we will construct a model of calcium oscillations in hepatocytes which will include the necessary feedback mechanisms.

32 Multi-strain epidemic models for transmission and evolution of drug resistant pathogens

Robert Cope
The University of Adelaide
Timetable: p. 12

The evolution of antimicrobial resistance in endemic infectious diseases is of substantial public health concern, particularly in developing countries. New drug-resistant strains are continually emerging, and this can occur in a variety of ways, depending on characteristics of the disease or the available treatments. We describe a general stochastic epidemic model for the emergence and transmission of drug-resistant disease strains in a population, wherein upon receiving (unsuccessful) treatment, individuals may transition into a different infectious class. We investigate the ways in which different parameter choices can describe different potential evolutionary dynamics, and how simple building blocks can be combined to produce more complex behaviours.

33 On system behaviour using complex networks of a compression algorithm

Debora Cristina Correa
The University of Western Australia
Co-authors: David M. Walker and Michael Small
Timetable: p. 16

We construct complex networks of scalar time series using a data compression algorithm. The structure and statistics of the resulting networks can be used to help characterize complex systems and one property, in particular, appears to be a useful discriminating statistic in surrogate data hypothesis tests. We demonstrate these ideas on systems with known dynamical behaviour and also show that our approach is capable of identifying behavioural transitions within EEG recordings as well as changes due to a bifurcation parameter of a chaotic system. The technique we propose is dependent on a coarse grained quantization of the original time series and therefore provides potential for a spatial scale-dependent characterization of the data. Finally the method is as computationally efficient as the underlying compression algorithm and provides a compression of the salient features of long time series.

34 Fat and muscle glucose regulation same-same or different?

Adelle Coster
University of New South Wales
Timetable: p. 15

Insulin regulates glucose uptake in mammalian fat and muscle cells. The extracellular insulin concentration controls the distribution of the glucose transporter protein GLUT4. We have previously shown that the regulation of glucose uptake in fat cells can be described by a compartmental system of ODEs with six steps: 1) endocytosis, 2) sorting/recycling from endosomes back to the cell surface, 3) rescue from degradation, 4) sequestration into storage vesicles, 5) release from retention in the storage vesicles and 6) fusion of the storage vesicles to the plasma membrane. Insulin stimulates three of these steps in fat cells.

Can the network structure of the model for the fat cell also describe the dynamics of translocation of GLUT4 in muscle cells? Five experimental data sets from different protocols are used simultaneously to optimise the model parameters and determine the main regulatory differences between fat and muscle cells. Predictions are then made about the effects of different biochemical perturbations on the system.

35 Graphene folding around carbon nanotubes

Barry Cox
The University of Adelaide
Co-authors: Tom Dyer and Ngamta Thamwattana
Timetable: p. 25

Folding graphene materials have the potential to create complex structures with new properties. Intercalating molecules into these folds is a method of one-dimensional functionalisation of the graphene sheet. Here we investigate the effects of incorporating a single-walled carbon nanotube in a graphene fold. Balancing the van der Waals interactions and the elastic energy leads to a curved structure that we derive using a variational approach. Results are compared with molecular dynamics simulations.

36 Resonance, symmetry and pattern selection in Langmuir circulation

Lidong Cui
Swinburne University of Technology
Co-authors: William R.C. Phillips
Timetable: p. 11

I undertake a weakly nonlinear analysis of resonant interactions of Langmuir circulation (LC), which is a large (up to stadium sized) roll-like pattern in water bodies that arises due to wave-current interactions. LC helps mix the upper ocean and is thus important in climate dynamics. In this regard, it is crucial to understand LC's scale and geometry. LC is described by an averaged set of partial differential equations known as the CL-equations. From the CL-equations we derive amplitude equations by both the multiple-scale method and the amplitude expansion method. With the amplitude equations, we discuss the 1:2 and the 1:3 resonances, and we also discuss the Eckhaus stability. We find, among other things, that the preferred spacing of LC rolls can be doubled, or even tripled, due to resonance. Resonance can also lead to mixed-modes as well as travelling waves, and can modify the Eckhaus stability. In the analyses, we consider various boundary conditions with different symmetry properties.

37 Iterative Deconvolution

Frank de Hoog
CSIRO
Timetable: p. 12

In many practical situations, the recovery of information about some phenomenon of interest f reduces to performing a deconvolution on indirect measurements g that often take the form of the Fourier convolution of f with a known point spread function p; namely

$$g(x) = \int_{-\infty}^{\infty} p(x-y)f(y)dy.$$

Examples include the frequency response of the stress and strain in rheological oscillatory shear measurements and the frequency response of electronic amplifiers, of microphones and loudspeakers, and of brain waves.

However in practice, only discrete measurements, on a limited domain are available and this limits the techniques that can be used to obtain approximations. Specifically, if the available data is relatively local, then the approximations to the solution also need to be local. When the point spread function p is narrow, iterative techniques will provide such local approximations if the number of iterations is small.

A property required to ensure that the deconvolution of g is unique (given that it exists), is that the Fourier transform of the point spread function p is positive. It is also a key property to take into consideration when constructing appropriate discretization of the Fourier convolution and for the construction of appropriate iterations. These will be discussed in the presentation.

38 New results in the instability of compressible boundary layers

Jim Denier
Macquarie University
Timetable: p. 11

I discuss how and when compressible boundary layer transition from a laminar to a turbulent state is of extreme importance in the design of a new generation of high speed transports. This talk will present some new results on this topic, in which we demonstrate a new mode of instability that occurs when the fluid physics is such that the boundary layers achieve "supervelocities". How these occur, and why they might be important will be explained.

39 Investigating the efficacy of antimalarial drugs using a mathematical model

Saber Dini
AMSI/University of Melbourne
Timetable: p. 11

Malaria is one of the deadliest infectious diseases in the world, causing around 500,000 deaths each year. Artemisinin-based combination therapies (ACTs) have been used for two decades as effective first-line treatment for malaria. However, the efficacy of these drugs has declined recently, due to the emerging resistance of malaria parasites to ACTs. This is hence threatening the lives of people in malaria endemic regions such as South-East Asia, and warrants developing alternative antimalarial treatments. Triple artemisinin-based combination therapy (TACT) has been suggested as a novel strategy to overcome the declining efficacy of ACT. Some pharmacological and clinical studies are underway, investigating the efficacy, safety and tolerability of TACTs. In this work, we use mathematical modelling to provide insights into how different mechanisms of resistance influence the efficacy of TACT. Of particular interest, we investigate which dosing scheme of a TACT suffices to produce World Health Organisation (WHO) recommended cure rates.

40 Exact invariant solutions of time fractional evolution systems with variable coefficient

Khongorzul Dorjgotov
Kyushu University
Timetable: p. 20

Lie symmetry analysis is widely used in the study of ordinary and partial differential equations and systems due to its efficiency and algorithmic nature. We consider the fractional diffusion-wave systems, in which the derivatives in time variable is replaced by fractional derivative of arbitrary order. The time fractional systems that we studied describes from diffusion process to the wave process, when the order of fractional derivative varies from $\frac{1}{2}$ to 1. We explicitly give the group invariant solutions to a class of Riemann-Liouville time fractional evolution or diffusion-wave systems with variable coefficients. These solutions correspond to each element in an optimal system of Lie algebra of infinitesimal symmetries of the evolution system under consideration. We express the solutions using three kinds of special functions: Mittag-Leffler functions, generalized Wright functions and Fox H-functions, and include some previously known solutions for particular cases. These solutions also solve time fractional diffusion-wave equations with variable coefficients. For comparison of the behavior of solutions , we illustrate plots subject to the order of fractional derivative.

41 Solving high condition number systems

Craig Douglas
University of Wyoming
Timetable: p. 15

This talk presents results that combine two theoretically sound methods (spectral projection and multigrid methods) together to attack ill conditioned linear systems. Our preliminary results show that the proposed algorithm applied to a Krylov subspace method takes many fewer iterations for solving an ill-conditioned problem downloaded from a popular online sparse matrix collection. All previous methods that are similar are for specific applications while our results are completely general.

42 Approximation of f-Divergence Measure in Information Theory and Applications

Silvestru Sever Dragomir
Victoria University
Timetable: p. 16

One of the important issues in many applications of probability theory & statistics is finding an appropriate measure of distance (or difference or discrimination) between two probability distributions. In this presentation we provide some approximations for the Csiszar f-divergence measure in information theory. Some particular instances of interest such as Kullback-Leibler divergence, Jeffrey's distance, Hellinger discrimination etc. are also given. For preprint versions of this work please see the Research Group in Mathematical Inequalities & Applications website `http://rgmia.org/index.php`.

43 Low order or high order? Wisdom may be in the middle...

Jerome Droniou
Monash University
Co-authors: Daniel Anderson
Timetable: p. 20

Tertiary oil recovery is a process through which a solvent, injected through a well in an underground oil reservoir, reduces the oil viscosity and thus enables it to flow through a production well. The mathematical model is a non-linear, coupled system of an elliptic and a parabolic equation, the latter being advection-dominated. Low order numerical schemes for advection-dominated models rely on upwinding for stability reasons, but said upwinding introduces additional numerical diffusion that reduces the accuracy of the approximation. High-order methods coupled with upwinding ensures both the stability of the scheme, and its accurate capture of the advection process... at an obvious increased computational cost.

In this talk, I will show that neither low-order nor high-order methods are the most efficient ones for such a coupled non-linear model, and that a middle-order method can realise the optimal accuracy/cost ratio. The demonstration will be carried out using the Hybrid High-Order method, which is designed to be applicable on generic meshes as encountered in practical applications, in which mesh elements can have complex geometry that prevent the usage of usual conforming/non-conforming/mixed finite element method.

44 On a conjecture about the simultaneous binary collision

Nathan Paul Duignan
The University of Sydney
Co-authors: Holger Dullin
Timetable: p. 20

This work explores a conjecture in celestial mechanics about the nature of the singularity at a simultaneous binary collision in the 4-body problem. The conjecture states that any attempt to remove this singularity via block regularisation will result in a regularised flow that is no more than $C^{8/3}$ differentiable with respect to initial conditions. By restricting our attention to planar vector fields, we examine how, despite the smoothness of a vector field, this curious loss of differentiability can occur. We discuss how this work extends to higher dimensions and whether it will resolve the conjecture.

45 An ODE model for the transmission of the disease Nosema ceranae in honey bee colonies with demographic structure

Jonathan Eade
The University of Sydney
Timetable: p. 22

I present a mathematical model for the transmission of the disease *Nosema ceranae* through a honey bee colony. *N.ceranae* is a parasite which attacks the midgut of a honey bee, and has been posited as a contributing factor in the honey bee colony collapse disorder which is affecting agricultural sectors worldwide. We formulate a system of ordinary differential equations, based on standard SIR disease models, that includes important demographic features of the colony. The addition of food, brood and an implicit age structure allows colony failures to be simulated on the same rapid time scale as observed colony collapses. Results show how the disease can weaken honey bee colonies and increase their susceptibility to other external stressors. A colony with a pre-existing infection may collapse under an external stressor where a healthy colony would not. Multi-year colony failures have also been simulated, in which an infected colony under stress is not strong enough post-winter to survive the transition to spring conditions.

46 A timely solution to the nurse rostering problem: an operations research approach

Mark Fackrell
The University of Melbourne
Co-authors: Ria Szeredi and Peter Taylor
Timetable: p. 15

The quality of a nurse roster has a great impact on the quality of patient care, due to its influence on nurse work performance. Furthermore, the numerous conflicting objectives of the hospital make the task of producing a high quality roster extremely difficult to undertake manually. Research into efficient ways to produce high quality nurse rosters is thus crucial. Motivated by the lack of application of theoretical research to the real world, we investigate a particular case of the nurse rostering problem at a major Victorian hospital. We present a mixed integer programming model that captures the real-world scenario as closely as possible. Upon implementation with real hospital data, we demonstrate the success of the model in achieving the various objectives of the hospital. Moreover, we find that the model significantly outperforms the manual process for creating rosters, in terms of both the quality of the resulting rosters and the time spent producing them.

47 Asymptotic analysis of a multiphase drying model motivated by coffee bean roasting

Nabil Fadai
University of Oxford
Co-authors: Colin P. Please and Robert A. Van Gorder
Timetable: p. 17

Coffee bean roasting has, with the exception of a few studies, been largely unexplored from a mathematical point of view. However, recent modelling of coffee bean roasting suggests that in the early stages of roasting, within each coffee bean, there are two emergent regions: a dried outer region and a saturated interior region. The two regions are separated by a transition layer (or drying front). In this talk, we consider the asymptotic analysis of a multiphase model of this roasting process which was recently put forth and studied numerically, in order to gain a better understanding of its salient features. The model consists of a PDE system governing the thermal, moisture and gas pressure profiles throughout the interior of the bean. By obtaining asymptotic expansions for these quantities in relevant limits of the physical parameters, we are able to determine the qualitative behaviour of the outer and interior regions, as well as the dynamics of the drying front. Although a number of simplifications and scaling are used, we take care not to discard aspects of the model which are fundamental to the roasting process. Indeed, we find that for all of the asymptotic limits considered, our approximate solutions faithfully reproduce the qualitative features evident from numerical simulations of the full model.

48 Towards accurate real-time control of lithium ion batteries

Troy Farrell

Queensland University of Technology

Co-authors: Ngoc Tham Tran, Mahinda Vilathgamuwa and San Shing Choi

Timetable: p. 16

We present a reduced order model for a lithium ion battery in which Padé approximants are used to simplify the complicated transfer functions associated with a detailed electrochemical model of the battery. The results from our reduced model are shown to compare favorably to those from the full model, with significant savings in computational time. Importantly, the form of the reduced model means that variables can be evaluated at specific discrete locations within the cell domain, without the need to compute all values of the variable at all discrete locations, as is the case with the spatial discretization methods most commonly used to implement partial differential equation models of battery operation. We show that this results in further significant time savings and enhances the suitability of the model for real-time battery control applications.

49 Gravity current generated by saline groundwater inflow

Duncan Farrow

Murdoch University

Co-authors: Andrew Bassom

Timetable: p. 23

Some freshwater lakes are in contact with saline groundwater. As saline groundwater seeps into a lake with a sloping boundary, a gravity current forms. The thickness and speed of this gravity current increases as more saline water seeps into the lake. This talk considers a model for the form and hydrodynamic stability of this gravity current.

50 Ordered field property in stochastic games

Jerzy Filar
The University of Queensland
Timetable: p. 23

Modern Game Theory dates back to von Neumann's 1928 proof of the minimax theorem for matrix games and the 1944 seminal treatise Theory of Games and Economic Behavior by von Neumann & Morgenstern. Despite many advances in Game Theory resulting from its subsequent popularity, perturbation theory for dynamic and stochastic games is still in its infancy. A fundamental issue pertinent to the development of such perturbation theory is the ordered field property (OFP) originally raised by Weyl who proved that for matrix games the game value and extreme optimal strategies lie in the same closed ordered field as data defining the game, in particular the rationals. Shapley's remark in his seminal 1953 paper on stochastic games pointing out that they lack that property stimulated a line of research aimed at characterising the largest subclass of these games possessing OFP. In this presentation, without any assumptions on the structure of the game, we show that the ordered field property holds for both discounted and limiting average stochastic games over the field of algebraic numbers.

51 A mathematical model of the use of supplemental oxygen to combat surgical site infection

Jennifer Flegg
The University of Melbourne
Timetable: p. 11

Infections are a common complication of any surgery, often requiring a recovery period in hospital. Supplemental oxygen therapy administered during and immediately after surgery is thought to enhance the immune response to bacterial contamination. However, aerobic bacteria thrive in oxygen-rich environments, and so it is unclear whether oxygen has a net positive effect on recovery. Here, we develop a mathematical model of post-surgery infection that predicts the efficacy of supplemental oxygen therapy on surgical-site infections.

A four-species coupled set of non-linear partial differential equations that describes the space-time dependence of neutrophils, bacteria, chemoattractant and oxygen is developed and numerical solutions obtained. We quantify the efficacy of different supplemental oxygen regimes on the treatment of surgical site infections in wounds of different initial bacterial load. A sensitivity analysis is performed to investigate how robust the predictions are to changes in the model parameters. Our findings illustrate how the nature of the contaminant and its initial density influence bacterial infection dynamics in the wound.

52 Interfacing diffusive particle models between various scales

Mark Flegg
Monash University
Timetable: p. 25

In many emergent fields of mathematical modelling a recurring difficulty can be systems which operate on multiple scales and require different mathematical frameworks in different parts of the domain. For systems of diffusive particles, I present methods for interfacing between continuum, lattice-based and lattice-free methods of simulation. These methods are widely useful beyond just particle systems, for example interfacing SSA and CME frameworks in chemistry, since they treat each trajectory individually rather than using flux-averaging techniques which are common in fields such as fluid dynamics.

53 Tailings dewatering by flocculation

Brendan Florio
CSIRO
Timetable: p. 23

In minerals processing it is often advantageous to separate the solid and liquid components of a slurry. For example, water from waste tailings can be re-used in processing, while the dewatered slurry becomes thicker and easier to dispose of in a green way. Separation is commonly achieved by flocculation in a gravity thickener whereby long-chain polymers are introduced to adsorb to the surface of solid particles, binding them together in large aggregates. Large aggregates then sink swiftly leaving a clear fluid at the top. Modelling the entire system requires knowledge of many facets, including population balances, the fractal nature of the aggregates, consolidation of the sediments and mixing of the viscous flocculant. A summary of the current state of these elements will be presented.

54 Fluid mechanics and the gentle art of viscometry

Larry Forbes
University of Tasmania
Timetable: p. 25

Whenever we solve a problem in viscous fluid mechanics, we need a value for the dynamic viscosity coefficient μ that features in the Navier–Stokes equation of motion. It is interesting to think about how this number is measured in practice. Viscometers are devices that use exact (simple) solutions of the Navier–Stokes equation to infer the dynamic viscosity μ based on some property of the flow; for example, one such device uses the Stokes solution for flow around a falling sphere to calculate μ based on how fast a sphere falls through the viscous fluid. Here, I am interested in a non-Newtonian fluid, that is governed by the Reiner–Rivlin equation, instead of the Navier–Stokes equation, and a brief reason for this interest will be mentioned in the talk. Such a fluid has *two* viscosity coefficients and standard viscometry is not applicable. Poiseuille flow in concentric cylinders still applies for Reiner–Rivlin fluids but in this talk I want instead to look at a classical problem of flow between rotating plates. A famous similarity solution due to von Kármán can be extended to the Reiner–Rivlin case, and might offer a way of measuring both viscosity coefficients. However, there are subtle numerical problems to be overcome first.

55 FEM-based numerics for approximating the dynamic Laplacian and extracting coherent sets

Gary Froyland
University of New South Wales
Timetable: p. 23

Transport and mixing properties of aperiodic flows are crucial to a dynamical analysis of a flow, and often have to be carried out with limited information. Finite-time coherent sets provide a skeleton of distinct regions around which more turbulent flow occurs. In the purely advective setting this is equivalent to identifying sets whose boundary interfaces remain small throughout their evolution. These sets manifest in geophysical systems in the forms of e.g. ocean eddies, ocean gyres and atmospheric vortices. In real-world settings, often observational data is scattered and sparse, which makes the difficult problem of coherent set identification and tracking even more challenging. I will describe an FEM-based numerical method to efficiently approximate the dynamic Laplace operator, and rapidly and reliably extract finite-time coherent sets from models or scattered, possibly sparse, and possibly incomplete observed data.

56 Construction of a mathematical model that reproduces the mechanism of classification and memory of information using timeshift and phase states of brain waves

Kengo Fujita
Kyushu University
Timetable: p. 19

Different parts of the brain play different roles. For example, the frontal lobe is responsible for thoughts and judgments, and temporal lobes and parietal lobes for memory. According to the experiment of Kawasaki, it was found that the frontal lobes and temporal lobes are active when thinking about auditory information, and the frontal lobe and the parietal lobe are active. When the frontal lobe classifies the input information, features were found in the phase states of the α-wave and the θ-wave included in the brain waves in the frontal lobe, the temporal lobe, and the parietal lobe. These results suggest that the brain uses phase states of brain waves when processing information. Furthermore, Fukami has proposed a mechanism for distributing information using the phase difference between the α-wave and the θ-wave. However, in the previous research, there is a problem that the activity of brain waves stops and accumulation of the memory ceases when the information input disappears. In this presentation, we propose a mechanism that can accumulate information using a mathematical model. We set a connection as input to the frontal lobe from the temporal lobe and parietal lobe with a time shift, and made loops with temporal lobe and parietal lobe and frontal lobe. As a result of simulation, only external inputs of a specific cycle could be accumulated. This result suggests that it is possible to process information using the time shift of information transmission and the difference in phase state of brain waves.

