ANZIAM 2019

55th Meeting
3–7 February 2019
Rutherford Hotel
Nelson, New Zealand

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 booklet are those of the individual authors.

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Editors: Michael Plank, Mark McGuinness, Amie Albrecht, Rachelle Binny, Emma Greenbank, Dimitrios Mitsotakis, Julie Mugford, Philip Wilson.

Web: http://sms.victoria.ac.nz/Events/ANZIAM2019

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1 Conference Details and History

1.1 Organising Committee

- Mike Plank (University of Canterbury) — co-director
- Mark McGuinness (Victoria University of Wellington) — co-director
- Amie Albrecht (University of South Australia)
- Rachelle Binny (Manaaki Whenua)
- Emma Greenbank (Victoria University of Wellington)
- Dimitrios Mitsotakis (Victoria University of Wellington)
- Julie Mugford (University of Canterbury)
- Phil Wilson (University of Canterbury)

1.2 Invited Speakers Committee

- Vivien Kirk (University of Auckland) — chair
- Snezhana Abarzhi (University of Western Australia)
- Nigel Bean (University of Adelaide)
- Hans de Sterck (Monash University)
- Cecilia González Tokman (University of Queensland)
- Jari Kaipio (University of Auckland)
- Frances Kuo (University of New South Wales)
- Terry O'Kane (CSIRO, Hobart)
- Mike Plank (University of Canterbury)

1.3 Invited Speakers

- Ruth Baker (University of Oxford)
- Judith Berner (NCAR, Boulder)
- Phil Howlett (University of South Australia)
- Claire Postlethwaite (University of Auckland)
- Raúl Rojas (Freie Universität Berlin)
- Anja Slim (Monash University)
- Ian Sloan (University of New South Wales)
- Yvonne Stokes (University of Adelaide)
- Martin Wechselberger (University of Sydney)

Raúl Rojas' plenary talk is generously supported by financial assistance from the Australian Research Council Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS).

1.4 Conference Code of Conduct

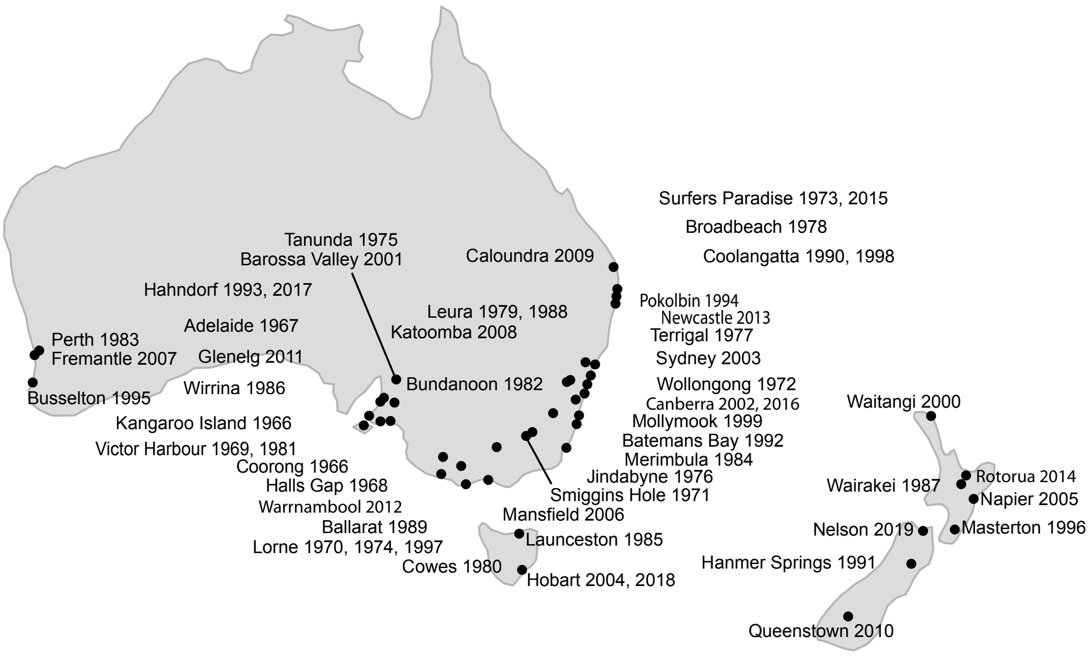
ANZIAM is committed to a professional, open, productive and respectful exchange of ideas. These aims require a community and environment that fosters inclusion, provides mutual respect, and embraces diversity. All attendees at the ANZIAM 2019 conference are required to agree to the following code of conduct.