57 Solving nonlinear PDEs for phase boundaries

Polwaththa Dilruk Darshana Gallage
La Trobe University
Timetable: p. 22

Some exact multi-dimensional time-dependent solutions are constructed for a fourth-order nonlinear parabolic partial differential equation by using a nonclassical symmetry led by a single relationship between the diffusion term and the reaction term. This models a phase field that describes a two-phase system near the critical temperature. Solutions are given for the changing phase of a cylindrical or spherical inclusion.

Using an inverse approach, exact solutions to a nonlinear second order evaporation-condensation equation and a fourth-order surface diffusion equation at axi-symmetric three-dimensional phase of a solid are constructed.

58 Forecasting maximum power demand in NSW with SARIMA-regression model

Benjamin Ganim
The University of Newcastle
Co-authors: Terry Perkins
Timetable: p. 19

Accurately predicting power demand is essential for ensuring the lights stay on for consumers. Electricity used by consumers is strongly influenced by the state of the weather which follows a clear seasonal pattern. These time correlated patterns can be examined using time series analysis and effectively modelled by a Seasonal Autoregressive Integrated Moving Average (SARIMA) model to present a simple but powerful model. The choice of SARIMA model is presented.

Given the potential for increasing unpredictability in weather events and base-load electrical supply, understanding the relation between these systems is crucial. We show that on the day electricity demand is strongly influenced by the real feel of the weather and exploit this result to construct a SARIMA-regression model for electricity demand. The model output reveals that regression in the linear and quadratic using on the day weather variables from Sydney Airport significantly improve the underlying SARIMA model over a 52-week horizon.

59 Social network analysis from obsidian artefacts

Caleb Gemmell
The University of Auckland
Timetable: p. 16

Obsidian artefacts were an important stone resource that was used for a variety of tools in pre-European Māori society. By using data from pXRF analysis to determine the original sources of these artefacts, we can create a bipartite network of the obsidian source locations and the locations of the archaeological sites. A social network analysis of this spatial and temporal distribution data provides an insight into the movement and interactions of these groups, as well as a method to test various hypotheses that explain the unique distribution of obsidian throughout the Northland and Auckland regions. Using further tools such as similarity measures, projected networks and community detection allows us to analyse which regions were behaving in similar patterns. Ultimately we aim to gain new information about the complexities of Māori society and iwi interactions, as well as what possibly influenced how these groups gathered resources; whether geographic, economic or social factors.

60 Shilnikov-like chaos in two nonlinear coupled photonic nanocavities

Andrus Giraldo
The University of Auckland
Co-authors: Bernd Krauskopf , Neil G. R. Broderick, Maia Brunstein, Alejandro M. Yacomotti and Juan A. Levenson
Timetable: p. 11

Recent experiments have shown that two coupled photonic crystal (PhC) nanocavities exhibit spontaneous symmetry breaking and bistable behaviour. In particular, bistability has been extensively studied in the last decades due to its usefulness for optical memories and logical switching. Theoretically, bistability and symmetry breaking have been observed in the Bose–Hubbard model, which describes the dynamics of the two coupled PhC nanocavities.

We consider an extension of the Bose–Hubbard model for the slowly varying amplitudes A and B of the electric fields in each nanocavity. It is given as a set of two complex ordinary differential equations determined by a photon lifetime τ, linear couplings between the cavities κ and γ, a detuning from the cavity resonance δ, and a coherent driving term f.

Our work focusses on the overall dynamics of this extended Bose–Hubbard model and, in particular, the existence and disappearance of periodic solutions. As more energy is pumped into the system, represented by an increase of the coherent driving term f, periodic solutions arise from Hopf bifurcations, which then disappear in sequences of homoclinic bifurcations. In particular, we find chaotic Shilnikov bifurcations and the appearance of chaotic attractors. They imply complicated dynamics taking place in the individual cavities, or both of them simultaneously. We present the overall changes of this system, from simple to chaotic dynamics, as a function of the coherent driving term and the detuning from the cavity resonance. More specifically, we present the bifurcation diagram in the (f, δ)-plane as the other parameter values are fixed at experimental values. Our global bifurcation analysis of the two coupled photonic crystal nanocavities predicts types of (chaotic) dynamics well within the range of future experiments.

61 Optimal mixing enhancement by local perturbation

Cecilia Gonzalez-Tokman
The University of Queensland
Timetable: p. 17

We consider the problem of how to apply local perturbations to optimally enhance the mixing of a (possibly time-dependent) dynamical system. We show a flexible modeling approach based on the transfer operator of the dynamical system, and pose the problem in the language of convex optimization. The optimal local perturbations can then be efficiently computed, at discrete time instants, by standard convex optimization techniques. The local perturbations satisfy physical constraints, such as preservation of the invariant measure of the dynamics (for example, for incompressible fluid flow, the perturbations preserve volume), and a variety of other physical constraints can also be easily enforced. We show that one can achieve surprisingly large speedups in mixing via optimizing the diffusion, as compared to fixed diffusion protocols.

62 Discrete mechanical systems: existence of trajectories

Sebastián Elías Graiff Zurita
Kyushu University
Co-authors: Kenji Kajiwara
Timetable: p. 15

In this talk I am going to show that discrete mechanical systems, when viewed as discrete-time dynamical systems, may behave in one of three different ways. Given an initial condition such a system can have no solution, a unique solution, or multiple solutions. But, given a mechanical system, we can construct a one-parameter family of discrete mechanical systems that have a unique solution, in a neighborhood of a given initial condition, for all values of the parameter. Our construction uses the alternative formulation of discrete mechanical system given in [1], which is different from the usual construction (see, for example, [2]), but equivalent in some sense. Finally, I will discuss briefly the error analysis for these systems, and I will show that it is possible to extend all the analysis to discrete mechanical systems with forces.

[1] G. W. Patrick, C. Cuell. Error analysis of variational integrators of unconstrained Lagrangian systems. Numer. Math. 113 (2009) 243-264.

[2] J. E. Marsden, M. West. Discrete mechanics and variational integrators. Numerica Acta 10 (2001) 357-514.

63 Generating connected spatially embedded graphs

Caitlin Gray
The University of Adelaide
Timetable: p. 16

Random networks are useful in providing insights into the formation of real-world networks and are used as underlying models in many fields. However, many random networks do not guarantee connectedness. This is not realistic as many real-world networks are inherently connected. In this talk, I will present an MCMC algorithm to produce connected spatially embedded random networks and study convergence properties through numerical simulation.

64 Tracking the location of metabolic controllers: Akt as a harmonic oscillator

Catheryn Gray
University of New South Wales
Timetable: p. 17

Akt/PKB (Protein Kinase B) is a key signalling molecule in the mammalian cell. As a major cross-talk node shared between several signalling pathways, it is involved in a variety of cellular processes, including glucose metabolism, cell growth and apoptosis. The dysregulation of Akt is implicated in a range of human disorders, from diabetes to cancer.

As a key nutrient sensor, Akt derives signalling specificity from both its biochemical state and, just as importantly, its intracellular location. Initially, Akt is synthesised in the unactivated state in the interior of the cell. However, activation (phosphorylation) of the nascent Akt only occurs at the cell membrane, necessitating the translocation of Akt from the interior to the periphery of the cell. Currently, knowledge concerning Akt translocation is rudimentary, although there is evidence that it is a staged process.

We have developed a deterministic, three-compartment, ordinary differential equation (ODE) model of Akt translocation. Given a conservation relation implicit in the model, it can be shown that this system is equivalent to the harmonic oscillator equation; a classic, well-studied ODE. With this framework, we elucidate the different modes of behaviour of the Akt translocation system, and derive conditions on the model for the manifestation of these modes. The results are also applicable to other signalling molecules where it can be assumed that a conservation relation holds true.

65 Using the Schottky-Klein prime function to compute harmonic measure distribution functions of a class of multiply connected planar domains

Christopher Green
Macquarie University
Co-authors: Marie A Snipes and Lesley A Ward
Timetable: p. 24

Consider releasing a Brownian particle from a basepoint z_0 in a planar domain $\Omega \subset \mathbb{C}$. What is the chance, denoted $h_{\Omega,z_0}(r)$, that the particle's first exit from Ω occurs within a fixed distance $r > 0$ of z_0? The function of r suggested by this question, denoted $h_{\Omega,z_0} : [0,\infty) \to [0,1]$, is called the harmonic measure distribution function, or h-function, of Ω with respect to z_0. We can think of the h-function as a signature that encodes the geometry of the boundary of Ω. In the language of PDEs, the h-function can also be formulated in terms of a suitable Dirichlet problem on Ω. For simply connected domains, the theory of h-functions is now quite well developed and several explicit results are known. However, until recently, for multiply connected domains the theory of h-functions has been almost entirely out of reach.

We will show how to construct explicit formulae for the h-functions of symmetric multiply connected slit domains $\hat{\Omega}$ whose boundaries consist of an even number of colinear slits. We will employ the special

function theory of the Schottky-Klein prime function $\omega(\zeta, \gamma)$ and its associated constructive methods in conformal mapping to build explicit formulae for the h-functions of domains $\hat{\Omega}$ with any finite even number of slits.

66 Can the left ventricle get enough oxygen?

Edward Green
The University of Adelaide
Timetable: p. 12

I present a mathematical model for oxygen transport in the left ventricle, the main chamber of the heart which pumps blood around the body. The model was parameterised for goats and sheep using data gathered from microscopic examination of the heart tissue by our experimental collaborators. The work rate of the heart was measured in two situations: with the animal at rest, and whilst running on a treadmill. The mathematical model was used to estimate the oxygen demand from the left ventricle in each case. The results suggest that oxygen demands are easily satisfied at rest, but only just satisfied during simulated heavy exercise. So, the answer to the question is 'Yes, it can', but evolution appears to have matched supply closely to demand.

67 Modelling Surtseyan Ejecta

Emma Greenbank
Victoria University of Wellington
Timetable: p. 22

Eruptions through crater lakes or shallow sea water, known as sub-aqueous or Surtseyan eruptions, are often some of the most dangerous eruptions in the world. These eruptions can cause tsunamis, lahars, base surges and the phenomenon of interest to our research, the Surtseyan ejecta. Surtseyan ejecta occur when a slurry of previously erupted material and water is washed into the volcanic vent. This slurry is incorporated into the magma and ejected from the volcano inside a ball of lava. There are two opposing processes affecting the ejectas behaviour: the first is the evaporation of the water in the inclusion, increasing the pressure, and the second is the vapour escaping through the pores of the magma.

In this talk I will focus on improved modelling of the behaviour of the ejecta. This model has a more systematic reduction of the resulting coupled nonlinear partial differential equations that arise from mass, momentum and energy conservation.

68 A cell growth model adapted for minimum cell size division

Saima Gul
Massey University
Timetable: p. 22

In this talk I present a cell growth model with a division function that models cells dividing only after they have reached a certain minimum size. In contrast with the earlier cases studied by Hall and Wake, the determination of the steady size distribution requires an eigenvalue that is not known explicitly, but is defined through a continuity condition. We show that there is a steady size distribution solution to this problem.

69 Analytic solutions for a reaction diffusion model of calcium waves on the surface of an egg

Bronwyn Hajek
University of South Australia
Timetable: p. 14

When an amphibious egg is fertilised, a wave of calcium ions travels around the egg to help prevent the entry of multiple sperm. This process can be described with a nonlinear reaction-diffusion equation with a cubic reaction term. Providing the nonlinear diffusion is related to the reaction term in a certain way, the nonclassical symmetry method may be used to find a transformation that will linearise and separate (time and space) the reaction-diffusion equation. Analytic solutions are then constructed, and various types of phenomena, including spirals, can be observed.

70 Inertial force on particles in curved microfluidic ducts

Brendan Harding
The University of Adelaide
Timetable: p. 24

When particles are suspended in fluid flow through a microfluidic device they are perturbed from streamlines by inertial lift forces. Much of the work on calculating these forces is performed in the context of straight ducts having a circular or rectangular cross-section. The problem becomes significantly more complex in the case of curved ducts. In this talk I will discuss some of the challenges that arise due to the curved geometry and show some preliminary results for the lift forces acting on the particle.

71 A Volterra equation with a physically but not mathematically unique solution: a bubble rising in a liquid with negative surface activity

John Harper
Victoria University of Wellington
Timetable: p. 12

Much is known about convective diffusion around a bubble rising in a liquid when the solute lowers the surface tension of the liquid. Some solutes, e.g. many salts in water, increase the surface tension even when very dilute if many (but not all) physical chemists are to be believed. The theory leads to a linear Volterra integral equation of the third kind. Its mathematical solution is non-unique, but physical constraints force uniqueness. Finding the solution numerically is easiest in the case which is both the most difficult by previously known methods and the most physically realistic: very weak negative surface activity.

72 Saddle slow manifolds and canard orbits in the Hodgkin–Huxley model

Cris Hasan
The University of Auckland
Co-authors: Bernd Krauskopf and Hinke Osinga
Timetable: p. 16

Many physiological phenomena have the property that some processes evolve much faster than others. For example, neuron models typically involve observable differences in time scales. The Hodgkin-Huxley model is well known for explaining the ionic mechanism that generates the action potential (a pulse of the voltage) in the squid giant axon. Rubin and Wechselberger nondimensionalized this model and obtained a singularly perturbed system an explicit time-scale ratio that separates two fast, two slow variables. The dynamics of this system are very complex and feature periodic orbits with a series of action potentials separated by small-amplitude oscillations. Such periodic orbits are also referred to as mixed-mode oscillations. The system features two-dimensional locally invariant manifolds called slow manifolds, which can be either attracting or of saddle type. We introduce a general method for computing two-dimensional saddle slow manifolds as well as so-called canard orbits. Our method is first tested and implemented for a four-dimensional extended normal form of a folded node. We then illustrate how slow manifolds and associated canard orbits organize mixed-mode oscillations and determine the firing rates of action potentials in the Hodgkin-Huxley model.

73 How should a local regime-switching model be calibrated?

Xin-Jiang He
University of Wollongong
Co-authors: Song-Ping Zhu
Timetable: p. 20

Local regime-switching models are a natural consequence of combining the concept of a local volatility model with that of a regime-switching model. However, even though Elliott et al (2015) have derived a Dupire formula for a local regime-switching model, its calibration still remains a challenge. This is primarily due to the fact that the derived volatility function for each state involves all the state price variables whereas only one market price is available for model calibration, and a direct implementation of Elliott et al's formula may not yield stable results. In this talk, a closed system for option pricing and data extraction under the classical regime-switching model is proposed with a special approach, splitting one market price into two "market-implied state prices". The success of our approach hinges on the recovery of the two local volatility functions being transformed into an optimal control problem, which is solved through the Tikhonov regularization. In addition, an efficient algorithm is proposed to obtain the optimal solution by iteration. Our numerical experiments show that different shapes of local volatility functions can be accurately and stably recovered with the newly-proposed algorithm, and this algorithm also works quite well with real market data.

Elliott, R. J., Chan, L. and Siu, T. K. (2015), A Dupire equation for a regime-switching model, International Journal of Theoretical and Applied Finance 18(04), 1550023.

74 Fluid-Structure interaction in pseudospectral codes: The smooth volume penalty method

Eric William Hester
The University of Sydney
Timetable: p. 20

Fluid-structure interactions (FSI) pervade applied mathematics, science and engineering, yet are often too complex to solve analytically. Animal swimming and flight, glacier-ocean interactions, blood circulation, geodynamics and volcanoes, dune formation and erosion, are a handful of important such examples. Standard numerical approaches utilise body-conforming grids. However, they are difficult to generate, update, and program, and often of limited accuracy. Pseudospectral methods are an exciting alternative for their exponential accuracy, but are restricted to regular geometries. The volume penalty method is a simple and flexible tool to incorporate arbitrarily shaped boundaries into existing codes. We examine the method, demonstrate its application to several interesting FSI problems, and show that the majority of the error stems from a "displacement length", which can easily be corrected.

75 A history-based multi-outbreak influenza model

Roslyn Hickson
IBM Research Australia
Co-authors: A.J. Swan
Timetable: p. 16

There is evidence that susceptibility to infection during an influenza outbreak is dependent on the number of previous influenza infections and/or how recent the infections were. We construct a multi-outbreak influenza model to explore the effect of these two factors modifying population susceptibility on the outbreak dynamics.

Classic deterministic compartment modelling of infectious disease spread divides the population into fully susceptible and fully immune compartments which are homogeneous. In reality, the population has differing degrees of immunity due to unique infection histories of individuals. There are two approaches within the deterministic compartmental modelling framework to address this issue; one is to have many compartments reflecting different levels of immunity, and the other is to capture the heterogeneity within a single susceptibility compartment in the model. The first approach has been well explored in the literature. We focus on the second approach by building a history-based compartmental model with the between outbreak immunological timescale modelled using a map between disease states. This map of immunity loss incorporates antigenic drift, births-deaths, and decreases in antibody response in the weeks-months timescale.

We use our developed model to explore fundamental questions on how the different susceptibility hypotheses and other key model parameters affect the outbreak dynamics. There are several limitations to our modelling approach to answer these questions. These include the limitation of only explicitly considering a single strain circulating within a season, which is not appropriate if there are cross-immunity effects, and the assumption of homogeneity in importance of history length and immune response. Despite these limitations we are able to provide important insights into these fundamental questions.

76 Relating elasticity and graphene folding conformation

James Murray Hill
University of South Australia
Co-authors: Barry J. Cox, Duangkamon Baowan and Wolfgang Bacsa
Timetable: p. 20

The variational calculus is employed to determine the folding behaviour of a single graphene sheet. Both elastic and van der Waals energies are taken into account, and from these considerations the shape of the curve is determined. By prescribing that the separation distance between the folded graphene in the parallel region is 3.32 Angstroms, an arbitrary constant β arising by integrating the Euler-Lagrange equation is determined. Furthermore, the full parametric representations for the folding conformation is derived, so that the folded graphene may be depicted graphically. Using typical values

of the bending rigidity in the range of 0.8-1.6 Electron Volts, the shortest stable folded graphene sheets are required to be at least 6.5 - 10 nanometers in length for the folded conformation.

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J. S. Bunch, A. M. van der Zande, S. S. Verbridge, I. W. Frank, D. M. Tanenbaum, J. M. Parpia, H. G. Craighead and P. L. McEuen, Electromechanical resonators from grapheme sheets, Science, 2007, 315, 490-493.

K.-T. Lam, C. Lee and G. Liang, Bilayer graphene nanoribbon nanoelectromechani-cal system device: a computational study, Appl. Phys. Lett., 2009, 95, 143107.

77 Plumes generated by desalination outfalls

Graeme Hocking
Murdoch University
Co-authors: Shaymaa Shraida
Timetable: p. 22

A bi-product of the desalination process is water of high salinity. In the West Australian desalination plants, this water is pumped into Cockburn Sound where it is (optimistically) believed to disperse. In this talk I will consider the flow of such a saline plume when the outfall is raised off the bed. Only two-dimensional flows will be considered, but these provide some interesting solutions. The usual Nekrasov integral equation formulation for free surface flow problems proves to work very well and steady solutions will be presented over a range of flow conditions. Future work will be discussed.

78 Extensional flow of an axisymmetric transversely isotropic fluid thread

Matthew James Hopwood
The University of Adelaide
Timetable: p. 15

Biological materials exhibit complex behaviours, including viscoelasticity and anisotropy. In many cases, these behaviours can be attributed to the material having a fibrous microstructure e.g. collagen gel and cervical mucus. We study a class of anisotropic materials that are known as 'transversely isotropic', where the material's physical properties are isotropic in the plane normal to some axis (e.g. the fibre direction). Motivated by potential applications to understanding the changes to the structure of cervical mucus throughout the menstrual cycle and its role in providing regulation to the passage of spermatoza, we consider the extensional flow of an axisymmetric, inertialess, transversely isotropic viscous fluid thread. A reduced set of governing equations is obtained by exploiting the thin geometry of the thread. We then present results for the special cases where the fibre alignment is nearly axial or radial.