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

Conference organisers will take seriously all reports of breaches of this code of conduct, and treat all parties with respect and due process without presupposition of guilt. Complaints will be handled with sensitivity, discretion and confidentiality. If a conference participant engages in harassing behaviour, they may be asked by the conference organisers to leave the conference.

Any event participant who experiences or witnesses harassment should contact one of the representatives listed on the conference webpage at `http://sms.victoria.ac.nz/Events/ANZIAM2019`.

1.5 Past Conference Locations



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

1.6 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
2018	N. Fadai	U Oxford
	E. Trendenick	QUT

1.7 The Cherry Ripe Prize

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

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

1.8 The J.H. Michell Medal

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

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

1.9 The E.O. Tuck Medal

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

2013	Shaun Hendy	VUW and Callaghan Innovation
	Geoffry Mercer	ANU
2015	Troy Farrell	QUT
2017	Kate Smith-Miles	Monash U
2018	Yvonne Stokes	U Adelaide

1.10 The ANZIAM Medal

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

1995	Renfrey Potts	U Adelaide
1997	Ian Sloan	UNSW
1999	Ernie Tuck	U Adelaide
2001	Charles Pearce	U Adelaide
2004	Roger Grimshaw	Loughborough U
2006	Graeme Wake	Massey U
2008	James Hill	UoW
2010	Bob Anderssen	CSIRO
2012	Robert McKibbin	Massey U
2014	Kerry Landman	U Melbourne
2016	Frank de Hoog	CSIRO Canberra
2018	Phil Howlett	UniSA

1.11 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

1.12 ANZIAM Student Support Scheme

The organising committee is thankful for funding received from the ANZIAM Student Support Scheme to assist the following students to attend the ANZIAM 2019 conference:

Rosemary Aogo	Matthew Hopwood	Andrew Phair
Claudio Arancibia-Ibarra	Cailan Jeynes-Smith	Georges Radohery
Jason Archer	Angus Lewis	Gagani Ranathunga
Sarah Belet	Conway Li	Martin Sagradian
Phillip Brown	Dennis Liu	Jesse Sharp
Alexander Browning	Benjamin Maldon	Alexander Tam
Jessica Crawshaw	Nathan March	Turker Topal
Sean Dawson	Claire Miller	Giorgia Vattiato
Dilruk Gallage	Julie Mugford	James Walker
Fillipe Georgiou	Ryan Murphy	David Warne
Brent Giggins	Diana Nguyen	Yuhuang Wu
Emma Greenbank	Cody Nitschke	

1.13 Sponsors

Financial support from the following sponsors is gratefully acknowledged:

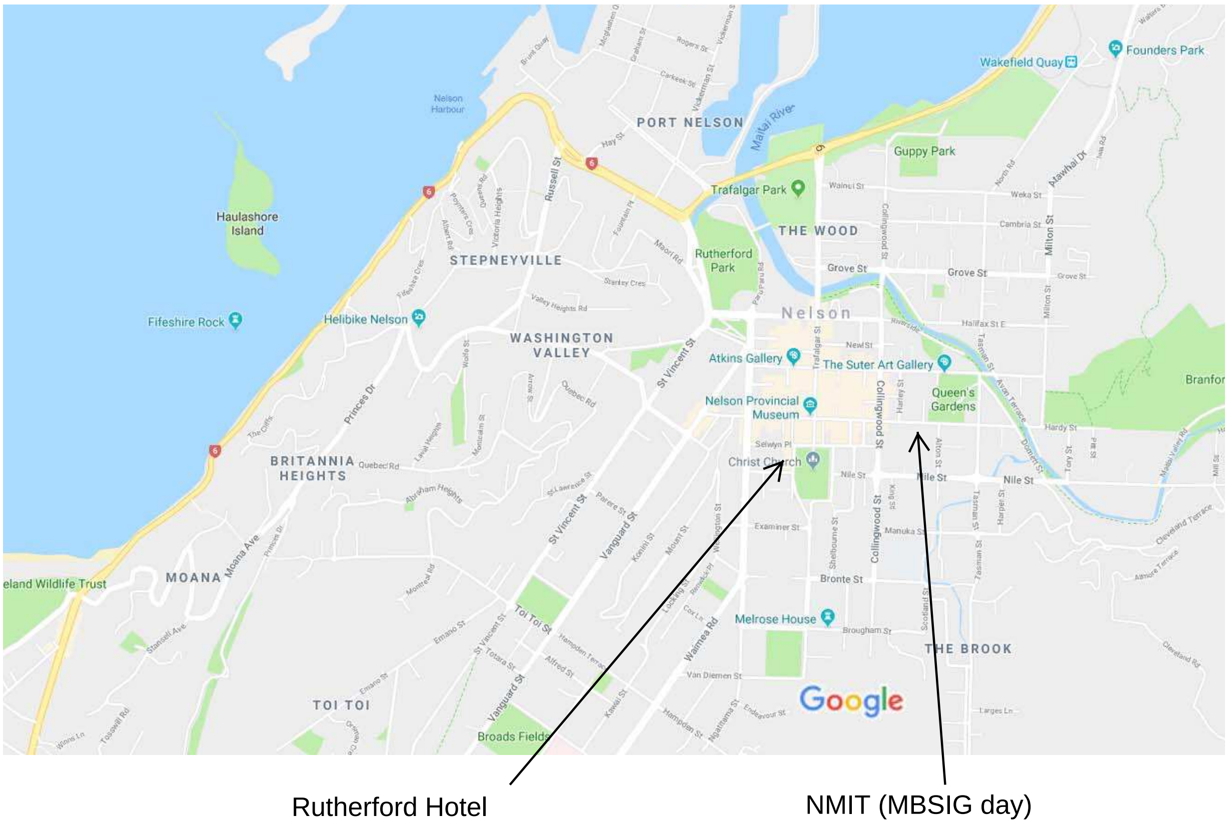
- Professor Kate Smith-Miles (U. Melbourne) Georgina Sweet Australian Laureate Fellowship
- Australian Research Council Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS)
- Technic Pty Ltd - COMSOL Multiphysics® Sales and Support in Australia and New Zealand
- Te Pūnaha Matatini, a New Zealand Centre of Research Excellence
- PDE Solutions Inc
- Wolfram Research Inc
- Lone Star Bar & Restaurant, 90 Hardy St, Nelson

2 Conference Events, Venues and Facilities

2.1 Conference Venue

ANZIAM 2019 is being held at the Rutherford Hotel, 27 Nile St West, Nelson 7010, New Zealand.

The registration desk will be open from 3–6 pm on Sunday 3 February and from 8–8.40 am on Monday 4 February.



Conference rooms are located on the ground floor of the Rutherford Hotel; the floor plan is shown below. The five meeting rooms are Maitai 2, Waimea, Wairau, Riwaka, and Heaphy.

Besides the mens and womens toilets, there are toilets that anybody can use, which are also accessible toilets, in the hotel foyer and in the Riwaka foyer. The toilet in the Riwaka foyer also has a changing table for infants.

2.2 Conference Welcome Reception

The welcome reception will be held from 6–8 pm on Sunday 3 February in the Riwaka Room and Courtyard. All conference delegates and registered guests are invited.

2.3 Internet Access

Wireless internet access is available for all delegates in the conference areas. Select and connect to the "Rutherford Conference Wireless" network. Enter the code "anziam2019" and click Connect to sign in to the network.

2.4 Social Media

ANZIAM attendees are encouraged to use social media to share ideas from the conference. The conference Twitter hashtag is #ANZIAM2019 and the ANZIAM account handle is @ANZIAMnews. It's good practice to include a reference to the presenter and their affiliation, and please seek permission from the presenter before posting a photo of them or their presentation online.

2.5 Invited Lectures and Contributed Talks

All invited lectures will take place in Maitai 2 and are scheduled for 50 minutes, inclusive of questions.

Contributed talks will be held in parallel sessions in Maitai 2, Waimea, Wairau, Riwaka and Heaphy. The duration of each contributed talk will be 15 minutes with an additional 5 minutes for questions and room change over.

All rooms are equipped with a resident laptop. Please upload your presentation in advance of the session you are speaking in. You can do this via USB stick either at the tech desk in Maitai 2 or directly to the resident laptop in the room you are presenting in.