79 Mixed Signals: Interaction between RyR and IP3R mediated calcium release shapes the calcium transient for hypertrophic signalling in cardiomyocytes

Hilary Hunt
The University of Melbourne
Co-authors: Gregory Bass, Llewelyn Roderick, Christian Soeller, Vijay Rajagopal and Edmund Crampin
Timetable: p. 19

Calcium plays a central role in mediating the contractile function of heart cells. However, calcium is also the second messenger in a wide variety of other intracellular signalling pathways, including hypertrophic signalling in cardiomyocytes. How intracellular calcium can encode several different, specific signals at once is not well understood.

Under hypertrophic stimulation, calcium released from IP3R channels triggers dephosphorylation and nuclear import of the transcription factor NFAT, with resulting gene expression linked to cell growth. Yet this must occur on a background of rising and falling cytosolic calcium which controls each heart beat.

Modelling these two signals within a single heart cell, we combine our knowledge of calcium channels with the evidence from a recent study on NFAT response to identify the key signal-carrying component of the IP3-dependent hypertrophic signalling pathway in cardiomyocytes.

80 Why there might be more slow-fast systems than you thought there were

Sam Jelbart
The University of Sydney
Timetable: p. 21

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

81 The effect of tumour heterogeneity on cancer treatments: the ninja virus

Adrianne Jenner
The University of Sydney
Timetable: p. 20

Heterogeneity within tumours has been identified as the major culprit impeding treatment efficacy. The heterogeneous nature of tumour geometry arises from an over-proliferation of mutated cells within a confined space. Over-proliferation of cells leads to a limited number of treatment entry points resulting in a less effective treatment. Currently, the challenge in the field is to develop a cancer treatment that overcomes both the heterogeneous tumour microenvironment and limited treatment entry points. Cancer-killing viruses can overcome most tumour heterogeneity obstacles; however, limited treatment diffusion is regularly observed experimentally. Using a Voronoi cellular automaton, we investigate the effects of tumour heterogeneity on cancer-killing viruses and propose a new generation of cancer-killing viruses: the ninja virus. The ninja virus is developed with time-dependent infection, where for a fixed initial period no infection will occur. This allows for further treatment diffusion and improves treatment efficacy dramatically. From our work, we illustrate the importance that mathematical modelling holds in cancer research and propose a novel innovative treatment.

82 Modelling density-dependent collective diffusion in microporous Knudsen flows

Owen Jepps
Griffith University
Co-authors: Marsel Gokovi
Timetable: p. 22

Knudsen flows can arise in applications of microporous materials, such as filtration, when external conditions induce low-density transport. Over a decade ago, we proposed a model (Jepps, Bhatia and Searles, PRL 91:126102, 2003) to predict the collective diffusion of Knudsen flows in uniform micropores (such as some microporous carbons and silicas). This model works in the zero-density (high Knudsen-number) limit, and has proven popular as a means of estimating Knudsen transport in this limit, and as a basis for developing density-dependent models. Most of these density-dependent models extend the zero-density model using approaches that are very different in philosophy to the original model. In this presentation, I will show how the original model can be adapted to include density dependence more rigorously, and compare its predictions with existing and new data.

83 The role of initial geometry in experimental models of wound closing

Wang Jin
Queensland University of Technology
Timetable: p. 14

Standard wound healing assays often deal with just one initial wound shape, and it is unclear whether varying it might impact how we interpret results from these experiments. Here, we use a new kind of wound healing assay, called a *sticker assay*, to explore the role of the initial shape. We examine healing with square, circular and triangular wounds. Measurements of the area as a function of time show that the rate of wound closure depends on the initial shape. This is interesting because the only aspect of the assay we change is the initial wound shape, and the reason for different closure rates is unclear. To provide more insight we calibrate a typical mathematical model to match the data. This shows that the rates of cell motility and proliferation associated with different initial wound shapes are approximately the same, implying that the differences in the closure rates are consistent with a typical mathematical model of wound healing. Therefore, parameter estimates from an experiment with a particular wound shape can be used to predict the development of wounds of different initial shape.

84 The 'sinh' transformation method for evaluating nearly singular boundary element integrals

Barbara Johnston
Griffith University
Timetable: p. 11

When implementing the boundary element method, three types of integrals (regular, 'nearly' singular and singular) must be evaluated, and these can be categorised by the distance between the source point and the boundary element in question. The most troublesome to evaluate is the subject of this talk, the 'nearly' singular integral. This integral occurs when the source point is close to, but not on, the element of integration, resulting in a sharply peaked integrand.

In 2004, David Elliott suggested applying a transformation, based on the sinh function, to smooth the integrand. The 'sinh' transformation was designed to automatically take into account the projection of the source point onto the element of integration and also the distance between the two. Applying this transformation to one-dimensional 'nearly' singular integrals gave relative errors that were several orders of magnitude lower than those for conventional Gauss-Legendre quadrature. David also calculated asymptotic error estimates for the truncation errors, based on work that he had previously published back in 1972.

This talk will trace the evolution of the 'sinh' transformation method, and its associated error estimates, as it was successfully applied in both one and two dimensions to weakly and strongly nearly singular integrals, and in various geometries.

85 Evaluating singular integrals for fun and profit

Peter Johnston
Griffith University
Timetable: p. 11

The accuracy of the boundary element method is heavily reliant on accurate evaluation of singular integrals. Over a long period of time, many researchers have proposed a variety of approaches to overcome this problem. The most common of these approaches are splitting the interval of integration, transformation methods and a combination of both.

During this talk I will provide an excursion through several complicated transformations to aid in the evaluation of singular integrals that arise in the boundary element method. Eventually, I will arrive at a very simple transformation that yields very interesting error behaviour.

Throughout this journey all the numerical analysis and error estimates were provided by David, always harking back to the pioneering work of "Donaldson and Elliott, 1972".

86 An analytical approach for quantifying the influence of nanoparticle polydispersity on cellular delivered dose

Stuart Johnston
The University of Melbourne
Timetable: p. 12

Nanoparticles provide a promising approach for the targeted delivery of therapeutic, diagnostic and imaging agents in the body. However, it is not yet fully understood how the physico-chemical properties of the nanoparticles influence cellular association and uptake. Cellular association experiments are routinely performed in an effort to determine how nanoparticle properties impact the rate of nanoparticle-cell association. To compare experiments in a meaningful manner, the association data must be normalised by the quantity of nanoparticles that arrive at the cells, a measure referred to as the delivered dose. The delivered dose is calculated from a model of nanoparticle transport through fluid. A standard assumption is that all nanoparticles within the population are monodisperse, namely, the nanoparticles have the same physicochemical properties. We present a semi-analytic solution to a modified model of nanoparticle transport that allows for the nanoparticle population to be polydisperse. This solution allows us to efficiently analyse the influence of polydispersity on the delivered dose. Combining characterisation data obtained from a range of commonly-used nanoparticles and our model, we find that the delivered dose changes by more than a factor of two if realistic amounts of polydispersity are considered.

87 Full reconstruction of a hidden variable model with just two observed variables

Benjamin David Kaehler
Australian National University
Timetable: p. 14

Consider a stochastic model with a number of observed variables that are independent only if we condition on a hidden variable. Several authors have written on the restriction that at least three observed variables are required for the parameters of the model to be fully recoverable from the joint probability distribution of the observed variables. I am interested in this question from the perspective of phylogenetics, where the observed random variables are the DNA of living species and the hidden variable is the DNA of a common ancestor. The restriction to three observed variables means that trees that model evolutionary relationships must be unrooted. That is, the properties of the most recent common ancestor of a fixed set of species are unknowable. I will show how this situation can be remedied by introducing some biologically justifiable constraints, so that the minimum number of observed variables drops to two and the root can be discovered.

88 Log-Aesthetic curves in industrial design as similarity geometric analogue of Eulers elastic curves

Kenji Kajiwara
Kyushu University
Co-authors: Jun-ichi Inoguchi, Kenjiro T. Miura and Wolfgang K. Schief
Timetable: p. 19

The class of plane curves called the Euler's elastic curves is one of the most important geometric objects and serves as a basic model in the elastic theory. It can be characterized (1) as a critical point of the elastic energy where it is given by the square of the Euclidean curvature, (2) as the stationary flow with respect to the isoperimetric deformation of plane curves in the Euclidean geometry governed by the modified KdV equation, which is one of the most typical integrable systems. In this talk, I consider a class of plane curves called the log-aesthetic curves (LAC) and their generalization which is used in industrial design. We investigate those curves under the similarity geometry and characterize them as stationary integrable flow on plane curves which is governed by Burgers' equation. We introduce "fairing energy" and propose a variational formulation of those curves whose Euler-Lagrange equation yields the stationary Burgers' equation. Our result suggests that the LAC and their generalization can be regarded as the similarity geometric analogue of the Euler's elastic curves, which provides a new mathematical framework of those curves and would yield various generalizations. As an example, we will mention the integrable discretization of LAC which may be useful for numerical implementation.

89 State-dependent delays in the El Niño Southern Oscillation system

Andrew Keane
University of Auckland
Co-authors: Bernd Krauskopf
Timetable: p. 12

Delay differential equations (DDEs) have been used successfully in the past to model climate systems at a conceptual level. An important aspect of these models is the existence of feedback loops that feature a delay time, usually associated with the time required to transport energy through the atmosphere and/or oceans across the globe. So far, the values of the delays are generally assumed to be constant. Recent studies have demonstrated that even simple DDEs with nonconstant delay times, which change depending on the state of the system, can produce surprisingly rich dynamical behaviour. Here, we identify physical arguments for the existence of such state-dependent delays in a DDE model for the El Niño Southern Oscillation climate system. We then conduct a bifurcation analysis by means of continuation software to investigate the effects of state-dependent delays on the dynamics of the system.

90 Correctly assessing drug efficacy in malaria relies on understand parasite kinetics before treatment

David Samuel Khoury
University of New South Wales
Co-authors: James McCarthy and Miles P Davenport
Timetable: p. 13

The two most prevalent species of malaria parasites are Plasmodium falciparum and Plasmodium vivax. P. falciparum causes the greater mortality, and so is morefrequently the focus of malaria research. However, P. vivax is still widespread and contributes significantly to the global disease burden. We aim to translate insights gained from the numerous studies of P. falciparum infection to further our understanding of P. vivax infection.

About 24% of people with P. falciparum infection experience an increase in parasite concentrations after receiving the recommended antimalarial treatment. Rises in parasite concentration occur when a patient is given treatment when they have many mature parasites that are about to proliferate (produce progeny), and treatment is unable to prevent this process completely. Proliferation of parasites is associated with inflammation and illness in malaria. Hence preventing rises in parasite concentration is likely important for reducing illness and mortality rates. Interestingly, in P. vivax malaria, $< 2\%$ of individuals have a rise in parasite concentration after treatment with the same antimalarial. We explore the reasons for this difference. Are drugs more effective against P. vivax? Or is there some other explanation for this difference? Using data from volunteers that received an experimental P. vivax and P. falciparum infection we construct a PDE model of parasite proliferation and using that model, and parameter estimates, we simulate the effect of drugs in the two parasite species. We find that a very fundamental difference in sequestration (hiding) between the two species is a critical consideration when interpreting data on the effects of drugs in these two species.

91 Evolution of monogamy in response to human post-menopausal longevity

Peter Kim
The University of Sydney
Timetable: p. 24

The human species is unique among mammals in its tendency towards monogamy, or pair bonding, a trait which also exists in hunter-gathering societies. Traditional explanations for this evolution have focused on the presence of paternal care and the needs of our offspring; however, recent research has challenged this claim, contending that the significant effects of mating competition on male choice result in evolutionary equilibria with high promiscuity and little mate guarding or pair bonding. We develop an ordinary differential equation model to investigate this question and determine conditions for mate guarding or pair bonding to supersede multiple-mating (promiscuous) strategies as the optimal allocation of male reproductive effort. Various situations were considered including the variation of reproduction rate, sex ratio, end of female fertility, and the effect of grandmother help in providing for offspring. While our results confirmed previous findings that pair bonding triumphs in response

to partner scarcity and male-biased populations, it was found that this effect only occurred in the extreme case of a 1:10 or higher female to male ratio. In contrast, the introduction of post-menopausal longevity combined with a grandmother effect provided a significantly more realistic and mechanism for monogamy to evolve.

92 Chaos and fluctuations in a modified Ehrernfest wind-tree model

Matthew King
Griffith University
Co-authors: Owen G Jepps
Timetable: p. 19

The non-equilibrium Ehrenfest wind-tree model is an interesting model for testing fluctuation relations, because it was believed to be a non-chaotic system that obeyed fluctuation relations. More recently, it was shown that over short times the dynamics is chaotic, but at almost all field strengths trajectories are eventually periodic. We have considered perturbations of the Ehrenfest wind-tree model that do not permit these eventually periodic orbits, and studied the Lyapunov exponents and fluctuation relations in these systems. For some perturbations the system remains chaotic for all times investigated, and the fluctuation relations are obeyed. However, we will also present results on some systems which appear to remain non-trivially non-chaotic at long times.

93 Nonlinear learning in games with incompetence

Maria Kleshnina
The University of Queensland
Timetable: p. 17

In this talk I will extend my results on games with linear incompetence to the cases with different nonlinear learning processes. We will show that the speed and the steepness of improvement may change the population time-dynamics dramatically. We also examine the long-time behaviour of the replicator dynamics under incompetence and show how this idea affects games' equilibiria.

This research is funded by ARC discovery grants DP160101236 and DP150100618.

94 The relation between Crouzeix-Raviart and Raviart-Thomas finite element methods

Kenta Kobayashi
Hitotsubashi University
Timetable: p. 20

We discuss the lowest degree Crouzeix-Raviart and Raviart-Thomas finite element methods applied to the Poisson equation with a piecewise constant righthand function f. Let u_h^{CR} and $(\mathbf{p}_h, u_h^{RT})$ be the Crouzeix-Raviart and Raviart-Thomas finite element solution respectively. Then, for the two-dimensional case, it is well-known that these two finite element solutions have a close relation. In particular, for each triangular element K in the proper triangulation $\mathcal{T}_h$, the following relation holds:

$$u_h^{RT} = \pi_K^0 u_h^{CR} + \frac{f}{48}\sum_{i=1}^{3}|\mathbf{x}_i - \mathbf{x}_K|^2, \qquad \mathbf{p}_h = \nabla u_h^{CR} - \frac{f}{2}(\mathbf{x} - \mathbf{x}_K)$$

where π_K^0 is the piecewise constant projection operator, $\mathbf{x}_i$ are the vertices of K and $\mathbf{x}_K$ is the centre of gravity of K. In our research, we generalize this relation to any dimension and proved the following:

$$u_h^{RT} = \pi_K^0 u_h^{CR} + \frac{f}{d^2(d+1)(d+2)}\sum_{i=1}^{d+1}|\mathbf{x}_i - \mathbf{x}_K|^2, \qquad \mathbf{p}_h = \nabla u_h^{CR} - \frac{f}{d}(\mathbf{x} - \mathbf{x}_K)$$

where d denotes the space dimension.

95 Robust chaos: blenders in a Hénon-like family

Bernd Krauskopf
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Co-authors: Stephanie Hittmeyer, Hinke Osinga and Katsutoshi Shinohara
Timetable: p. 11

Blenders are geometric objects that allow one to construct complicated dynamics and robust homoclinic tangencies in the theoretical setting of nonuniformly hyperbolic dynamics. A defining feature of a blender is the property that its invariant manifolds behave as geometric objects of a higher dimension. We consider an explicit example of a blender, which arises in a family of three-dimensional Hénon-like maps. We employ advanced numerical techniques to compute one-dimensional stable and unstable manifolds of saddle points to very considerable arclengths. In this way, we not only present the first images of an actual blender but also obtain a convincing numerical test for the blender property. This allows us to determine when and how the blender disappears when a system parameter is changed. The relevance of the blender property for chaotic attractors will be discussed.

96 Network using Michaelis-Menton kinetics: an algorithm to find target genes from expression data

Mythreye Krishnan
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Co-authors: Michael Small, Anthony Bosco and Thomas Stemler
Timetable: p. 21

The most challenging aspect of gene expression data analysis is to process the large and complex data using mathematical models and find biologically relevant information that gives insight to the underlying mechanism. We derived a simple ordinary differential equation using Michaelis-Menton kinetics to process the microarray data. Different biological systems of asthma and allergy in humans and cancer in mice have been studied. The resulting analysis extracts highly linked target genes, the changes in which might cause change in the other genes, in other words, potential experimental targets that can be exploited for studies such as gene therapy. Our aim is to identify novel targets that can be analyzed further in addition to the previously identified nodes. We present a method that can be used to process the microarray data to find target genes using relevant links between them.

97 A sequential stochastic mixed integer programming model for elective surgery scheduling

Ashwani Kumar
The University of Melbourne
Co-authors: Alysson Costa, Mark Fackrell and Peter Taylor
Timetable: p. 15

Demand for healthcare services is growing rapidly in Australia and across the world, and rising healthcare expenditure is increasing pressure on the sustainability of the government-funded healthcare system. To keep up with the rising demand, we need to be more efficient in delivering surgical services.

In this talk, we will discuss a stochastic mixed integer programming model to optimise the master surgery schedule (MSS) in order to achieve a better patient flow under downstream capacity constraints. We optimise the process over several scheduling periods and we use various sequences of randomly generated patients' length of stay scenario realisations to model the uncertainty in the process. This model has the particularity that the scenarios are chronologically sequential, not parallel. We use a very simple approach to enhance the non-anticipative feature of the model and we empirically demonstrate that our approach is useful in achieving the desired objective. We use simulation to show that the most frequently optimal schedule is the best schedule for implementation. Furthermore, we analyse the effect of varying the penalty factor, an input parameter that decides the trade-off between the number of cancellations and occupancy level on the patient flow process. We demonstrate empirically that if we can operate on elective surgery patients over weekends, then we can achieve a better throughput and more efficient utilisation of resources. Finally, we develop a robust MSS to maximise the utilisation level while keeping the number of cancellations within acceptable limits.

98 Modelling the impact of T-cell avidity on cancer vaccines

Adarsh Kumbhari
The University of Sydney
Timetable: p. 17

Therapeutic vaccines treat cancers that have already developed by stimulating cytotoxic T-cells. Despite showing promise, positive clinical outcomes have yet to be realised. Vaccines elicit a low-avidity T-cell response and the mere presence of low-avidity T-cells can inhibit cancer killing by tumour-lytic high-avidity T-cells via the stripping of surface antigen on target cells. This may explain the observed inefficacy of therapeutic cancer vaccines. We look at a variety of T-cell profiles and how the parameters that characterise these profiles affect tumour progression.

99 Chimeras on spheres

Carlo Laing
Massey University
Timetable: p. 23

We consider a network of nonlocally coupled heterogeneous phase oscillators lying on the surface of a sphere. This network was previously studied with identical oscillators and spatiotemporal patterns known as chimeras were found, mostly as a result of direct numerical simulation. Here we take the continuum limit of an infinite number of oscillators and use the Ott/Antonsen ansatz to derive a continuum level evolution equation for an order parameter-like quantity. Most of the patterns previously found in these types of network correspond to relative fixed points of this evolution equation, and we show the results of numerical investigations of these fixed points: their existence and stability, and the bifurcations involved in their loss of stability as parameters are varied. Our results answer a number of questions posed by previous authors who studied such networks, and provide a better understanding of these networks dynamics.

100 Rigorous results in electronic structure calculation

Marko Lange
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Timetable: p. 20

Electronic structure calculations, in particular the computation of the ground state energy, are of enormous importance in quantum chemistry. Minimization methods for computing the ground state energy can be developed by employing a variational approach, where the second-order reduced density matrix defines the variable. This concept leads to large-scale semi-definite programming problems that provide a lower bound for the ground state energy. Upper bounds of the ground state energy are calculated for instance with the Hartree-Fock method.

However, Nakata et al observed that, due to numerical errors the solver produced erroneous results with a lower bound larger than the Hartree-Fock upper bound. Violations within one mhartree were observed. I present here a method for computing tight rigorous error bounds without violations as mentioned above.

101 Infection-acquired versus vaccine-acquired immunity in an SIRWS model

Tiffany Ngo Nam Leung
The University of Melbourne
Timetable: p. 16

Waning immunity is known to occur for some infectious diseases after natural infection and vaccination. We present a susceptible-infectious-recovered-susceptible (SIRS)-type transmission model that includes the waning and boosting of immunity. We allow the duration of infection-acquired immunity to differ from that of vaccine-acquired immunity. We evaluate its impact on (i) the proportions of primary and secondary infections, and (ii) the epidemiological patterns of an infectious disease (pertussis as an example), focussing on the peaks and period of the epidemic cycles that characterise the average infection prevalence.