2.6 Student Evening

All students are invited to the student evening from 6:30 pm on Monday 4 February. The Evening provides a chance to meet fellow students in an informal setting, with dinner provided and drinks available for purchase. This event is being organised by the ANZIAM student representative Phillip Brown (phillip.j.brown@adelaide.edu.au). Financial support for this event from Te Pūnaha Matatini is gratefully acknowledged.

2.7 Women in Mathematical Sciences Lunch

The 2019 Women in Mathematical Sciences ANZIAM Lunch will be held on Tuesday 5 February in the Oceano Restaurant. 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 2019 that wish to attend, regardless of gender or membership of WIMSIG. We are grateful to Prof. Kate Smith-Miles for providing financial support from her Georgina Sweet Australian Laureate Fellowship and to Te Pūnaha Matatini for financial support.

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 2019 female plenary speakers, to discuss issues concerning women in mathematics in Australia and New Zealand, and to network with fellow WIMSIG members and supporters. Check out the WIMSIG website (www.austms.org.au/WIMSIG-QA) for information on/advice from the female plenary speakers at this and past ANZIAM and AustMS conferences.

Registration for this lunch is required for catering purposes.

2.8 Tuesday Afternoon

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 Nelson region. Please see conference website for suggested activities and links.

The ANZIAM AGM will be held on Tuesday 5 February starting at 7:30 pm in Waimea. All ANZIAM members are encouraged to attend the AGM.

2.9 Conference Dinner

The Conference Dinner will be held in Maitai 1 on Wednesday 6 February. Pre-dinner drinks will be served from 6:30 pm in the Riwaka Foyer and Courtyard, for a 7 pm start to the dinner.

2.10 Alex McNabb Special Session

There will be a half day Special Session in honour of Alex McNabb DSc, FRSNZ, one of New Zealand's leading real-world mathematicians. This will take place on Wednesday morning in the Waimea room.

2.11 Mathematical Biology Special Interest Group Meeting

The MBSIG meeting will be held in room T309 at the Nelson-Marlborough Institute of Technology, 322 Hardy St, Nelson (see map on p8) on Friday 8 Feburary. Note this is a different venue and is about a 10 minute walk from the Rutherford Hotel. See conference website for NMIT campus map and meeting programme:
http://sms.victoria.ac.nz/Events/ANZIAM2019

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 13 minutes. Talks must stop after 15 minutes to allow 5 minutes for questions and room changes. Asterisks indicate student talks.

	Monday morning				
8:00–8:40	Registration				
8:40–9:00	Conference opening Maitai 2				
9:00–9:50	**Invited: Judith Berner (National Center for Atmospheric Research, Boulder, Colorado, USA)**, Maitai 2 On the dynamical mechanisms governing El Niño–Southern Oscillation irregularity (#14, p30) *Chair: Bernd Krauskopf*				
	Maitai 2	Waimea	Wairau	Riwaka	Heaphy
	Chair: Edward Green	*Chair:* David Khoury	*Chair:* Scott McCue	*Chair:* Steve Taylor	*Chair:* Chris Baker
10:00–10:20	**Barbara Johnston** A comparison of models for subendocardial and partial thickness ischaemia (#91, p70)	**Robert Moss** Real-time assessment and prediction of influenza severity (#134, p92)	**Liam Morrow*** Controlling viscous fingering patterns in a Hele-Shaw cell through geometry manipulation (#133, p91)	**Ian Lizarraga** Computational singular perturbation method for nonstandard slow-fast systems (#111, p80)	**Martin Sagradian*** Arbitrary rotationally symmetric doubly-connected conductors: potential theory problems (#169, p110)
10:20–10:40	**David Warne*** Bayesian inference and information criteria for selection of reaction-diffusion models of collective cell behaviour (#201, p126)	**Dennis Liu*** Modelling of reporting behaviour in the FluTracking surveillance system (#110, p79)	**Koya Sakakibara** Numerical scheme for solving Hele-Shaw problems based on the method of fundamental solutions (#170, p110)	**James Yang*** Singularly-perturbed linear-quadratic zero-sum stochastic differential games (#209, p130)	**Yuto Miyatake** Reducing the effect of discretization errors in estimating ODE models by iteratively reweighted least squares (#131, p90)
10:40–11:00	**Phillip Brown*** Modelling colon cancer: Early modelling work (#19, p33)	**Georges Ferdinand Randri-afanomezantsoa Radohery*** Modelling antimalarial treatment in drug-resistant malaria (#162, p106)	**Matthew Hopwood*** Transversely isotropic extensional flow (#81, p65)	**Akane Kawaharada** Relation between spatio-temporal patterns generated by cellular automata and a singular function (#96, p72)	**Nathan March*** A fast semi-analytical homogenization method for block heterogeneous media (#123, p86)
11:00–11:20	Morning tea				

Monday morning continued

	Maitai 2	Waimea	Wairau	Riwaka	Heaphy
	Chair: Alys Clark	*Chair:* Mick Roberts	*Chair:* Shaun Hendy	*Chair:* Hinke Osinga	*Chair:* Amie Albrecht
11:20–11:40	**Tarunendu Mapder** Hedging for cellular persistence in stress response (#122, p85)	**Roslyn Hickson** Modelling hypothesised interactions during transmission dynamics of two malaria species (#79, p64)	**Andriy Olenko** Analysis of spherical data with applications to CMB studies (#147, p99)	**Gray Manicom*** Modelling task-switching with heteroclinic networks. (#121, p85)	**Alexander Fedotov** Justification of the approximate methods for solving operator equations (#54, p51)
11:40–12:00	**Rosemary Aogo*** Using a PDE to dissect the role of Plasmodium translocon of exported proteins during infection (#3, p25)	**James Walker*** Bayesian model selection in epidemiology (#200, p126)	**Barry Cox** Wrinkles in nanosurfaces (#39, p43)	**Cecilia Gonzalez Tokman** Lyapunov spectrum of Perron-Frobenius operator cocycles (#69, p59)	**Turker Topal*** Analysis of arbitrary polygonal waveguides: TM and TE modes (#191, p121)
12:00–12:20	**Nabil Fadai** An accurate and efficient discretization for stochastic models of cell migration and cell proliferation (#51, p49)	**Yuhuang Wu*** Estimation of reactivation frequency of latent HIV and the impact of fluctuating frequencies (#208, p130)	**Pierluigi Cesana** A probabilistic model for martensitic interfaces (#29, p38)	**Brent Giggins*** Ensemble forecasting with stochastically perturbed bred vectors (#67, p58)	**Ayham Zaitouny** Multivariate transitions detection method: Applications to geological boundaries analysis (#211, p131)
12:20–12:40	**Claire Miller*** Mechanistic control of epidermal tissue height (#130, p90)	**David Khoury** Measuring drug efficacy in malaria (#98, p73)	**Robert Otupiri*** Dynamics of an all-fibre laser with saturable absorber (#150, p100)	**Wenqi Yue*** Reduced dynamics for the Kuramoto-Sakaguchi Model Through Collective Coordinates (#210, p131)	**Daisuke Furihata** Structure-preserving methods based on discrete laws on Voronoi meshes (#61, p54)
12:40–1:00	**Brodie Lawson** Perlin noise for automatic generation of complex spatial patterns: an application to cardiac fibrosis (#107, p78)	**Amy Hurford** Parasite-induced shifts to a lethargic host state results in evolutionary bistability (#83, p66)	**Emma Greenbank*** Modelling Surtseyan Ejecta (#73, p61)	**Andrus Giraldo** Dynamic complexity in two coupled photonic crystal nanocavities (#68, p58)	**Eric Hester*** A straightforward geometric approach to fluid-solid interactions using the signed distance function (#78, p63)
1:00–2:00	Lunch				

Monday afternoon

2:00–2:50	**Invited: Phil Howlett (University of South Australia)**, Maitai 2 Ngā hiahia kia titiro ki te tīmata, ā, ka kite ai tātou te mutunga (you must understand the beginning if you wish to see the end) (#82, p65) *Chair: Mark McGuinness*				
	Maitai 2	Waimea	Wairau	Riwaka	Heaphy
	Chair: Alona Ben-Tal	*Chair:* Matthew Holden	*Chair:* Rowena Ball	*Chair:* Carlo Laing	*Chair:* Tammy Lynch
3:00–3:20	**Peter Cudmore** BondGraphTools: Modelling network bioenergetics (#41, p44)	**Michael Plank** Mitigating fisheries-induced evolution (#157, p104)	**Brendan Florio** Measuring the fractal dimension of aggregate clusters using the perimeter-area method (#58, p53)	**Tomoharu Suda*** Application of Helmholtz-Hodge decomposition to the construction of Lyapunov functions (#179, p115)	**Garry Newsam** A random process model for laying out HF antenna arrays (#140, p95)
3:20–3:40	**Ielyaas Cloete*** How does hormone receptor phosphorylation tune the calcium signal in hepatocytes? (#36, p42)	**Rachelle Binny** Optimal control of irrupting pest populations in a climate-driven ecosystem (#15, p31)	**Elliot Carr** Calculating thermal diffusivity from laser flash experiments (#27, p37)	**Chris Lustri** Localising nonlocal singular perturbations in the Benjamin-Ono wave equation (#115, p82)	**Oliver Maclaren** Accelerating the solution of geothermal inverse problems using the adjoint method (#119, p84)
3:40–4:00	Afternoon tea				