Our results show that the effectiveness of a vaccine to reduce infection prevalence increases more by extending the duration of infection-acquired immunity than extending that of vaccine-acquired immunity. We find that increasing vaccine uptake (i) always lowers the proportion of primary infections but may lead to an increase in overall transmission, and (ii) raises the peaks and lengthens the period of the epidemic cycles. Our study highlights that for a particular disease and associated vaccine, a detailed understanding of how the duration of protection can influence infection prevalence is important as we seek to optimise vaccination strategies.

102 Modelling South Australia's electricity prices

Angus Hamilton Lewis
The University of Adelaide
Timetable: p. 20

Electricity spot prices are known to exhibit characteristics not often observed in other financial markets - seasonality on multiple scales, mean reversion, large price spikes, price drops and negative prices. These characteristics are largely attributed to the lack of effective storage options for electricity. The goal of my research is to capture the aforementioned characteristics using a stochastic model. Such a model is useful to help market participants manage risk and for valuation of financial contracts and real options for investment.

We use a regime-switching time-series model, which is an extension of a hidden Markov model, to model prices. A subtle but important part of our model is that we require each regime to be completely independent. This coupled with the fact that the regime sequence is not directly observable, makes parameter estimation difficult as the likelihood function is not computable for realistic datasets, hence, we use data-augmented MCMC for Bayesian inference.

In this talk I will present our modelling process for the South Australian electricity market, touching on model inference and model selection. South Australia is a particularly interesting case study due to its relative isolation, high prices and huge price spikes (up to AUD$14000 compared to the average price of around AUD$80).

103 Pricing puttable convertible bonds with integral equation approaches

Sha Lin
University of Wollongong
Timetable: p. 20

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

104 The BEST Approach to the Search for Extraterrestrial Intelligence (SETI)

Robert Lodder
University of Kentucky
Timetable: p. 15

The Bootstrap Error-adjusted Single-sample Technique (BEST) is shown to perform better than the Mahalanobis distance metric in analysis of SETI data from a Project Argus near-infrared telescope. The BEST algorithm is used to identify unusual signals, and returns a distance in asymmetric nonparametric multidimensional central 68% confidence intervals (equivalent to standard deviations for 1-D data that are normally distributed, or Mahalanobis distance units for normally distributed data of d dimensions). The BEST algorithm is designed for high-speed parallel processing supercomputers, but is also shown to operate efficiently on single processors. Calculation of the Mahalanobis metric requires matrix factorization and is $O(d^3)$. In contrast, calculation of the BEST metric does not require matrix factorization and is $O(d)$. Furthermore, the accuracy and precision of the BEST metric are greater than the Mahalanobis metric. Using synthetic multivariate data, the bias and RSD of the BEST and Mahalanobis metrics are compared as a function of the number of dimensions in hyperspace and the number of training samples in the calibration set. Full near-IR spectra of a stellar system (KIC 8462852, or "Tabby's star") are analyzed successfully using the BEST to identify unusual signals.

105 The evolution of hunting effort in hunter-gatherer populations

Sara Li-Yen Loo
The University of Sydney
Timetable: p. 22

The evolution of large-game hunting in human life history is a counter-intuitive behaviour. Despite low daily success probabilities and large proportions of sharing, hunter-gatherer males make greater investments in large-game hunting and food sharing. While costly, investment into these behaviours pays off with more successful hunters being deemed as better partners, thus increasing their likelihood of paternity. It is the effort with which, and time where, an individual invests their energy that determines one's status. We therefore model the effect of a hunting effort on male hierarchy and investigate the evolution of this large-game hunting behaviour as it trades off with fertility. We investigate the intergenerational dynamics of a population defined by a probability density in two traits, hunting effort and hierarchical status, and analyse the mechanisms by which such large-game hunting behaviour can evolve.

106 Modelling donor flow

Meirian Sara Lovelace-Tozer
The University of Melbourne
Timetable: p. 14

Due to its short shelf-life, blood is a limited resource, yet sufficient and quality supply from blood donors is vital to meet demand for blood transfusions. The Australian Red Cross is the primary blood service provider Australia-wide, and depends on voluntary, non-remunerated donors. To maximise donor retention rates, it is paramount that donors have a satisfactory donation experience. Donor feedback indicates that wait times play a significant role in their decision to return.

The goal of this project is to establish a model which accurately represents the flow of donors through an Australian Red Cross blood service centre.

107 Switching time optimization for switched systems with time-dependent and state-dependent switching conditions

Ryan Loxton
Curtin University
Timetable: p. 15

Switched systems operate by switching among various different modes. Determining the optimal times at which the mode switches should occur is a fundamental problem in systems and control, with particular importance to the numerical solution of optimal control problems. This talk will discuss the switching time optimization problem for two classes of switched systems: those with time-dependent switching conditions (where the switches are directly controllable), and those with state-dependent switching conditions (where the switches occur when the system hits certain switching surfaces in the state space). It is often claimed in the literature that standard numerical optimization techniques struggle when applied to switching time optimization problems. In this talk we present new results showing that this challenge is over-stated; contrary to popular belief, switching times can in fact be optimized effectively using standard optimization methods. We verify this with a numerical example involving a switched system model for the production of 1,3-propanediol, an industrial polymer used in paints, adhesives and lubricants.

108 Finite margin call stock loan evaluation

Xiaoping Lu
University of Wollongong
Timetable: p. 19

A stock loan is a financial contract that allows the borrower to obtain a loan with stocks as collateral. In this talk, we will discuss the American connection between stock loans and options, and show that the problem of finite maturity margin call stock loans can be evaluated as the corresponding American barrier options with rebate. The governing partial differential equation is established under the Black-Scholes framework. Mathematically, the valuation problem is a moving boundary problem, which does not have an analytical solution except for special cases. I show that the problem can be solved semi-analytically with great accuracy and efficiency. Numerical examples are presented to demonstrate my solution procedure.

109 Nonlocal solitary waves in nearest-neighbour particle chains

Christopher Lustri
Macquarie University
Timetable: p. 24

Systems consisting of a chain of particles that interact only with their nearest neighbours often produce solitary wave solutions. However, inhomogeneous chains in which the particle parameters vary, such as period-2 dimer chains, exhibit more complicated behaviour. Experimental and numerical studies of dimer particle chains indicate that we can observe nonlocal solitary waves, in which the wavefront is followed by a small-amplitude oscillations that do not decay in amplitude away from the wave-front. These are known as nanoptera.

I will consider 2-periodic particle chains (dimers) in which neighbouring particles interact through a Toda potential, and particles alternate between heavy and light. In particular, I will perform an asymptotic analysis in the small mass ratio limit.

Using exponential asymptotic techniques, I will show that these systems contain Stokes lines, and by carefully considering the exponentially small solution components, will determine the form of the trailing oscillations produced behind the traveling wave. Finally, I will show that there is a simple formula that can be used to identify dimer configurations that produce purely localised solitary wave solutions without far-field oscillations, which are more robust and decay more slowly than general solutions containing nanoptera.

110 Investigating the dynamics of coupled models with applications to Group A Streptococcus and Scabies

Michael Lydeamore
The University of Melbourne
Co-authors: James M. McCaw, Patricia T. Campbell and Jodie McVernon
Timetable: p. 17

Infections with Group A Streptoccocus (GAS) are highly prevalent in remote communities in the Northern Territory. One of the primary drivers of GAS infection is scabies, a small mite which causes a break in the skin layer, potentially allowing GAS to take hold. This biological connection is reaffirmed by the observation that mass treatment for scabies in these remote communities sees a reduction in the prevalence of GAS infection, despite GAS not being directly targeted. In the most extreme case, it has been hypothesised that the eradication of scabies in remote communities may lead to an eradication of GAS related infection thereafter.

We present a biologically informed model of scabies infection, which captures the life-cycle dynamics of the scabies mite and the effects of treatment. We then investigate two reduced models for scabies: one which notes only the key stages of mite development, and the second deduced from a fast-slow analysis. We investigate the differences in the transient dynamics between these models, particularly after a mass drug administration, where a large proportion of the population is treated rapidly, in an Approximate Bayesian Computation (ABC) framework.

Finally, we couple these scabies models to a susceptible-infected-susceptible (SIS) model that is representative of GAS infections, where individuals who are infected with scabies are assumed to have a greater susceptibility to GAS through the use of a multiplier known as an enhanced susceptibility factor. We investigate the impact of varying this enhanced susceptibility factor and determine feasible ranges for the duration of GAS infection, incorporating the posterior distributions from the scabies model investigation. Finally, we investigate whether the "eradicate scabies eradicate GAS" scenario is possible under our modelling assumptions.

111 Microbial co-existence and selection in enteric fermentation

Tammy Lynch
Massey University
Timetable: p. 24

In this talk we present a mathematical model created to allow for testing of developing knowledge of enteric fermentation. The model uses concepts from chemostat modelling and enzyme kinetics and thermodynamics to model dynamic control of microbe growth. The addition of thermodynamic control that includes both substrate and product inhibition on the rate of biochemical processes, produces substrate thresholds below which metabolism stops as has been seen experimentally. It allows for fermentation pathway selection based on rumen environment and can lead to coexistence of different species consuming the same substrate but using different fermentation pathways, providing an

explanation for observed microbial diversity in the rumen that is not dependent on spatial or temporal changes in the system.

112 An analytical solution for the HJB equation arising from the Merton problem

Guiyuan Ma
University of Wollongong
Timetable: p. 19

An analytical solution of the well-known HJB (Hamilton-Jacobi-Bellman) equation that arises from the Merton problem subject to some general utility functions is presented for the first time. In the literature only when the utility function is of some specific form can an analytical solution be obtained. The solution presented in this talk is written in the form of a Taylor series expansion and constructed through the homotopy analysis method. The fully nonlinear HJB equation is decomposed into an infinite series of linear PDEs which can be solved analytically.

To demonstrate convincingly the success of applying the homotopy analysis method to solve this fully nonlinear HJB equation, which has many applications beyond mathematical finance, four examples are presented. The first few of these show the accuracy of the homotopy analysis method; while the latter two demonstrate the versatility of this solution approach.

113 Pressing charges: analytical solutions to the diffusion model charge carriers in dye-sensitized solar cells

Benjamin Maldon
University of Wollongong
Timetable: p. 20

Dye-Sensitized Solar Cells (DSSCs) have attracted great academic interest since their debut in O'Regan and Grätzels seminal 1991 paper, owing largely to their reduced cost and unconventional approach to renewable energy. Researchers in the area are confident that methods for optimising efficiency in DSSCs have not been completely exhausted, but the mathematical modelling in this area is limited. In this talk we will explore the dominant diffusion model, derive a new analytical solution and use it to calculate the efficiency of a DSSC.

114 Mathematical modelling of HIV dynamics in humanized mice

Alexey Martyushev
Kyushu University
Timetable: p. 21

Human immunodeficiency virus (HIV) infects and replicates primarily in CD4 T-cells, a subtype of immune system cells. A dramatic loss of CD4 T-cells within the first months post infection does not immediately disorder the host immune system that remains protective against other pathogens for many years, before occurring acquired immune deficiency syndrome (AIDS). The slow disease progression with maintaining functional immunity in chronic HIV infection is a poorly understood process, but it determines the survival of patients, limited in antiretroviral drug (ART) use. To understand the process, a mathematical model governed by ordinary differential equations (ODEs) was fitted to the time series data of the CD4 T-cell count and viral load in the peripheral blood of experimentally infected humanized mice. In the experiment, two groups of the animals were infected with two different HIV strains: (i) eight animals were infected with a wild-type (WT) virus, and (ii) six animals were infected with a genetically modified virus, deficient in the Vpu protein production. The experimental data exposed both a rapid increase of the viral load and a progressive decline of the CD4 T-cell count in the WT infected mice. Interestingly, most of the hosts infected with the Vpu-deficient virus sustained the baseline CD4 T-cell level during the trial period of 105 days, while the viral load peaked slower than in the WT group. The modelling results revealed that neither a self-proliferation rate nor a recruitment rate of CD4 T-cells from precursors can explain the difference between the two experimental groups. However, a lower production rate of infectious virions by infected cells due to the Vpu-deficiency can explain the observations. The results of this study demonstrate the protection mechanism of the CD4 T-cell level in HIV infection.

115 Continuum approximations for lattice-free multi-species models of collective cell migration

Oleksii Matsiaka
Queensland University of Technology
Timetable: p. 16

Cell migration within tissues involves the interaction of many cells from distinct subpopulations. In this work we present a discrete model of collective cell migration where the motion of individual cells is driven by random forces, short range repulsion forces to mimic crowding, and longer range attraction forces to mimic adhesion. This discrete model can be used to simulate a population of cells that is composed of $K > 1$ distinct subpopulations. To analyse the discrete model we formulate a hierarchy of moment equations that describe the spatial evolution of the density of agents, pairs of agents, triplets of agents, and so forth. To solve the hierarchy of moment equations we introduce two forms of closure: (i) the mean field approximation, which effectively assumes that the distributions of individual agents are independent; and (ii) a moment dynamics description that is based on the Kirkwood superposition approximation. The moment dynamics description provides an approximate way of incorporating spatial patterns, such as agent clustering, into the continuum description. Comparing the performance

of the two continuum descriptions confirms that both perform well when adhesive forces are sufficiently weak. In contrast, the moment dynamics description outperforms the mean field model when adhesive forces are sufficiently large. This is a first attempt to provide an accurate continuum description of a lattice-free, multi-species model of collective cell migration.

116 Steady free-surface flow over a bottom obstruction in three dimensions

Scott McCue
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Co-authors: Nicholas Buttle, Ravindra Pethiyagoda and Timothy Moroney
Timetable: p. 19

The problem of steady free-surface flow over a bottom obstruction in two dimensions has received significant attention in the literature. The linear version of the problem has an exact solution that I learnt of as an Honours student. With this solution many of the key features can be understood, such as qualitative differences between slower flows with a train of waves downstream (subcritical) and faster flows without waves (supercritical). The nonlinear version presents computational challenges that have been revisited a number of times (starting with Larry Forbes and Len Schwartz in 1982). In this talk I will consider the three-dimensional version of this problem which, at least in the nonlinear case, has not received much attention. For three-dimensional flows the wave system appears like a ship wake. I will discuss qualitative features of the waves and the effects that nonlinearity have on the flow.

117 Anomalous Diffusion on a Growing Domain

Anna McGann
University of New South Wales
Timetable: p. 15

Subdiffusive transport has been observed in many physical and biological systems leading to intensive efforts to provide robust theoretical models for this phenomenon. Additionally many physical and biological phenomena occur on domains which evolve with time. We have derived a diffusion equation, using a continuous time random walk, for particles on a domain that grows with time. This allows us to construct models that represent physical and biological systems which incorporate both diffusion and a domain that is growing. The resulting equations feature fractional derivatives. The implementation of the master equation is illustrated with a simple model of subdiffusing proteins in a growing membrane.

118 MMM, Microwaves Measure Moisture

Mark Joseph McGuinness
Victoria University of Wellington
Co-authors: Sean Bohun, William Lee and Vincent Cregan
Timetable: p. 20

Measure the moisture content of bauxite in real time on a conveyor belt as it is offloaded from a ship - this is the challenge that alumina company Rusal Aughinish brought to a European Study Group with Industry, held during one week in June last year at the Univeristy of Limerick in Ireland. Rusal are using a recently installed microwave analyser, and they sought our judgement on the reliability of the moisture measurements produced by the analyser. If you come to this talk, you will hear how we tackled the data and information provided, and what we learned about the physics of microwaves propagating through a field of polarisers. Come, and be amazed at the twist and turns of our negotiations of the path to enlightenment.

119 Evaluating burn damage and exploring first aid treatment with partial differential equations and *in vivo* Porcine experiments

Sean McInerney
Queensland University of Technology
Co-authors: Matthew Simpson and Elliot Carr
Timetable: p. 22

A burn is a common injury which inflicts a high proportion of people at some point in their life. Despite this, many people are uncertain of what to do if they or someone they are responsible for is inflicted with a burn. Through the use of mathematical modelling, in conjunction with experimental data, this talk will begin to address how to measure potential damage to tissue and the effectiveness of different first aid treatments. In particular, the type of burn that is investigated is a scald burn on in vivo pigs, where the wound is treated using water of varying temperatures, applied for different periods of time. Due to how thin the skin is, a single probe is placed below the tissue to track temperature over time. This limitation in spatially variable data necessitates a single layer, one dimensional model, to allow for parameter inference to be performed. By calibrating the mathematical model to the experimental data, approximations of thermal diffusivity and other model parameters are obtained. With the calibrated model, a temperature profile can be extended in space and time to infer information not captured in the experimental data. A novel metric for potential damage to tissue is also proposed in an attempt to quantify harm and explore the effects of different scenarios. This metric incorporates the amount of tissue that exceeds some threshold temperature and for how long. This metric, alongside the calibrated mathematical model, provides insight into the damage caused by burns and different approached to reduce this damage.

120 The impact of stem cell division models in epithelial multi-cellular tissue modelling

Claire Miller
The University of Melbourne
Timetable: p. 19

Proliferation of stem cells is critical to normal healthy function in epithelial tissues. These tissues have very specific structures depending on their type. Using the skin, specifically the epidermis, as an example stem cells proliferate only in a single basal layer of the tissue. Consequently, being able to maintain the stem cell population in this layer during division is an important consideration for mathematical models of the tissue under normal homeostatic conditions.

We have developed an agent-based multi-cellular computational model to simulate tissue homeostasis in the epidermis. We have identified that division modelling methodologies that are currently used cause loss of stem cells from the proliferative layer and, ultimately, from the tissue completely. A common fix for this issue is to artificially pin the stem cells to the basal layer. This is, however, unphysiological, and we suggest an alternative more mechanistic approach which uses a rotational force during the daughter cell separation phase of the cell division model.

In this talk we will explain why stem cell loss occurs from a base proliferative layer using traditional division models and then present our new approach. We will also compare the impact of the approaches on simulated epidermal tissue function.

121 Accurate error bounds for linear systems using H-matrices

Atsushi Minamihata
National Institute of Advanced Industrial Science and Technology
Co-authors: Takeshi Ogita and Shin'ichi Oishi
Timetable: p. 14

A used verification method for a linear system $Ax = b$ uses an approximate inverse matrix R. We need to evaluate an inclusion of RA in this method. We focus on an inclusion of RA by using a matrix multiplication with rounding down for lower bounds and *a priori* error estimation of matrix multiplication for upper bounds, and present an accurate error bounds.

122 A modern linear algebra library for C++17

Tim Moroney
Queensland University of Technology
Timetable: p. 14

Numerical linear algebra underpins much of computational science. Software such as MATLAB has demonstrated the benefit of providing linear algebra facilities to practitioners in a natural, mathematical-inspired language. For C++, libraries such as Eigen and Armadillo have served the community well for many years. But these libraries were designed and written for a much different language: modern C++ includes features such as auto type deduction, move semantics and most recently class template argument deduction that have quickly changed the idioms and expectations of programmers. We present a linear algebra library for C++17 that comes as close as possible to MATLAB, but no closer in its syntax and semantics, while retaining the look and feel of a modern C++ library. Expression templates with hooks for BLAS and LAPACK provide the implementations for the underlying low-level routines. We demonstrate how straightforward it is to translate MATLAB code to this environment, and the immediate performance gains provided by doing so.

123 A level set based numerical scheme for doubly connected Hele-Shaw flow

Liam Morrow
Queensland University of Technology
Timetable: p. 12

A Hele-Shaw cell is an experimental apparatus consisting of two flat plates separated by a small gap filled with a viscous fluid and a inviscid fluid is injected. Significant attention has been devoted to the study of fingering patterns which develop in a Hele-Shaw cell due to the Saffman-Taylor instability. Mathematically, these problems are typically treated by assuming the inviscid fluid is surrounded by an infinite body of viscous fluid. Here I consider a related problem when the inviscid bubble is surrounded by a finite amount of fluid such that we have two interfaces to solve for. While this problem has previously been studied analytically, there is a lack of numerical schemes which solve the full nonlinear moving boundary problem. Here we present a robust level set based scheme in both radial and channel geometries. We show that this scheme is able to replicate the characteristic fingering patterns up to the point where one of the interfaces bursts through the other.