Monday afternoon continued

	Maitai 2	Waimea	Wairau	Riwaka	Heaphy
	Chair: Barbara Johnston	*Chair:* Roslyn Hickson	*Chair:* Barry Cox	*Chair:* Zoltan Neufeld	*Chair:* Troy Farrell
4:00–4:20	**Sean Vittadello*** Mathematical models of cell proliferation in experiments with synchronised cells (#198, p125)	**Andrew Black** A household model for vector-borne diseases (#16, p31)	**Josef Giddings** Wet chemical etching of silicon dioxide microfibres (#65, p57)	**Elle Musoke*** A surface of heteroclinic connections in a 4D slow-fast system (#137, p93)	**Melanie Roberts** Towards a process based model of gully erosion for improved Great Barrier Reef water quality (#165, p108)
4:20–4:40	**Peter Johnston** Assessing catheter contact during cryo-ablation (#93, p71)	**Sarah Belet*** An agent-based model for the spread of Wolbachia in mosquito populations (#11, p29)	**Gagani Ranathunga*** Mathematical modelling to aid fabrication of components for medical devices (#161, p106)	**David Simpson** Stability in piecewise-smooth maps: Fixed points, fractals, and friction. (#173, p112)	**Pascal Cheon*** Domain truncation in pipeline monitoring (#31, p39)
4:40–5:00	**Adelle Coster** Stochastic queueing models: intracellular dynamics, regulation and optimisation with data (#38, p43)	**Rebecca Chisholm** Population-level effects of immunological memory contingent on multiple infection episodes (#32, p40)	**Benjamin Maldon*** Modelling dye-sensitized solar cells by nonlinear diffusion (#120, p84)	**Alexander Browning*** Travelling waves in a mathematical description of a biologically inspired smart material (#20, p33)	**Duncan Farrow** How much money should be spent on managers vs workers? (#53, p50)
5:00–5:20	**Ryan Murphy*** An individual-based mechanical model of cell movement in heterogeneous tissues (#136, p93)	**Mick Roberts** Red and grey squirrels, SQPV and the dilution effect (#164, p107)	**Lyndon Koens** Static and dynamic self-assembly of a pair of microscopic magno-capillary disks (#101, p75)	**Madeleine Cartwright*** A collective coordinate framework to study the dynamics of travelling waves in stochastic PDEs (#28, p38)	**John Hearne** Designing an optimal schedule for breaking the hazardous fuel continuum while maintaining habitat quality (#76, p62)
5:20–5:40	**Hayden Tronnolone** Growing yeast off the grid (#193, p122)	**Jason Archer*** An agent-based approach for modelling the dilution effect in plants (#5, p26)	**Shaun Hendy** Instabilities in the melting of metal nanowires (#77, p63)	**Kenta Kobayashi** The circumradius condition and its application (#100, p74)	**Steven Psaltis** Mathematical modelling of property variation in the southern pines (#160, p105)
6:30	ANZIAM student evening				

Tuesday morning

8:30–9:20	**Invited: Raúl Rojas (Freie Universität Berlin)**, Maitai 2 Artificial intelligence for autonomous driving (#166, p108) *Chair: Cecilia Gonzalez Tokman*