124 The geometry of a three-dimensional invariant manifold in a four-dimensional slow-fast system

Elle Musoke
The University of Auckland
Timetable: p. 11

Neurons, electric circuits and chemical reactions are examples of systems in which some variables change much more slowly than others. When a system has the defining characteristic of variables evolving on different time scales, we say that it is slow-fast. We consider the four-dimensional Olsen model for peroxidase-oxidase reaction that does not have a clear split into slow and fast variables. Fenichel theory guarantees the existence of so-called slow manifolds and associated stable and unstable manifolds that are locally invariant. Previous studies focused on a reduced three-dimensional version of the Olsen model with a one-dimensional saddle slow manifold having a two-dimensional stable manifold. Building on this work, we use numerical continuation methods in conjunction with appropriately defined boundary-value problems to compute two-dimensional submanifolds of the largely unexplored three-dimensional stable manifold of a slow manifold in the full four-dimensional system.

125 Revisiting delay-embedding by using Hilbert-Schmidt integral operator theory for dynamical reconstruction

Naoto Nakano
Kyoto University
Timetable: p. 16

Delay embedding is well-known for non-linear time-series analysis, and it is used in several research fields. Takens theorem ensures validity of the delay embedding analysis: embedded data preserves the topological properties possessed by the original dynamics so long as one embeds it within some phase space of sufficiently large dimension. This means that, for example, an attractor can be reconstructed by the delay coordinate system topologically. However, configuration of embedded data may easily vary with the delay width and the delay dimension, namely, "the way of embedding. Here, we investigate the mathematical structure of the framework of delay-embedding to provide ansatz to choose the appropriate way of embedding, in order to utilise for time-series prediction. In short, mathematical theories of the Hilbert-Schmidt integral operator and the corresponding Sturm-Liouville eigenvalue problem underlie the framework. We will show some numerical results of the present method.

126 A fast numerical method for ideal fluid flow in domains with multiple stirrers

Mohamed Nasser
Qatar University
Co-authors: Christopher C. Green
Timetable: p. 14

A collection of arbitrarily-shaped solid objects, each moving at a constant speed, can be used to mix or stir ideal fluid, and can give rise to interesting flow patterns. Assuming these systems of fluid stirrers are two-dimensional, the mathematical problem of resolving the flow field - given a particular distribution of any finite number of stirrers of specified shape and speed - can be formulated as a Riemann-Hilbert problem. I show that this Riemann-Hilbert problem can be solved numerically using a fast and accurate algorithm for any finite number of stirrers based around a boundary integral equation with the generalized Neumann kernel. Various systems of fluid stirrers are considered, and my numerical scheme is shown to handle highly multiply-connected domains (i.e. systems of many fluid stirrers) with minimal computational expense.

127 Nitrogen removal in the activated sludge process

Mark Nelson
University of Wollongong
Timetable: p. 19

The activated sludge process is the most widely used process for the biological treatment of both domestic and industrial wastewaters. Wastewater treatment plants based on the activated sludge process are in widespread use in both developed and developing countries.

The activated sludge model number 1 is an internationally accepted standard for activated sludge modeling. This model describes nitrogen and chemical oxygen demand within suspended-growth treatment processes, including mechanisms for nitrification and denitrification.

We analyse the biological treatment of a wastewater when a cascade of three reactors is used. The reactor configuration consists of an anaerobic reactor followed by an anoxic reactor followed by an aerobic reactor. The process configuration includes one settling unit and two recycle units. The settling unit is placed after the aerobic reactor and its recycle stream is fed into the anoxic reactor. The recycle units transfer to and fro between the anoxic and the anaerobic reactors.

A combination of direct numerical integration with continuation methods is used to investigate the steady-state behaviour of the system. We investigate how the operation of the recycle units effects the concentration of total nitrogen in the effluent stream and identify conditions for effective nitrification and denitrification to occur in the reactor.

In addition to identifying operating conditions which minimise the total nitrogen in the effluent stream we conclude that continuation methods provide the right tool to investigate how changes in process parameters effect outputs in a systematic manner

128 Modelling collective cell migration in a channel

Zoltan Neufeld
The University of Queensland
Co-authors: Ross Bennett
Timetable: p. 16

The coordinated collective migration of cells during embryogenesis is key to the development of vertebrates, and improper migration can lead to severe developmental diseases and deformities. As a simple model for such cell migration we study the particle based Vicsek model in a channel geometry with a constant input flux. The simulations produce two distinct types of motion - one corresponds to desired, well-ordered migration, while the other corresponds to undesirable and disordered migration. We characterise the different types of collective behaviours and propose a theoretical description to determine the conditions for coherent collective cell migration.

129 Non-stationary nonparametric and regularised time series analysis of observed atmospheric dynamics

Terry O'Kane
CSIRO
Co-authors: DP Monselesan, JS Risbey, I Horenko and CLE Franzke
Timetable: p. 22

For many atmospheric phenomena, low frequency variability manifests as transitions between quasi-stationary states or regimes, often initiated by weak stochastic forcing of the large scale slow modes by the fast-noisy small scales, or through the organised amplification of initially small disturbances via the inverse energy cascade such as occurs in quasi-two dimensional geophysical flows. In multi-scale systems time dependence of the model parameters can be induced by the influence of the unresolved scales leading to large scale regime transitions between quasi-stationary states.

When pre-filtering has been performed, intrinsic variability on timescales shorter than the averaging period is removed and causal connections are affected. Analysis based solely on methods where the dimensionality is reduced such that only the leading few modes are retained, often justified in terms of projection onto an arbitrarily determined slow manifold, can also be interpreted as a form of pre-filtering. Where scale separation is absent, arbitrary filtering and truncation of the underlying data, common to many studies of low frequency climate variability, can lead to the misrepresentation of the relative importance of the drivers of variability at given spatio-temporal scales. In general, more sophisticated stochastic approaches to mode reduction must be applied and, in particular, where some form of parameterization of the unresolved scales is incorporated. Determining the parameters of the optimal stochastic model in the relatively short timeseries of the available (atmospheric reanalysis) data represents a challenge.

Here, we apply a data-driven multiscale method that allows for approximation to non-stationary dynamical processes, including parameterization of subgrid scales by stochastic forcing. This work

applies the finite element, bounded variation, vector autoregressive method (FEM-BV-VARX), to fit a non-stationary stochastic model to the data and then apply information theoretic criteria to determine the optimal set of time evolving free model parameters. Specifically, we examine the full three-dimensional structure of the troposphere. The severe computational challenge requires dimension reduction in order to avoid ill-conditioning. Our focus is on the consequences of various dimension reduction strategies. We show that a careful and systematic approach to the problem can in fact lead to a deeper insight into the major atmospheric circulation modes and progress toward a more unified approach to analysing observational data.

130 The energy integral in the first post-Newtonian approximation for general relativity

Joe O'Leary
University of South Australia
Timetable: p. 20

The general theory of relativity is now widely accepted as providing the most accurate theory of gravity. However, the field equations of General Relativity (GR) are a system of ten non-linear, coupled partial differential equations where known solutions often exhibit such high degrees of symmetry that modelling realistic astrophysical situations is often restricted. In order to combat the complexities associated with Einstein's non-linear theory of gravity, linear approximation methods have been developed to determine n-body equations of motion and approximate solutions to the field equations of GR. The post-Newtonian (PN) approximation for general relativity is widely adopted by the geodesy and astronomy communities. Presently, the levels of accuracy required in geodetic techniques require that reference frames, planetary/satellite orbits and signal propagation be treated within the PN regime. In this talk, we present a novel derivation of the energy associated with a test particle in the first PN approximation. The integral obtained is deduced by seeking a Jacobi-like integral associated with the PN equations of motion.

131 Real beards & real networks: a spin-glass model of interacting individuals

Dion O'Neale
The University of Auckland
Timetable: p. 23

"I want to be different, just like all the other different people" sang the band King Missile. Whether they are the Beatniks of the 1950s, the punks of the 1970s, or the hipsters of today, non-conformists often tend to look the same, seemingly at odds with their goal of non-conformity. The spin-glass model, originally developed to describe the interaction of magnetic spins, and since applied to situations as diverse as the electrical activity of networks of neurons, to trades on a financial market, has recently been used in social science to study populations of interacting individuals comprised of a mix of both conformists and anti-conformists - or hipsters. Including delay effects for the interactions between individuals has been shown to give a system with non-trivial dynamics with a phase transition from stable behaviour to periodic switching between two states (let's call them bushy bearded and clean shaven). Analytic solutions to such a model are possible, but only for particular assumptions about the interaction and delay matrices. In this work we will show what happens when the interactions in the model are based on real-world networks with "small-world" effects and clustering.

132 Modelling malaria parasites' survivability the dry season

Samson Ogunlade
UNSW Sydney
Timetable: p. 12

In many malaria endemic areas, seasonal transmission occurs such that during the wet season, individuals are highly exposed to infection, but not in the dry season, when mosquito numbers decline. We seek to investigate how parasites survive the dry season without ongoing transmission. By extending an existing stochastic mathematical model, we simulated individuals who were repeatedly exposed to malaria infection over their lifetime. In our model, general and strain specific immunity were generated by the host at a rate proportional to the concentration of parasites. Hence, previous exposure to parasites reduced the parasite growth rates of subsequent infections. Our simulation predicts that individuals more exposed to malaria infection generate more general immunity which, counter-intuitively, leads to longer infection that could span the entire dry season.

The predictions of these simulations were tested using data from a cohort study. Individuals from a community were determined to be either infected or uninfected at the end of the dry season. Infected individuals were then treated and regular follow-ups were conducted to determine when individuals became infected. Survival analysis was used to determine the rate of exposure to new infections for people who were infected at the end of the dry season and people who were not infected. This analysis showed that those who were infected fastest in the study were also those who had the highest levels of infection at the start of the study (i.e. at the end of the previous dry season). Results from our work provide support for the hypothesis that highly exposed individuals may be responsible for the parasite carriage in the dry season.

133 Sparse spectral methods for PDEs on triangles with multivariate orthogonal polynomials

Sheehan Shakiban Olver
Imperial College London
Timetable: p. 19

Univariate orthogonal polynomials have a long history in applied and computational mathematics, playing a fundamental role in quadrature, spectral theory and solving differential equations with spectral methods. Unfortunately, while numerous theoretical results concerning multivariate orthogonal polynomials exist, they have an unfair reputation of being unwieldy on non-tensor product domains and their use in applications has been limited. In reality, many of the powerful computational aspects of univariate orthogonal polynomials translate naturally to multivariate orthogonal polynomials, including the existence of Jacobi operators, fast evaluation of expansions using Clenshaws algorithm and the ability to construct sparse partial differential operators, *a la* the ultraspherical spectral method [Olver & Townsend 2012]. We demonstrate these computational aspects using multivariate orthogonal polynomials on a triangle, including the fast solution of general partial differential equations.

134 Global manifolds parametrised by isochrons

Hinke Osinga
The University of Auckland
Timetable: p. 22

Isochrons are sets of points in the basin of a stable periodic orbit that have the same asymptotic phase, that is, these points synchronise with a given point on the periodic orbit. We generalise this notion to periodic orbits of saddle type by considering the parametrisations of the stable manifold by forward-time isochrons and of the unstable manifold by backward-time isochrons. Computing these families of isochrons as (un)stable submanifolds of the period-map allows us to find, represent and illustrate two-dimensional global invariant manifolds in a new and efficient way.

135 Numerical modelling and characterisation of an all-fibre laser with saturable absorber

Robert Nawiekang Otupiri
The University of Auckland
Timetable: p. 13

We present a detailed experimental and numerical study of self-pulsations in an all-fibre laser with saturable absorber. Pulses are generated in a process known as Q-switching, and we show how the pulsing behaviour depends on a variety of parameters including the pump power, the strength of absorption, as well as the decay times of gain and absorber media. To this end, we consider a system of three differential equations, initially developed by Yamada and adopted here to the experimental laser system, which consists of an erbium-doped fibre generating the required gain in combination with a thulium-doped fibre providing the necessary absorption. The dynamics exhibited by this laser system are studied with a focus on the strength of absorption; this is realised by considering, for different absorber lengths, how the system behaves as a function of the pump power. We demonstrate good agreement between the analysis of the model and experimental observations, in terms of the origin of Q-switched pulsations in a Hopf bifurcation, as well as regarding the influence of the strength of absorption on the overall behaviour of the system.

136 Nonlinear exact coherent structures in pipe flow

Ozge Ozcakir
Monash University
Timetable: p. 24

There is little computational work on travelling wave computations in pipe flows at very large R in existing literature apart from those reported in Ozcakir (2016). In this talk, we present results that extend reliable travelling wave computations through greater efficiency to a far greater Reynolds number (up to $R = 5 \times 10^5$) regime than previously reported. Firstly, we confirm that travelling waves states which are referred to as C1 and C2 in Ozcakir (2016) are indeed finite R realization of nonlinear viscous core states because of much closer agreement of numerical results with asymptotics. The second part of the talk concerns determination of a new branch of solution (WK2) which connects to Wedin-Kerswell (WK) when continued to sufficiently large R. that ascertains that it is a finite R realisation of asymptotic VWI states, with peak roll, wave, and stream amplitudes scaling as R^{-1}, $R^{-5/6}$ and $O(1)$ respectively. In the last part or the talk linear stability of travelling waves are discussed. We extend linear stability calculations to large enough R so that asymptotics of unstable eigenvalues are apparent. These scalings are in agreement with the $R^{-1/2}$, R^{-1} asymptotics for edge and meandering modes predicted by Deguchi & Hall (2016) for uni-directional shear flow. Finally, we present preliminary travelling wave calculations for non-Newtonian fluids.

137 A model of calcium dynamics in anatomically accurate parotid acinar cells

Nathan Pages
The University of Auckland
Timetable: p. 13

We construct an anatomically-accurate three-dimensional model of calcium oscillation in a cluster of parotid gland acinar cells.

Parotid acinar cells are responsible for the secretion of saliva. Olfactory and gustatory stimuli provoke the release of agonists that bind to the basal membranes of the acinar cells. This triggers a cascade of events that results in the production of IP_3, which, in turn, releases calcium ions from intracellular compartments.

The major current question in the modelling of saliva production and calcium oscillation is whether or not the complex spatial structure of the acinus, or the spatial heterogeneities within each acinar cell, have any significant effect on the calcium oscillations possible mechanism.

We will discuss how we built a computational model to answer this question. Preliminary results suggest that the spatial structure impose severe constraints on the possible mechanism that could cause calcium oscillation.

138 Using Approximate Bayesian Computation to understand the impact of climate in seasonal influenza in Australia

Jessica Penfold
The University of Adelaide
Timetable: p. 15

Influenza in humans exhibits a strong seasonal cycle in temperate climates, with a peak of varying intensity appearing each winter. However, the exact cause of this seasonal cycle remains poorly understood. We aim to develop a climate-based SIR model to understand influenza seasonality by developing a functional form of transmissibility using climate data. Using a variety of existing climate-based functional forms of transmissibility from current literature, we use modern Approximate Bayesian Computation model selection methods to choose the best functional form for climate-dependent transmissibility. By analysing a unique dataset comprising ten years of GP-reported influenza surveillance data in Sydney, we explore the problem of ensemble prediction using a weighted ensemble of models to predict future influenza seasons.

139 Modelling cell proliferation times

Catherine Penington
Macquarie University
Timetable: p. 23

Typically, discrete stochastic models of cell proliferation use a rate to determine whether or not a cell proliferates at a particular time, producing an exponential distribution for the time between proliferation events. Actual experiments, however, suggest that cells have a Gaussian distribution in their time to proliferation, with a relatively small standard deviation. This talk will discuss the similarities and differences in the group behaviour depending on the proliferation model: both the surprising match after a single time step, and the large differences as simulations progress.

140 On the evaluation of Landau constants in amplitude equations away from a critical point. Part 1: supercritical regimes

Khanh Pham
Swinburne University of Technology
Co-authors: Sergey A. Suslov
Timetable: p. 13

A classical weakly nonlinear stability analysis of shear fluid flows based on a perturbation amplitude expansion is re-considered to derive Stuart-Landau type equations that model a temporal evolution of disturbance amplitude in linearly unstable flow regimes. A robust computational procedure for evaluating Landau coefficients appearing in such amplitude equations is suggested that incorporates a generalized amplitude normalisation condition. It is proved rigorously that such a condition recovers the standard solvability condition at the critical point, where the basic flow first becomes unstable with respect to infinitesimal disturbances. It is also shown that the use of this generalised condition results in a well-posed problem for the determination of coefficients of Stuart-Landau series both at the critical point and a finite distance away from it. It is emphasised that the choice of the normalization condition required to define the Landau coefficients away from the critical point is not unique. In conjunction with the suggested computational procedure this offers a flexibility to adjust a weakly nonlinear projection of the full problem solution onto the space spanned by the basic flow vector and the eigenvector of the linearized problem to focus on the specific flow features of interest.

141 Dynamics of reactivation from latency in macaques infected with simian immunodeficiency virus

Mykola Pinkevych
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Timetable: p. 22

HIV can be effectively controlled by anti-retroviral therapy, but cannot be eradicated due to the presence of HIV in latently infected CD4+ cells that cause the reactivation of virus if a patient stops anti-retroviral treatment. However there is a lack of knowledge about the basic dynamics of reactivation of latently infected cells, because this occurs at levels below our threshold of detection. In order to answer these questions we combined mathematical modelling with a novel experimental method of sequence barcoded viruses to track the reactivation of individual latently infected cells.

Rhesus macaques were infected intravenously with a sequence-tagged SIV-M virus with $\approx 10,000$ different clonotypes. Animals were treated with antiretroviral therapy for a various times prior to treatment interruption. After interruption serum samples were subjected to gene sequencing in order to identify the frequency of individual tagged viruses. We developed a mathematical model incorporating latent cell reactivation and viral growth to analyse the experimental data. Using this model we estimate that the frequency of re-activation from latency ranges from around 20 re-activations per day to 0.5 re-activations per day, depending on the timing and duration of treatment. A single reactivated latent cell can produce an average viral load equivalent to $\approx 0.1 - 0.5$ viral copies/ml of virus, depending on assumption about duration of drug action.

The combination of the monkey model with mathematical analysis is a useful tool to understand the dynamics of reactivation from latency, the estimation of the efficacy of treatment and as a guide as to what interventions may be effective at early control of reactivation.

142 The other end of the spectrum: size-based models of marine ecosystems and fishing

Michael Plank
University of Canterbury
Timetable: p. 17

Many marine fish species can grow in body mass more than seven orders of magnitude over their lifetime. As fish grow, their target prey and their growth, mortality and reproduction rates change drastically with body mass. This means that body mass is a crucial variable in any mathematical model. Size-spectrum models put body mass foremost by doing a bookkeeping of biomass as it flows from prey to predator, and from parent to offspring. This is a different paradigm from the classical species-based predator-prey model. This talk will give an overview of size-spectrum models and the insights they have given us into marine community dynamics. Size-spectrum models are based on a generalisation of the McKendrick-von Foerster equation to a nonlinear, partial integro-differential equation. I will show some theoretical results about the equilibrium size structure and stability, as

well as applications in fisheries management and fisheries-induced evolution. Size-spectrum models are particularly suited to investigating the effects of different distributions of fishing mortality over body mass and species, which is a key question for ecosystem-based fisheries management.

143 Do T-cells compete for antigen?

Pantea Pooladvand
The University of Sydney
Timetable: p. 20

When antigen is presented to helper T-cells, the immune response is two-fold. First, the T-cells will go through rapid expansion, followed by a contraction phase which subsequently contributes to immunological memory.

It is difficult to assess the contribution of precursor frequency to the T-cell numbers at the peak of the response due to the widely differing views in recent publications. Does the initial number of T-cells determine the peak or is the T-cell response limited by the amount of antigen present?

Inspired by new experimental results from our collaborators, we introduce a simple system of ODEs to investigate this problem by considering that the T-cells compete for limited amount of antigen. We propose that this competition between T-cells limits the peak of response and we compare the dynamics from this system to our collaborators' data.

144 Shaping liquid drops by vibration

Andrey Pototsky
Swinburne University of Technology
Timetable: p. 24

We present and analyze a minimal hydrodynamic model of a vertically vibrated liquid drop that undergoes dynamic shape transformations. In agreement with experiments, a circular lens-shaped drop is unstable above a critical vibration amplitude, spontaneously elongating in horizontal direction. Smaller drops elongate into localized states that oscillate with half of the vibration frequency. Larger drops evolve by transforming into a snake-like structure with gradually increasing length. The worm state is long-lasting with a potential to fragment into smaller drops.

145 The Cardiac Cell under the Mathematical Microscope

Vijay Rajagopal
The University of Melbourne
Timetable: p. 15

Diseases of the heart such as cardiac hypertrophy and diabetes induced cardiomyopathy are symptoms of sub-cellular deregulation and remodelling of biochemical processes that govern heart muscle contraction. It is often noted that morphological and structural changes also occur in parallel to these biochemical changes. However, whether these structural changes are minor, adaptive or pathological responses to the changing conditions is largely unknown. We are developing in-silico finite element models of the heart cell that are derived from state-of-the-art structural microscopy data to investigate the role of sub-cellular structural remodelling on heart cell function. I will present results from a modelling study we conducted to investigate the effect of mitochondrial remodelling on cardiac cell bioenergetics. I will also present tools we are building to make the development of these models easier and more widely adoptable for similar investigations in other cell types.

146 Hard-core interactions in one-dimensional velocity jump models

Tertius Ralph
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Co-authors: Steve Taylor
Timetable: p. 15

Excluded-volume effects can play an important role in determining transport properties in the diffusion of particles through crowded environments. Here, the diffusion of finite-sized hard-core inter-acting particles is considered systematically using the method of matched asymptotic expansions. We will use the Langevin approach to diffusion where stochastic increments are applied to the velocity rather than to the space variable. The result is a non-linear PDE for the one-particle probability density function taking into account crowding effects. Stochastic simulations will be used for a comparison with the analytic/numerical solutions derived. The analytic/numerical solutions compare well with stochastic simulations provided the excluded volume fraction is small.

147 A Distribution-Moment approximation for coupled airway dynamics of the airway wall and airway smooth muscle

Anand Rampadarath
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Co-authors: GM Donovan
Timetable: p. 11

Asthma is fundamentally a disease of airway constriction. Due to a variety of experimental challenges, the dynamics of airways are poorly understood. Of specific interest is the narrowing of the airway due to forces produced by the airway smooth muscle (ASM) wrapped around each airway. The interaction between the muscle and the airway wall is crucial for the airway constriction which occurs during an asthma attack. While crossbridge theory is a well-studied representation of complex smooth muscle dynamics, and these dynamics can be coupled to the airway wall, this comes at significant computational cost – even for isolated airways. Because many phenomena of interest in pulmonary physiology cannot be adequately understood by studying isolated airways, this presents a significant limitation. We present a distribution moment approximation of this coupled system as well as comparative results between this approximation and the full PDE based model. These results show that in many situations the distribution moment approximation is a viable option which provides an orders of magnitude reduction in computational complexity; this is valuable not only for isolated airway studies, but moreover offers the prospect that rich ASM dynamics might be incorporated into interacting airway models where previously this was precluded by computational cost.

148 A multiscale approximation of a Cahn–Larché system with phase-separation on the microscale

Lisa Reischmann
University of Augsburg
Timetable: p. 22

We consider the process of phase-separation of a binary system under the influence of mechanical deformation and we derive a mathematical multiscale model, which describes the evolving microstructure taking into account the elastic properties of the involved materials. Motivated by phase-separation processes observed in lipid monolayers in film-balance experiments, the starting point of the model is the Cahn–Hilliard equation coupled with the equations of linear elasticity, the so-called Cahn–Larché system. Owing to the fact that the mechanical deformation takes place on a macroscopic scale whereas the phase separation happens on a microscopic level, a multiscale approach is imperative. We assume the pattern of the evolving microstructure to have an intrinsic length scale associated with it, which, after nondimensionalisation, leads to a scaled model involving a small parameter $\varepsilon > 0$, which is suitable for periodic-homogenisation techniques. For the full nonlinear problem the so-called homogenised problem is then obtained by letting $\varepsilon \to 0$ using the method of asymptotic expansion. Furthermore, we present a linearised Cahn–Larché system and use the method of two-scale convergence to obtain the associated limit problem, which turns out to have the same structure as in the nonlinear case, in a mathematically rigorous way. Properties of the limit model will be discussed.

149 Thin-film multiphase modelling of collagen gel mechanics

James Reoch
The University of Adelaide
Timetable: p. 15

Cells are often grown within collagen gels *in vitro* for applications in tissue engineering. The behaviour of cells is regulated by their mechanical environment; however the forces exerted by cells in turn affect the mechanical behaviour of the gel. We aim to gain more insight into the interactions between the cells and the gel using mathematical modelling. We have developed a multiphase model for this system, incorporating cells and their traction forces alongside chemical effects like osmosis. We have modelled this problem to date in one-dimensional Cartesian and spherical coordinates, mimicking experiments performed with spheres of collagen gel. However, often these gels are produced in Petri dishes, resulting in a thin disc. We have therefore modified our model to explore this type of geometry. We show how, in certain parameter regimes, we are able to exploit thin-film approximations and reduce the two-dimensional system to a leading-order, one-dimensional model.

150 Modelling HIV latency using distribution of lifespans of infected cells

Josephine Reyes
University of New South Wales
Timetable: p. 24

Understanding the mechanisms of HIV latency is important in the development of strategies for managing infection. Time from infection until production of virus has been shown to vary among infected cells, hence challenging the dichotomous assumption that cells are either latent or productively infected at time of infection. We will explore the implications of an alternative hypothesis that times from infection to producing virus (reactivation) follow a probability distribution, of which latency is just an extreme of this spectrum. We show the emerging dynamics from this mathematical model and test its ability to explain features or reservoir formation and decay observed in SIV data. Analysis of SIV DNA levels in macaques that start treatment at different times shows that the decay rates of cells are different in early and late initiation of treatment. Modelling suggests that data can be explained by a spectrum of time-to-viral production by infected cells.

151 Age-specific heterogeneity in CD8+ T-Cell homeostasis

Arnold Reynaldi
UNSW Sydney
Co-authors: Norah L. Smith, Timothy E. Schlub, Vanessa Venturi, Brian D. Rudd and Miles P. Davenport
Timetable: p. 20

Infants and the elderly are more susceptible to infection as a result of an immature or senescent immune system. However, little is understood about the development, persistence and death of immune cells over the lifespan. CD8+ killer T-cells are a subset of the immune cells that is important in controlling infections by killing infected cells. In this study, we aim to understand the maintenance of T-cells over the lifespan. Recently, we have developed a novel mouse model in which we can track the survival of T-cells produced at various stages of development. This provided numbers of cells produced at different ages, and how long they persisted. Comparing various mathematical models of varying complexity, the population of T-cells can be described by a three-parameter model including an initial rate of decay (of cells produced at birth), how this initial decay rate slows with age of the animal, and how, for cells produced at any age, the rate of decay slows with the age of the cell. T-cells produced during infancy showed the most rapid early decay (half-life of 14 days). However, the decay of these cells slowed, and a population of T-cells produced at birth persisted for the life of the animal. Cells produced later in life (produced at 25 weeks) display a high level of persistence. A mathematical model was also developed to understand how cell production and survival leads to a developmental layering of cells produced at different ages, and how this contributes to the total T cell pool in adult life. Based on the model, in a 100-day-old mouse, 43% of its T-cells were produced from the thymus within the last 30 days. In contrast, in a 300-day-old mouse, only 20% of the cells were produced within the last 30 days. Overall, this modeling indicates that the age at which cells were produced contributes to the heterogeneity observed in the adult T-cell population.

152 Fine-grained multi-factor hail damage modelling

Melanie Roberts
IBM Research Australia
Timetable: p. 19

A fine-grained multi-factor estimation of crop-hail damage is required to progress from manual inspection of crops post-event to automated assessment and accurate forecasting of the expected impact on agricultural areas. Such automated processes will enable more accurate claims processing, improve customer satisfaction and reduce insurance losses. This paper demonstrates the value of Gaussian processes for the construction of such a multi-factor model of crop-hail damage. This is underpinned by a survey of public datasets and a description of the target dataset to support an operational crop-hail damage model.

153 Is your family pet a source of antibiotic resistance?

Mick Roberts
Massey University
Timetable: p. 17

Antibiotics are used extensively to control infections in domestic pets, either in the form of a course of oral tablets or a single injection. There are several methods by which bacteria can develop resistant strains, including mutation during reproduction and horizontal gene transfer. We present a model for the development of antibiotic resistance within a single host animal. We derive criteria for a mutant strain to replace the existing wild-type bacteria, and for co-existence of the wild-type and mutant. Where resistance develops through horizontal gene transfer, we derive criteria for the resistant strain to be excluded or co-exist with the wild-type. We show how resistance may develop during antibiotic treatment when either or both mechanisms operate.

154 Neurons, temperature and timescales: what GSPT might tell us about temperature regulation?

Timothy Roberts
The University of Sydney
Co-authors: Martin Wechselberger
Timetable: p. 22

The human body can only survive if its core temperature lies within a narrow range of permissible values. Thus, regulation of core body temperature is a critical task for the body to perform. The preoptic area and anterior hypothalamus (PO/AH) of the brain is thought to play a key role in this process, acting as an integrative centre for temperature regulation. It is responsible for monitoring the body's core temperature, collecting information about ambient environmental temperature (via communications from neurons elsewhere in the body) and integrating this data to determine and control how the body should respond to changing conditions. Current electrochemical models of PO/AH neuron function appear to be able to describe the varied behaviours required to monitor core body temperature; however, the mathematical and physiological mechanisms that allow this are not fully understood. In this talk I will look at how the methods of bifurcation theory and geometric singular perturbation theory (GSPT) might help us to understand how model neurons function and what this can tell us about the physiological mechanisms underlying temperature sensitivity.

155 Projective integration of multiscale ODEs via Dynamic Mode Decomposition

Tony Roberts
The University of Adelaide
Timetable: p. 13

Multiscale ODEs commonly arise in discretisations of PDEs, in agent based methods, and in molecular simulations. The so-called projection integration uses short bursts of such detailed microscale simulations, followed by extrapolation over a macroscale time, to efficiently compute simulations over long times. Here I introduce using Dynamic Mode Decomposition (DMD) to perform the extrapolation. DMD fits a low rank sum of exponentials to the microscale simulation and so should distinguish microscale and macroscale modes for better filtering, and hence make better forecasts over the macroscale simulation.

156 Who gets the girl? On the operational sex ratio as an index for male strategy

Danya Rose
The University of Sydney
Timetable: p. 24

The operational sex ratio (OSR) is defined as the ratio of eligible males to fertile females in a population. If males compete with each other for paternities according to their father's strategy, does mating with as many females as possible (multiple-mating), or does preventing other males access to one's own mate (mate-guarding) win out? We build a two-strategy ODE model of a primate-like population in which males inherit their father's mating strategy when they mature, and investigate the correlation between OSR and dominant strategy.

157 Demography determines gene drives success in eradicating pests

Joshua Ross
The University of Adelaide
Co-authors: Kym Wilkins, Thomas Prowse, Phill Cassey and Paul Thomas
Timetable: p. 22

Synthetic, selfish gene drives may offer a novel solution to the control of invasive, alien species. Mathematical modelling of these systems is important for a variety of reasons, from ensuring the risks to non-target populations is low, to determining if the biased inheritance and gene-drive strategy is able to outcompete the rise of resistance alleles in the population, hence leading to a suitable strategy. Most models to date have assumed mass action mating. This form of reproduction is inappropriate for vertebrate pest populations (e.g., mice), and we find it gives rise to overly optimistic conclusions regarding gene drive efficacy. More realistic polygynous mating demonstrates that standard implementations of gene-drive strategies will be unsuccessful in the absence of an Allee effect. An Allee effect may assist gene drive success, but efficacy appears to be highly sensitive to the strength of the Allee effect. Our results indicate that a detailed understanding of the demography of the species is necessary for evaluating gene drive strategies.

158 Linear systems in Matlab with zero residual

Siegfried Rump
Technical University Hamburg
Timetable: p. 17

Several examples of linear systems are given for which the residual of the computed approximation (computed in working precision) is precisely zero. Nevertheless, the computed approximation by Matlab's backslash operator is highly inaccurate, and often no warning is issued. Examples for matrix inversion in that spirit are given. Moreover, it is demonstrated that rounding the exact real result to the nearest floating-point numbers may be worse than using an approximation computed by some floating-point algorithm.

159 But I'm a data scientist too, aren't I?

Louise Ryan
University of Technology, Sydney
Timetable: p. 14

The statistics profession is in a period of disruptive change, heralded by explosive growth in information technology and the big data revolution. New specialties such as machine learning, data science and analytics seem to go from strength to strength and sometimes it seems like statistics is being discarded like one of last decades fashion embarrassments. In this presentation, I will offer some perspectives on the changing landscape for statistical science. I will draw on some of my own recent projects where statistics as usual fall short and outline some of the areas where I think there are great opportunities for bringing a statistical perspective to the broader data science arena. I have already given several versions of this presentation at venues around the world, but have updated it with some recent new developments.

160 Why does an inverted-flag flap in a uniform steady flow?

John Elie Sader
The University of Melbourne
Timetable: p. 25

The dynamics of a cantilevered elastic sheet, with a uniform steady flow impinging on its clamped end, have been studied widely and provide insight into the stability of flags and biological phenomena. Recent measurements show that reversing the orientation of the sheet, with the flow impinging on its free-edge, dramatically alters its dynamics. In contrast to the conventional flag, which exhibits (small-amplitude) flutter above a critical flow speed, the inverted-flag displays large-amplitude flapping over a finite band of flow speeds. In this talk, a combination of mathematical theory, scaling analysis, numerical simulations and measurement is used to investigate the origin of this large-amplitude flapping motion. Flapping is found to be a vortex-induced vibration and is predominantly periodic, with a transition to chaos as flow speed increases. These findings have implications to leaf motion and other biological processes, such as the dynamics of hairs, because they also can present an inverted-flag configuration.

161 Topographical uniqueness condition for the weak form of a linear depth-averaged vorticity model

Balazs Sandor
Griffith University
Timetable: p. 21

The vorticity form of the depth-averaged shallow water equations are considered and simplified up to a linear model based on ongoing research of the authors. In this talk we would like to examine this minimal model from the mathematical point of view. Using the Lax-Milgram theorem, a uniqueness condition has been deduced for the weak form of the model. This uniqueness condition has straight geometrical consequences on the bed topography of the fluid body. We would like to present this result and also some of the first application attempts. We have open questions about the connection of the uniqueness of the solutions and the evolution of circulating domains via the variation of topographical parameters and whether a solution which describes splitting circulating domains is necessarily non-unique.

162 The sausage-string structure of mode-locking regions of piecewise-linear maps

David John Warwick Simpson
Massey University
Timetable: p. 24

Mode-locking regions are subsets of parameter space where a dynamical system is entrained to a fixed frequency or rotation number. In two-parameter bifurcation diagrams they appear as narrow regions ordered by rotation number. For piecewise-linear maps they have pinch points, called shrinking points, and an overall structure that resembles a string of sausages. This has been identified in models of diverse systems, including power converters, neurons, and economics, and remains incompletely understood. In this talk I will explain how each shrinking point organises the bifurcation structure locally. A handful of key scalar quantities assigned to a shrinking point govern the relative size, properties, and arrangement of nearby mode-locking regions. In sectors radiating from a shrinking point, periodic, quasiperiodic, and chaotic dynamics are accurately captured by a one-dimensional skew sawtooth map.

163 Optimal quantification of contact inhibition in cell populations

Matthew Simpson
Queensland University of Technology
Timetable: p. 23

Contact inhibition refers to a reduction in the rate of cell migration and/or cell proliferation in regions of high cell density. Under normal conditions contact inhibition is associated with the proper functioning tissues, whereas abnormal regulation of contact inhibition is associated with pathological conditions, such as tumour spreading. Unfortunately, standard mathematical modeling practices mask the importance of parameters that control contact inhibition through scaling arguments. Furthermore, standard experimental protocols are insufficient to quantify the effects of contact inhibition because they focus on data describing early time, low-density dynamics only. Here we use the logistic growth equation as a caricature model of contact inhibition to make recommendations as to how best to mitigate these issues. Taking a Bayesian approach we quantify the trade-off between different features of experimental design and estimates of parameter uncertainty so that we can re-formulate a standard cell proliferation assay to provide estimates of both the low-density intrinsic growth rate, λ, and the carrying capacity density, K, which is a measure of contact inhibition.

164 Needlet approximation on the sphere

Ian Sloan
University of New South Wales
Timetable: p. 12

Spherical needlets are highly localized radial polynomials on the sphere $\mathbb{S}^d \subset \mathbb{R}^{d+1}$, $d \geq 2$, with centres at the nodes of a suitable quadrature rule. The original spherical needlet approximation as proposed by Narcowich, Petrushev and Ward makes use of coefficients defined by inner product integrals. In this talk I first review the needlet construction, and then report on recent joint work with Yu Guang Wang, Q Thong Le Gia and Robert Womersley, which uses an appropriate quadrature rule to construct a fully discrete (and hence truly constructible) needlet approximation. We prove that the global fully discrete approximation has rates of convergence in Sobolev spaces $\mathbb{W}_p^s(\mathbb{S}^d)$, for $2 \leq p \leq \infty$, that for $s > d/p$ are exactly the same as for the original needlet approximation. We also demonstrate that these rates are achieved in numerical practice.

165 Hunting for a moving target on a graph and building dynamical systems from complex networks

Michael Small
The University of Western Australia
Timetable: p. 23

I introduce the problem of hunting for a moving target on a complex network (a large graph with heterogeneous and long-tailed degree distribution). In particular: how long will it take, on average for the hunter to capture the target? A related question, in the particular case where nodes of the graph may be thought of as states of the dynamical systems and links as observed transitions (in the deterministic setting, but where we have only been allowed finitely much data), is how does one move about the graph so that the sequence of observed states best emulate independent output of the same deterministic dynamical system?

166 The effect induced in the far-field pattern by the rounding of corners of a scatterer illuminated by a plane wave electromagnetic field

Paul Smith
Macquarie University
Co-authors: Audrey Markowskei
Timetable: p. 25

When a perfectly electrically conducting two-dimensional scatterer, which is smooth except at finitely many sharp corner points, is illuminated by an E-polarised electromagnetic plane wave, the surface current density exhibits singularities at those corner points, whilst in the H-polarised case the surface density exhibits singularities in its derivative at those points. Once the corners are rounded, the surface density becomes non-singular. It is of interest to examine the impact of this rounding upon observed physical quantities such as the far-field as the rounding becomes more pronounced.

An integral equation formulation is a satisfactory basis of numerical studies of the scattering of plane waves by a smooth obstacle; its solution provides a surface density from which all physical quantities can be calculated. Whilst this approach can be adapted to accommodate obstacles with sharp corners, efficient methods for the calculation of the desired surface density depend upon the introduction of graded meshes. In this presentation, we describe the appropriate modifications that are subsequently employed to quantify the changes induced in the far-field pattern when the corners are rounded. We examine the difference of the far-field pattern from that of the unrounded structure as a function of the parameter $k\rho$ where k is the wavenumber and ρ is the radius of curvature of the rounded corner. It is found that the difference is $O((k\rho)^m)$ as $k\rho$ approaches zero, for some positive exponent m depending upon boundary and other conditions. A number of structures with single or multiple corners are examined with a variety of boundary conditions: E- or H-polarised cases as well as the impedance loaded case.

167 Optimization in the Darkness of Uncertainty: when you don't know what you don't know, and what you do know isn't much!

Kate Smith-Miles
The University of Melbourne
Timetable: p. 21

How do we find the optimal solution for a constrained multi-objective optimisation problem when we have no analytical expression for the objective functions, and very limited function evaluations within the huge search space due to the expense of measuring the objective functions? Calculus cant help you, and trial and error is not an option! This talk will describe a common practical optimization problem found in many industrial settings with these challenges, and introduce some methods for expensive black-box optimization. Finally, we will address the question of how best to evaluate the performance of such methods by generating new test instances with controllable characteristics.

168 From birds and bees to flying machines

Mandyam Srinivasan
The University of Queensland
Timetable: p. 16

Flying insects and birds are remarkably adept at seeing and perceiving the world and navigating effectively in it. This presentation will describe our recent progress in understanding how honeybees and birds (budgerigars) use their vision to control and regulate their flight speed, measure travel distance, negotiate narrow passages safely, avoid mid-air collisions and perform smooth landings, using computational principles that are often elegant and unprecedented. It will conclude with an update of our advances in the design and testing of biologically inspired vision systems for the guidance of autonomous aerial vehicles.

169 Domain Decomposition applied to the thin-plate spline saddle point problem

Linda Stals
Australian National University
Timetable: p. 15

Data fitting is an integral part of a number of applications including data mining, 3D reconstruction of geometric models, image warping and medical image analysis. A commonly used method for fitting functions to data is the thin-plate spline method. This method is popular because it is not sensitive to noise in the data.

We have developed a discrete thin-plate spline approximation technique that uses local basis functions. With this approach the system of equations is sparse and its size depends only on the number of points in the discrete grid, not the number of data points. Nevertheless the resulting system is a saddle point problem that can be ill-conditioned for certain choices of parameters. In this talk I will present a domain decomposition based preconditioner that results in a well conditioned system for a wide choice of parameters.

170 Stability of the non-Newtonian asymptotic suction boundary layer

Sharon Stephen
The University of Sydney
Co-authors: Paul Griffiths
Timetable: p. 23

The stability of an asymptotic suction boundary layer is considered to investigate the effect of non-Newtonian viscosity on the transition process from a laminar to a turbulent flow at large Reynolds number. As such, we investigate the flow past a flat plate, with uniform suction applied at the surface, for a non-Newtonian flow. Suction is applied in practical situations to delay transition to turbulence. This flow exhibits a constant boundary-layer thickness, making it attractive to numerical and theoretical analysis. For a Newtonian flow, recent interest has been in identifying coherent structures [1] and a self-sustaining vortex/Tollmien-Schlichting wave interaction [2]. The focus here is the effect of a non-Newtonian fluid and is motivated by applications to use non-Newtonian flows to delay transition to turbulence. In this first investigation for non-Newtonian flows we consider the effect on the linear stability of lower branch neutral modes that are governed by a triple-deck structure.

[1] Deguchi, K. and Hall, P. 2014 Free-stream coherent structures in parallel boundary-layer flows. J. Fluid Mech., 752, 602-625.

[2] Dempsey, L. J. and Walton, A. G. 2017 Vortex/Tollmien-Schlichting wave interaction states in the asymptotic suction boundary layer. Q. Jl Mech. Appl. Math, 70, 187-213.

171 Why oversized holes in microstructured optical fibres?

Yvonne Stokes
The University of Adelaide
Co-authors: Michael Chen
Timetable: p. 15

A microstructured optical fibre (MOF) is a long and thin glass fibre, typically around 150μm in diameter and more than a km in length, containing a pattern of air holes, with diameters comparable to the wavelength of light, that run parallel to the axis of the fibre. Such a fibre is made by heating and stretching a preform of 1–3cm in diameter and 10–20cm in length, with appropriate internal structure, a process known as fibre drawing. For a desired set of optical properties, the holes in the fibre must have specific shapes be arranged in a specified pattern. Mathematical modelling is essential for solving the inverse problem of determining the preform geometry and draw parameters required to obtain a desired fibre.

Asymptotic techniques have been used to obtain an efficient model of fibre drawing yielding solutions that match well with experiments. However, at times the air channel diameters seen in experiments are significantly larger than predicted by the model, most notably for air channels of larger initial diameter and when the fibre is drawn using a high tension or draw ratio. Using a modified model, that takes account of the air in the channels and the temperature gradient along the neck-down region from preform to fibre, we will investigate the possibility that the air in the channels results in a pressure that, in turn, causes channel diameters larger than would otherwise be seen.

172 Lie-Markov models derived from finite semigroups

Jeremy Sumner
University of Tasmania
Timetable: p. 13

In recent years, our research group has developed mathematical methods to construct "Lie-Markov" models and explored their particular application to phylogenetics. These models occur as continuous-time Markov chains and satisfy the strong condition that the associated transition matrices are closed under matrix multiplication. In this talk, I will present a general method for deriving a Lie-Markov model from a given finite semigroup presented in abstract form. If the degree of the semigroup is k, the resulting model is a Markov chain on k states and multiplicatively closure follows manifestly from the product rule in the semigroup. Remarkably for $k = 2, 3, 4$ states, we found that the resulting Markov chains are irreducible if and only if the underlying semigroup occurs as a direct product of cyclic groups and/or left-zero semigroups. Whether this property continues to hold for any number of states is an open problem.

173 On the evaluation of Landau constants in amplitude equations away from a critical point. Part 2: subcritical regimes and a physical example

Sergey Suslov
Swinburne University of Technology
Timetable: p. 13

We show how the procedure for deriving Stuart-Landau type equations that model a temporal evolution of disturbance amplitude (as outlined in Part 1 of our talk) is extended to include linearly stable flow regimes. Specifically, here we focus on deriving a low-dimensional model capable of predicting the threshold disturbance amplitude below which the solution returns to its undisturbed state and above which it undergoes the transition to a different nonlinear state in systems bifurcating subcritically. Unlike supercritical flows subcritical systems are prone to resonances that are traced back to the interaction between the mean flow distortion induced by the decaying fundamental disturbance harmonic and other decaying disturbance modes. Here we illuminate the reasons why such difficulties are not encountered in supercritical systems and suggest a methodology of deriving a two-equation dynamical system of coupled amplitude equations with non-singular coefficients. Such a model resolves resonances and is capable of predicting the threshold amplitude for disturbed weakly nonlinear subcritical flows. As an example, the developed procedure is applied to subcritical plane Poiseuille flow. The developed model predictions are found to be in a reasonable agreement with experimentally detected threshhold amplitudes reported in literature.

174 The information geometry of sensor management

Arthur George Suvorov
RMIT University
Timetable: p. 20

In problems of parameter estimation from sensor data, the Fisher metric allows for a measure of the information content of a particular configuration. However, when measurements are drawn from distributions which are dependent on the positions, velocities and angles made between the sensors, a family of Fisher metrics arise. The problem then turns from optimising a given Fisher metric, to identifying an optimal member from a family, once a suitable definition of optimality is obtained. It has been shown that the collection of all Fisher metrics on a manifold itself forms a Riemannian manifold, often referred to as the sensor manifold. Each point of this sensor manifold corresponds to a Fisher metric. We show that the distance measure on this manifold provides a means of finding an optimal, dynamical sensor configuration from an information-theoretic standpoint. We also show that geodesics on this space have physical interpretations related to sensor management, and provide several worked examples to demonstrate the mathematical machinery.

175 Symmetrical few-body orbits

Winston Sweatman
Massey University
Timetable: p. 20

In this talk I will consider some few-body orbits of the gravitational N-body problem. Although somewhat artificial, orbits with symmetry or in lower dimension space can provide insight and inspiration for the more general problem.

176 Some remarks on a time-explicit particle methods for flow problems

Daisuke Tagami
Kyushu University
Timetable: p. 23

We have recently obtained error estimates of a generalised particle method for convection-diffusion problems, and have now continued to estimate it for the incompressible Navier–Stokes equations.

When introducing an implicit scheme in time based on the predictor-corrector strategy to particle methods for the incompressible Navier–Stokes equations, we need to solve the pressure Poisson equation at each time step. However, the pressure Poisson equation causes the increasing of computational costs, especially in case of huge computational models appearing in High-Performance Computing (HPC) fields. Therefore, many researchers in HPC fields introduce explicit schemes in time based on an equation of state of gas.

In this talk, we regard one of such explicit schemes as a perturbation problem derived from the compressible Navier–Stokes equations, and give some remarks on the relations between them and the incompressible Navier–Stokes equations. Moreover, we show some numerical results by using a time-explicit particle methods for the incompressible Navier–Stokes equations.

177 Investigating the effect of nutrient-limited growth on floral pattern formation in yeast biofilms

Alexander Tam
The University of Adelaide
Timetable: p. 15

Yeast species have a huge effect on human life, and in many applications it would be advantageous to control their growth. For example, yeasts are used extensively in food and drink production and in biotechnology, but are also a leading cause of persistent hospital-acquired infections. It is therefore of interest to understand the fundamental mechanisms that determine colony morphology. Yeast biofilms are complex systems in which growth is influenced by nutrient consumption, fluid flow, and mechanical forces. In this work, we investigate the hypothesis that nutrient-limited growth is the mechanism by which patterns form. Analysis of experimental images shows that biofilms expand radially at a roughly constant speed, and undergo a transition from circular to floral morphology, which is characterised by the formation of finger-like 'petals'. We use this data to parametrise a reaction-diffusion model with non-linear degenerate cell diffusion. In doing this, we show that two-dimensional travelling wave solutions to our model are linearly unstable to transverse perturbations for experimentally feasible parameters. There is good agreement between experimental floral patterns and predictions using the most unstable wave number of this analysis. Our model, which incorporates nutrient-limited growth alone, therefore provides a potential explanation for petal formation in yeast biofilms.

178 Sampling without replacement: a story of noncentral hypergeometric distributions

Peter Gerrard Taylor
The University of Melbourne
Co-authors: S. Loertscher and E.V. Muir
Timetable: p. 23

In elementary probability and statistics courses, we are taught how to derive the distribution of the number X of marked objects we see when we sample without replacement n objects from a population of N objects, D of which are marked. This distribution, known as the *hypergeometric distribution*, finds application in many areas, among which are analysis of card games, capture-recapture experiments and sample surveys.

A basic assumption in this derivation is that marked objects are just as likely to be selected as unmarked objects. It is easy to think of situations where this assumption does not hold, for example a capture/recapture experiment where the experience of being captured makes an animal less likely to be captured a second time. This leads us to the concept of a noncentral hypergeometric distribution in which marked and unmarked objects can have different probabilities of being selected.

It turns out that surprisingly little has been written about this generalisation: there are two noncentral hypergeometric distributions known in the literature, attributed to Fisher and Wallenius respectively. In this talk I shall make some observations about these distributions and then introduce a third class of noncentral hypergeometric distribution, motivated by an application in microeconomics.

179 Preserving quality of milk powder shipments

Steve Taylor
The University of Auckland
Timetable: p. 20

Milk powder can undergo a complexity of chemical reactions, all influenced by oxygen, moisture and temperature. Yet, even small changes in milk powder lead to noticeable changes in its flavour. When milk powder is shipped around the world, it is subjected to diverse environmental conditions for prolonged periods of time. We discuss how mathematical modelling sheds light on what can be done to preserve its flavour under these conditions.

(This problem was a challenge from Fonterra to the mathematics in industry study group MINZ 2016. Problem moderators: Luke Fullard, Valerie Chopovda, Steve Taylor.)

180 Experimental feature driven development for mathematical models of LiFePO4 batteries

Joseph Alex Teague
Queensland University of Technology
Timetable: p. 16

The internal operation of a lithium ion battery is difficult to measure experimentally, due in part to its intricate nature and the instability of the electrolyte solution, requiring the battery to be well sealed. A mathematical model that accurately simulates battery usage would be useful, both in optimising battery usage for efficiency or extended lifetime, and to inform battery design. However, to date, even the most sophisticated models fail to accurately recover the dynamics of battery charge and discharge cycling. Additionally, most attempts at validation only include a single charge or discharge of the battery at a time, and ignore effects occurring at the end of these events. In this presentation, we discuss the incorporation of qualitative features observed in experimental charge/discharge cycling data in the development of a mathematical model and numerical simulation of a LiFePO4 battery. We also discuss the links between these observations and the dynamics within the cell and present the key outcomes of our model, including our ability to validate against challenging, multi-cycle, experimental data.

181 Pulsing dynamics in an excitable laser subject to delayed optical feedback

Soizic Terrien
The University of Auckland
Timetable: p. 13

Controllable sources of short pulses of light are key elements in many applications, including telecommunications and optical signal processing. We consider here an excitable semiconductor laser subject to delayed optical feedback. In such a device, recent experiments have shown that trains of short pulses of light can be triggered independently by external perturbations. In particular, several pulses can be sustained simultaneously, with different timing in between pulses. A mathematical model in the form of a system of delay differential equations describes the pulsing dynamics in very good agreement with the experiment. A bifurcation analysis shows the coexistence of one stable equilibrium with several periodic solutions, which all correspond to pulsing regimes with equidistant pulses. Most of them are only weakly stable, and we demonstrate that all pulsing dynamics correspond to very long transients toward one of these periodic solutions. Consequently, all pulses become equidistant in the long term. Moreover, we investigate the effect of external perturbations on the stable pulsing regimes, which relates to the basins of attraction of the different periodic solutions. We show that pulse trains can be individually and reliably switched on and off through external perturbations. These results pave the way to fast all-optical control of pulsing regimes in lasers. Moreover, since the mechanism for self-pulsations relies only on excitability and self-feedback our results might be of more general interest, beyond laser dynamics.

182 Modelling phagocytosis

Ngamta Thamwattana
University of Wollongong
Timetable: p. 12

Phagocytosis refers to a process in which one cell type fully encloses and consumes unwanted cells, debris or particulate matter. It plays an important role in immune systems through the destruction of pathogens and the inhibiting of cancerous cells. In this study, we combine models on cell-cell adhesion and on predator-prey modelling to generate a new model for phagocytosis that is capable of relating the interaction between cells in both space and time. Numerical results are presented, demonstrating the behaviours of cells during the process of phagocytosis.

183 Globally unstable behaviour in the rotating-disc boundary layer

Christian Thomas
Monash University
Co-authors: Christopher Davies
Timetable: p. 25

Linear disturbance development in the von Kármán boundary layer over a rotating-disc is investigated for an extensive range of azimuthal mode numbers n. The study expands upon earlier investigations that were limited to those values of n nearer to the onset of absolute instability (Lingwood 1995), where disturbances to the genuine inhomogeneous flow were shown to be globally stable (Davies & Carpenter 2003). Numerical simulations for sufficiently large n display a form of global instability that is similar in appearance to that found on the rotating-disc with mass suction (Thomas & Davies 2010). Solutions indicate that a change in the response of the global behaviour arises for $n \in [80 : 100]$ that is marginally greater than those disturbances studied previously. Furthermore, the corresponding Reynolds number coincides with the upper bound of experimental predictions for transition, which would suggest that transition to turbulence is unlikely to be observed beyond that reported experimentally, as globally unstable disturbances will have become fully established. These new stability characteristics are directly related to the Huerre & Monkewitz (1990) local-global stability criterion that requires the region of local absolute instability (for a fixed n) exceed a certain threshold size before globally unstable behaviour can be established. Coupling solutions of the linearized complex Ginzburg-Landau equation with numerical simulations based on the radially homogeneous flow approximation, conditions are derived that can be used to predict the azimuthal mode number needed to establish global instability. The response is governed by a detuning effect, based on radial variations of the temporal frequency and matching shifts in temporal growth that increases for larger n, eventually becoming big enough to engineer globally unstable characteristics. Finally, we conclude that these newly observed linear global modes are unlikely to have a strong bearing on the long term disturbance development of the impulse response. This is because a global mode would be unlikely to establish itself over an extended radial range before nonlinear effects were triggered by the huge growth associated with the wavepacket maxima of the lower n-valued convective instabilities.

184 Improving health benefits of in-home care for chronic patients through optimal service timing

Ali Tirdad
The University of Melbourne
Co-authors: Peter Taylor, Mark Fackrell and Jing Fu
Timetable: p. 15

We provide an Markov Decision Process (MDP) model for delivery of an in-home care service for patients with chronic conditions in Melbourne, called MonashWatch. In this program patients receive calls frequently from their health coaches, and are directed to necessary health services. The idea is to keep patients with chronic conditions healthier at home to prevent/reduce avoidable hospitalisations and visits to the emergency department. We assume that the reduction in number of unscheduled admissions

will be the consequence of having healthier patients. To do so, we look into how MonashWatch can maximise the health benefits, measured with QALYs (Quality Adjusted Life Years), of its service for all the patients by optimally allocating its resources to the patients. We model the MonashWatch program as an MDP, and provide the optimal policy to call the patients at the beginning of each period (e.g. day) based on the health state of a patient on the last call, health behaviour of a patient, and the passed time from the latest call. To generate the policies, we use Whittle index policy which is efficient and flexible to later variation in the model inputs, such as changes in registered patients' number in the program, patients' behaviour, and capacity of the program.

185 Mathematical modelling of hydrophilic agrochemical penetration in astomatous plant cuticles: surfactant and hygroscopic effects

Eloise Tredenick

Queensland University of Technology

Timetable: p. 17

The agricultural industry requires improved efficacy of sprays being applied to crops and weeds to reduce their environmental impact and increase financial returns. One way to improve efficacy is by enhancing foliar penetration. The plant leaf cuticle is the most significant barrier to agrochemical diffusion within the plant leaf. The importance of a mechanistic model has been noted previously in the literature, as each penetration experiment is dictated by its specific parameters, namely plant species, environmental conditions such as relative humidity and spray formulation including adjuvant addition. Here we develop a model to incorporate the effects of adjuvant addition, ion binding and evaporation with the hygroscopic nature of deliquescent ionic solutions, along with the ability to vary the active ingredient concentration and type, relative humidity and plant species. We validate our model results against two experimental data sets. Furthermore, we discuss the key model sensitivities and relate theoretical predictions to physical mechanisms.

186 Mathematics of the Faraday Cage

Nick Trefethen
University of Oxford
Timetable: p. 11

Everybody has heard of the Faraday cage effect, in which a wire mesh does a good job of blocking electric fields and electromagnetic waves. Surely the mathematics of such a famous and useful phenomenon has been long ago worked out and written up in the textbooks?

It seems to be not so, and indeed, one of the few treatments to be found in the textbooks, by Feynman, is incorrect. The shielding effect turns out to be not as simple as one might expect: it depends on the wires having finite radius. Nor is it as strong as one might imagine: it improves only linearly as the wire spacing decreases. This talk will present results on electrostatic Faraday shielding by Jon Chapman, Dave Hewett and myself, published in SIAM Review. Mathematically, this is a problem of harmonic measure. Physically, Faraday shielding cage can be regarded as electrostatic induction by a surface of limited capacitance.

187 An integrable discrete model for soil-water infiltration

Dimetre Triadis
Kyushu University
Co-authors: Philip Broadbridge, Kenji Kajiwara and Kenichi Maruno
Timetable: p. 20

We have recently presented an integrable discrete model of one-dimensional soil water infiltration. It is based on the continuum model by Broadbridge and White: a nonlinear convection-diffusion equation with a nonlinear flux boundary condition at the surface. This is transformed to the Burgers equation with a time-dependent flux term by the hodograph transformation. Our discrete model preserves underlying integrability, and takes the form of a self-adaptive moving mesh scheme. The discretisation builds on linearisability of the Burgers equation, producing the linear diffusion equation. Naïve discretisation of the linearised equation using the Euler scheme is often used in the theory of discrete integrable systems, but this does not necessarily produce a good numerical scheme for the original equation. Taking desirable properties of a numerical scheme into account, we propose an alternative discrete model that produces solutions with similar accuracy to direct computation on the original nonlinear equation, but with clear benefits regarding computational cost.

188 Diffusion-limited growth limits in microbial colonies

Hayden Tronnolone
The University of Adelaide
Co-authors: Benjamin J. Binder
Timetable: p. 24

When placed on a solid substrate, many types of microbes, such as bacteria and fungi, grow into colonies comprising numerous individual cells. The shape of these colonies is highly dependent on the availability of nutrients diffusing throughout the substrate. When nutrient is limited, the colony may undergo diffusion-limited growth (DLG), which typically manifests itself as a non-uniform colony growth pattern. Such a change can occur without any change in the behaviour of individual cells, such as observed in the bacterium *Bacillus subtilis*; however, certain microbes may instead respond actively to low nutrient levels. Dimorphic yeasts, such as *Saccharomyces cerevisiae*, transition to the pseudohyphal growth mode, which consists of a change in the cell budding pattern, an elongation of the cells, and the ongoing adhesion of mother and daughter cells. As both responses produce visually similar patterns, the relative contributions of of pseudohyphal growth and DLG to the colony shape are not known. To resolve this uncertainty, a combination of discrete and continuous mathematical models are used to identify the conditions under which DLG is expected to occur. Using the results produced by these models, representative experimental examples of microbial colonies are examined to identify which colony morphologies are likely to have arisen due to DLG and, ultimately, which species are influenced by this effect.

189 Error analysis of Crouzeix-Raviart and Raviart-Thomas finite element methods

Takuya Tsuchiya
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Co-authors: Kenta Kobayashi
Timetable: p. 17

We discuss the error analysis of the lowest degree Crouzeix-Raviart and Raviart-Thomas finite element methods applied to a two-dimensional Poisson equation. To obtain error estimations, we utilize the techniques developed by Babuska-Aziz and the authors. We present error estimates in terms of the circumradius and the diameter of triangles in which the constants are independent of the geometric properties of triangulations. Numerical experiments confirm the obtained results.

190 Viscous fingering patterns driven by heterogeneous substrate wettability

Lachlan James Tyrrell
Queensland University of Technology
Timetable: p. 12

A Hele-Shaw cell is an experimental apparatus which consists of a pair of parallel glass plates held close together and filled with a viscous fluid. Notably, a fingering pattern occurs when a less viscous fluid is forced into the cell, due to Saffman-Taylor instability. Motivated by understanding the fingering behaviour driven by a non-uniform wettability along one of the Hele-Shaw plates, we have investigated the effect of perturbing the transverse contact angle where the viscous fluid meets the plates. To do so, we have introduced a small perturbation term that alters the pressure and causes differing behaviour in the evolution of fingering patterns. Linear stability analysis suggests that the effect of the perturbation term will cause an initially flat surface to evolve into a fingering pattern rather than remaining flat. The focus of this presentation will be on describing preliminary linear stability analysis and fully nonlinear solutions which are computed using a complex variable formulation and conformal mapping techniques.

191 Mean first passage time problems and localised pattern formation - analysis, results, and surprising connections

Justin Tzou
Macquarie University
Timetable: p. 23

Mean first passage time (MFPT) problems, a classic example of which is the gambler's ruin problem, generally ask the question - how long on average does it take for a random walker to first encounter a set of targets? Analysis of these problems in the past has been restricted to the scenario where targets are stationary. In this talk, we discuss how to derive and analyse the boundary-value problem associated with moving targets, and report some counter-intuitive results. For localised spot patterns in reaction-diffusion systems, we will demonstrate a hybrid asymptotic-numerical method for obtaining key analytic results for their stability and dynamics. Finally, we draw some surprising links between these two seemingly very different problems.

192 A multiphase model for HDL-assisted stabilisation of early atherosclerotic plaques

Ishraq Uddin
The University of Sydney
Timetable: p. 22

Atherosclerosis is among the leading causes of death worldwide due to its implication in heart attacks and strokes. The disease is characterised by the localised thickening of artery walls due to the buildup of fatty cholesterol-filled streaks. A key factor in determining whether an atherosclerotic plaque becomes problematic is the interplay between low density lipoprotein (LDL) and high low density lipoprotein (HDL), which are responsible for transporting cholesterol around the body: LDL is pro-atherogenic and its buildup in the artery wall will trigger an immune response whereby the recruited immune cells become engorged on lipid and remain in the artery wall, whereas HDL has the atheroprotective properties of enabling lipid export and the egress of immune cells from the plaque. Plaque dynamics consist of many nonlinear interactions between various cellular and biochemical species including the interactions between immune cells and lipoproteins.

In this talk, I present a multiphase PDE model for an early stage atherosclerotic plaque. The model accounts for interactions between macrophages, apoptotic cells and lipids, modelling the plaque space as a one dimensional domain with a moving boundary. Our model is based on a multiphase framework, and incorporates the effects of cell crowding by having the domain expand or contract according to the total amount of material. We discuss how this model gives insight into how early plaque growth and stabilisation depends on the levels of LDL and HDL in the bloodstream.

193 On a second order PDE that models cell division

Bruce van Brunt
Massey University
Co-authors: Graeme Wake, Ali Zaidi and Messoud Efendiev
Timetable: p. 24

In this talk we examine a second order functional partial differential equation that models size structured cell division and growth. The problem is of the initial boundary value type and the differential equation features a simple nonlocal term in the form of a rescaling. The simplest equation of this type with linear growth can be solved analytically. We present a solution method and use the result to establish the existence of a long time attracting solution (the SSD solution). The long time dynamics can change dramatically if we consider the exponential growth case. We look briefly at a critical case where there is no (classical) SSD solution.

194 Look who's talking: bipartite networks as representations of a topic model of New Zealand parliamentary speeches

Demival Vasques Filho
University of Auckland
Timetable: p. 15

Quantitative methods that describe the participation to debate of Members of Parliament and the parties they belong to are lacking. Here we propose a new approach that combines topic modelling with complex networks techniques, and use it to characterise the political discourse at the New Zealand Parliament. We implement a Latent Dirichlet Allocation model to discover the thematic structure of the government's digital database of parliamentary speeches, and construct from it two-mode networks linking Members of the Parliament to the topics they discuss. Our results show how topic popularity changes over time and allow us to relate the trends followed by political parties in their discourses with specific social, economic and legislative events. Moreover, the community analysis of the two-mode network projections reveals which parties dominate the political debate as well as how much they tend to specialize in a small or large number of topics. Our work demonstrates the benefits of performing quantitative analysis in a domain normally reserved for qualitative approaches, providing an efficient way to measure political activity

195 A mathematical model supports a key role for anion exchanger Ae4 (Slc4a9) in salivary gland fluid secretion

Elias Vera Siguenza
The University of Auckland
Timetable: p. 12

We construct a dynamical model of a salivary gland acinar cell with the objective of investigating the role of two anion exchangers, the Ae2 (Slc4a2) and Ae4 (Slc4a9), in fluid secretion.

Transepithelial chloride movement drives water transport in salivary gland acinar cells. A basolateral sodium-potassium adenosine-triphosphatase pump (NaK-ATPase) and the sodium-potassium-chloride co-transporters (Nkcc1) are primarily responsible for concentrating the intracellular space with chloride well above its equilibrium potential. Gustatory and olfactory stimuli induce the release of calcium ions from the internal stores of acinar cells, which trigger saliva secretion. Calcium-dependent chloride and potassium channels promote ion secretion into the luminal space thus creating an osmotic gradient that promotes water movement in the secretory direction. The current model for saliva secretion proposes that chloride-bicarbonate anion exchangers, coupled with basolateral sodium-proton (Nhe1) anti-porters, regulate intracellular pH and act as a secondary chloride uptake mechanism.

Recent studies demonstrated that Anion exchanger 4 (encoded by the Slc4a9 gene - Ae4) deficient mice exhibit an approximate 30% decrease in gland salivation. Surprisingly, the same study revealed that absence of Anion exchanger 2 (encoded by the Slc4a2 gene - Ae2) does not impair salivation, as

previously suggested. These results seem to indicate that the Ae4 is responsible for the majority of the secondary chloride uptake and thus a key mechanism for saliva secretion.

Our model produces mathematical support for such controversial findings. Our results suggest that the exchanger's co-transport of monovalent cat-ions is key in establishing the osmotic gradient necessary for optimal saliva secretion.

196 The replicator equation in discrete time

Geetika Verma
University of South Australia
Co-authors: Amie Albrecht, Kostia Avrachenkov and Phil Howlett
Timetable: p. 21

The replicator equation is used to understand the dynamic evolution of populations in both continuous time and discrete time. In this talk I consider a simple model with two species and use the replicator equation to study discrete time evolution of the population in the presence of small random or deterministic perturbations to each generation caused either by genetic mutation or migration. Our most important observation is that for small perturbations the model contains two important capture regions that ensure stability of the iterated map describing the evolution but that for larger perturbations one or both of these regions may disappear. Our future research will try to extend our analysis to more complex models.

197 Mathematical models for cell migration with real-time cell cycle dynamics

Sean Trinity Vittadello
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Co-authors: Scott W. McCue, Gency Gunasingh, Nikolas K. Haass and Matthew J. Simpson
Timetable: p. 13

Fluorescent ubiquitination-based cell cycle indicator, also known as FUCCI, allows the visualisation of the G1 and S/G2/M cell cycle phases of individual cells. FUCCI consists of two fluorescent probes, so that cells in the G1 phase fluoresce red and cells in the S/G2/M phase fluoresce green. FUCCI reveals real-time information about cell cycle dynamics of individual cells, and can be used to explore how the cell cycle relates to the location of individual cells, local cell density, and different cellular microenvironments. In particular, FUCCI is used in experimental studies examining cell migration, such as malignant invasion and wound healing. Here we present new mathematical models which can describe cell migration and cell cycle dynamics as indicated by FUCCI. The *fundamental* model describes the two cell cycle phases, G1 and S/G2/M, which FUCCI directly labels. The *extended* model includes a third phase, early S, which FUCCI indirectly labels. We present experimental data

from scratch assays using FUCCI-transduced melanoma cells, and show that the predictions of spatial and temporal patterns of cell density in the experiments can be described by the fundamental model. We obtain numerical solutions of both the fundamental and extended models, which can take the form of travelling waves. These solutions are mathematically interesting because they are a combination of moving wavefronts and moving pulses. We derive and confirm a simple analytical expression for the minimum wave speed, as well as exploring how the wave speed depends on the spatial decay rate of the initial condition.

198 Geometric Optimisation

Graeme Wake
Massey University
Timetable: p. 12

A largely forgotten piece of classical, but very useful, geometry will be described: that of Steiner symmetrisation. This is a very elegant piece of quite straightforward mathematics, essentially pre-calculus in its simplicity. Answers to elementary questions like "What is the largest paddock you can enclose with given length of fence?" are established essentially by construction. Recently it has been very successfully applied to several important optimisation problems for objects such as bubbles, drums and bombs. It is used by myself and others in the insurance industry to predict shape factors as a measure of the likelihood of the occurrence of spontaneous fires, see Wake (1973). This much harder question prompted the development of an extension of Jacob Steiner's work, which will be explained.

Wake G.C. Estimation of critical parameters in thermal ignition, *Combustion and Flame, J. Combustion Institute* **21** (1973) 19-2l.

199 A sequential approach to data-augmented MCMC

James Nicholas Walker
The University of Adelaide
Timetable: p. 16

Data-augmented MCMC (DA-MCMC) is an effective strategy for inferring parameters of state space models where transitions are largely unobserved. The algorithm requires that inference is started anew each time our data set is updated; this means that DA-MCMC can become slow for large data sets. An alternative algorithm for this kind of inference problem is Sequential Monte Carlo (SMC); this allows estimates to be updated as the data set is updated, but suffers from inefficiencies if too little of the process is observed. This talk outlines a new sequential data-augmented MCMC algorithm which allows for estimates to be updated as in an SMC algorithm, but has the efficient steps of a DA-MCMC algorithm. Applications of this algorithm are shown in the context of epidemic models.

200 Viscous Rayleigh-Taylor flows in two and three dimensions using GPU acceleration

Stephen Walters
University of Tasmania
Timetable: p. 14

The Rayleigh-Taylor instability describes the situation where a denser fluid sits atop a less dense fluid. If the interface between the fluids is perfectly flat and horizontal, an unstable equilibrium exists. Any small perturbation to this interface will grow. Initially this growth will be exponential, but viscosity will eventually cause the interface to roll over. In this talk, a spectral method is presented which guarantees certain boundary conditions are met. The method is computationally expensive, but has been found to run faster using parallel processing on a Graphical Processing Unit. Run time has been reduced by factors in the hundreds. This increase in computational power and the accuracy of the spectral method enabled the forward integration of the model well past the 'roll-over' time, and is presented in a few short videos.

201 Calcium Signalling in T-Cells

David Waters
The University of Auckland
Timetable: p. 20

Calcium oscillations are ubiquitous in many cell types and control a wide range of cellular activities. Particularly, in T-cells, calcium oscillations are known to control cell differentiation, proliferation, and activation. Very puzzling experimental results from the 1990s showed that blocking certain calcium pumps initiated calcium oscillations. This behaviour is odd and fairly unique to T-cells, yet remains without theoretical explanation. We construct and study theoretical models of T-cell calcium signalling in an attempt to provide an explanation. We study the bifurcation structure of our models which allows us to describe a theoretical mechanism for this behaviour.

202 Multiphase modelling of early fibrous cap formation in atherosclerosis

Michael Greg Watson
The University of Sydney
Co-authors: Mary R Myerscough, Helen M Byrne and Charlie Macaskill
Timetable: p. 24

Advanced atherosclerotic plaques are characterised by the accumulation of cellular debris and extracellular fat in the arterial intima. Smooth muscle cells (SMCs) are recruited from the media to synthesise a cap of fibrous tissue that sequesters this thrombogenic material from the bloodstream and contributes to the prevention of plaque rupture. The fibrous cap therefore provides crucial protection from clinical events such as heart attack and stroke, but the mechanisms that underlie cap formation remain poorly understood. Evidence suggests that certain plaques will remain strong and stable, while others become fragile and dangerously vulnerable to rupture.

Using a multiphase approach with non-standard boundary conditions, we investigate early fibrous cap formation in the intima by modelling SMC migration from the media in response to chemical signalling from the endothelium. Simulations indicate that the emergence of a cap-resembling SMC profile requires a critical balance between the relative rates of cell supply from the media, chemotactic migration within the intima and cell loss by apoptosis (or phenotype change). We identify a number of disease-associated parameters that may be linked to variations in cap stability.

203 Two-stroke relaxation oscillators

Martin Wechselberger
The University of Sydney
Timetable: p. 12

In classic van der Pol-type oscillator theory, a relaxation cycle consists of two slow and two fast orbit segments per period (slow-fast-slow-fast). A possible alternative relaxation oscillator type consists of one slow and one fast segment only. In electrical circuit theory, Le Corbeiller (published in IEEE 1960) termed this type a “two-stroke” oscillator (compared to the “four-stroke” vdP oscillator).
I will provide examples of such oscillators that are common in biochemical oscillator theory and discuss these problems from a geometric singular perturbation theory (GSPT) point of view “beyond the standard form”. It is worth mentioning that Fenichel’s seminal work on GSPT (published in JDE 1979) discusses this more general setting, but it has not received much attention in the literature.

204 Shape optimization with geometric constraints using Moreau-Yosida regularization

Florian Wechsung
University of Oxford
Co-authors: Patrick Farrell
Timetable: p. 21

Shape optimization has received significant interest from both a theoretical and an applied point of view over the last decades. The approaches used can be roughly categorized into those based on using a parametrization for the shape or its deformation and then applying an optimization algorithm to the discretized problem (discretize-then-optimize) and those that formulate the problem as optimization over an infinite-dimensional space of shapes or deformations and then discretize afterwards (optimize-then-discretize). We follow the latter approach and search for diffeomorphisms $T \in [W^{1,\infty}(\Omega)]^d$ that deform an initial shape Ω. The optimization problem then reads as follows

$$\underset{T \in \mathcal{X} \cap K}{\text{minimize}} \quad J(T(\Omega)). \tag{1}$$

We choose $\mathcal{X} = \{T \in [W^{1,\infty}(\Omega)]^d : T \text{ is a } W^{1,\infty}\text{-diffeomorphism}\}$ as the space of admissible deformations as Lipschitz regularity of the domain is needed by many problems in which a PDE constraint is included in the optimization problem.

Furthermore we want to include certain geometric constraints; this is represented by the requirement $T \in K$. A classical example for a geometric constraint that is often considered is volume/mass conservation, i.e. $K = \{T \in \mathcal{X} : \text{vol}(T(\Omega)) = \text{vol}(\Omega)\}$. In our work we investigate constraints of the form

$$K = \{T \in \mathcal{X} : T(\partial\Omega) \subset C\} \tag{2}$$

for some convex set $C \in \mathbb{R}^d$. A classical application where this is relevant is wing design in Formula 1, where the teams are given bounding boxes in which the wing needs to be contained.

To include this constraint, we begin by considering the indicator function $\phi : L^2(\partial\Omega) \to (-\infty, +\infty]$, defined via

$$\phi(T) = \begin{cases} 0, & \text{if } T(\partial\Omega) \subset C \\ +\infty, & \text{otherwise,} \end{cases} \tag{3}$$

and observe that (1) is equivalent to

$$\underset{T \in \mathcal{X}}{\text{minimize}} \quad J(T(\Omega)) + \phi(T). \tag{4}$$

Classically the Moreau-Yosida regularization of ϕ is then used to implement path-following methods; in the context of shape optimization this has been done in [1]. However, in [2] it was shown that the Moreau-Yosida regularization of ϕ can also be used to formulate augmented Lagrangians. We adapt the latter approach to the case of PDE constrained shape optimization and present numerical examples implemented in the `Firedrake` finite element software.

[1] M. Keuthen and M. Ulbrich: Moreau-Yosida regularization in shape optimization with geometric constraints, *Computational Optimization and Applications*, 62, 2014. [2] K. Ito and K. Kunisch: Augmented Lagrangian methods for nonsmooth, convex optimization in Hilbert spaces, *Nonlinear Analysis: Theory, Methods & Applications*, 41, 2000.

205 Linear response in weakly-coupled systems

Caroline Wormell
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Co-authors: Georg A. Gottwald
Timetable: p. 21

It is assumed by many practitioners that complex chaotic systems have physical measures which vary differentiably under a perturbation in the flow of the system. This assumption appears to bear out to some extent in practice, but is largely unexplained, especially as certain simple chaotic systems such as the logistic map are known to not have this so-called linear response.

We analyse a weak-coupling model, made up of J simple, independent "heat-bath" chaotic maps driving a distinguished chaotic map. We find that when J is large and the heat-bath maps are sufficiently heterogeneous, the distinguished variable has a linear response regardless of whether any of the maps taken by themselves do. However, depending on the kind of coupling, the region of validity of Taylor approximations to the response may be very small, and in the infinite J limit the system may not have linear response.

206 Dynamics of a coupled calcium system

Xueshan Yang
The University of Auckland
Timetable: p. 21

Many models have been built to study the behaviour of calcium oscillations in spatially homogeneous cells. In these models, all the variables of interest are assumed to evolve in time only, without spatial dependence. However, in a variety of cell types, intercellular calcium oscillations are observed. Furthermore, it has been observed that the calcium dynamics in one cell can influence the dynamics in neighbouring cells. Motivated by this observation, we are interested in building a model of intercellular calcium oscillations to help understand the mechanisms underlying interactions between cells. This talk presents preliminary results about the dynamics of a coupled pair of calcium oscillators, focusing on the differences resulting from varying the coupling type and strength.

207 The effect of thermoregulation on honey bee colony health and survival

Zeaiter Zeaiter
The University of Sydney
Timetable: p. 22

In recent years honey bee colonies have been experiencing increased loss of hives. One cause of hive loss is colony collapse disorder (CCD). Colony collapse disorder is characterised by a previously healthy hive having few or no adult bees but with food and brood still present. This occurs over several weeks. It is not known if there is an exact cause of CCD but rather it is thought to be the accumulation of multiple stressors placed on a hive. One of these stressors is the breakdown of thermoregulation inside the hive. the bee life cycle begins with eggs that hatch into larvae that become brood. The hive contains combs which are made up of multiple cells; these cells house the brood. Pupal cells are capped off by adult bees (and so are known as capped brood) and they undergo changes to develop into an adult bee. In order for these capped brood to develop correctly, physically and mentally, the temperature within the hive must be regulated by the hive bees to ensure optimal development of the capped brood. Variations in the temperature, caused by the breakdown of thermoregulation, lead to deformations in the adults that emerge from capped brood. This later leads to these bees becoming inefficient foragers which also have shorter life spans. We model the effect of thermoregulation on hive health using a system of DDEs which gives insights into how varying hive temperatures have an effect on the survival of the colony. Most notably adding the dynamics of hive thermoregulation creates an Allee effect. We approximate the DDE model by an ODE system to gain further insights into the dynamics of the problem.

208 Mathematical models for checkpoint blockade treatments in cancer immunotherapy

Collin Zheng
The University of Sydney
Timetable: p. 25

Cytotoxic T-lymphocytes, commonly called killer T-cells, are among our immune systems most potent and well-understood weapons against cancer. However receptors such as CTLA-4 and PD-1 on the surfaces of T-cells inhibit their activation and proliferation. Antibody drugs, called checkpoint blockades, can block these negative checkpoint receptors. We will present a mathematical model on tumour-lymphocyte dynamics in the presence of a CTLA-4 blockade, discuss its implications to future treatment direction and more broadly discuss the current modelling efforts in this area.

209 American-style Parisian options and their fair price

Song-Ping Zhu
University of Wollongong
Timetable: p. 20

In this talk, pricing of various American-style Parisian options will be discussed. After showing the fundamental difference between American-style "in" and "out" Parisian options, I shall demonstrate how a closed-form analytic solution for American-style up-and-in Parisian options can be worked out, which does not explicitly involve a moving boundary as far as the mother option is concerned. For American-style up-and-out Parisian options, a very efficient numerical approach is proposed, based on the moving window technique developed by Zhu and Chen (2013), in order to simplify the solution procedure. Preliminary numerical results are presented to show some very interesting features of American-style Parisian options.

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