	Maitai 2	Waimea	Wairau	Riwaka	Heaphy
	Chair: Jennifer Flegg	*Chair:* Rachelle Binny	*Chair:* Jim Denier	*Chair:* Joshua Ross	*Chair:* Elliot Carr
9:30–9:50	**Anudeep Surendran*** Spatial structure arises from chase-escape interactions with crowding effects (#180, p115)	**Claudio Arancibia-Ibarra*** Complex dynamics of a diffusive modified Holling-Tanner predator-prey model (#4, p25)	**Sophie Calabretto** Global instabilities in the flow around a rotating sphere (#25, p36)	**Adrian Ortiz-Cervantes*** A network approach for finding the right amount of topics in topic modelling (#148, p99)	**Winston Sweatman** Periodic orbits with four masses (#182, p116)
9:50–10:10	**Mark Flegg** Diffusion-limited enzyme kinetics (#57, p52)	**Emily Gentles*** State space models for long range animal movement (#63, p56)	**Peter Duck** Compressible three-dimensional boundary layers with short spanwise scales (#49, p48)	**Jody Fisher*** Modelling turbulence and the Anthropocene: synergetic effects reduce ocean biomass (#55, p51)	**Joseph O'Leary*** Satellite orbits: Newtonian, post-Newtonian and Einsteinian (#144, p97)
10:10–10:30	**Jesse Sharp*** Optimal control of acute myeloid leukaemia (#172, p111)	**Giorgia Vattiato*** Effect of individual heterogeneity on emergent population characteristics (#197, p124)	**Brendan Harding** The effect of inertial lift force on a spherical particle suspended in flow through microfluidic ducts (#74, p61)	**Michael Small** Propagation dynamics on multiplex (i.e. duplex) networks (#176, p113)	**Nur Atiqah Dinon*** The dynamics of Kuiper belt objects (#46, p47)
10:30–10:50	Morning tea				

Tuesday continued

	Maitai 2	Waimea	Wairau	Riwaka	Heaphy
	Chair: Saber Dini	*Chair:* Amy Hurford	*Chair:* Graeme Hocking	*Chair:* Melanie Roberts	*Chair:* W. Sweatman
10:50–11:10	**Alona Ben-Tal** Mathematical modelling of nasal high flow (#12, p29)	**Julie Mugford*** Developing methods to improve the accuracy of classification based crowdsourcing (#135, p92)	**Hyeongki Park*** A hinged linkage mechanism that follows discrete integrable equations (#152, p101)	**Dion O'Neale** Bipartite networks for fun and profit (#145, p97)	**Jinesh Joseph*** Long-term evolution of Apollo Asteroids (#94, p71)
11:10–11:30	**Fillipe Georgiou*** Continuum modelling of phagocytosis based on cell-cell adhesion and prey-predator relationship (#64, p56)	**Matthew Nitschke*** Modelling the role of the environment in the initial stages of multicellular evolution (#143, p96)	**Malte Peter** Graded resonator arrays for spatial frequency separation and amplification of water waves (#153, p102)	**Demival Vasques Filho*** Structure and dynamics of social bipartite and projected networks (#196, p124)	**Robert Lodder** Nonparametric approach to weak signal detection in the search for extraterrestrial intelligence (SETI) (#112, p80)
11:30–11:50	**Catheryn Gray*** Hysteresis and the drift to depletion: Akt under repeated insulin stimulation (#70, p59)	**Daniel Wilson*** Topology-dependent density optima for efficient simultaneous network exploration (#206, p129)	**Hyuck Chung** Acoustic scattering by a circular cylinder and air flow around it (#33, p40)	**Hamish Jelleyman*** Teleconnection networks of extreme weather events in Antarctica (#87, p68)	**Craig Douglas** A data enabled model for coupling dual porosity flow with free flow (#48, p48)
11:55–12:25	**Invited: Claire Postlethwaite (University of Auckland)**, Maitai 2 Spiral waves and heteroclinic cycles in Rock-Paper Scissors (#158, p104) *Chair: Michael Small*				
12:25–12:55	**Invited: Yvonne Stokes (University of Adelaide)**, Maitai 2 Drawing of microstructured optical fibres: modelling and validation. (#178, p114) *Chair: Mary Myerscough*				
1:00–2:15	Lunch Women in Mathematical Sciences Lunch – Oceano Restaurant				
	Free afternoon				
7:30 pm	ANZIAM AGM – Waimea room				

Wednesday morning

9:00–9:50	**Invited: Ruth Baker (University of Oxford)**, Maitai 2 Mathematical and computational challenges in interdisciplinary bioscience: efficient approaches for interrogating stochastic models of biological processes (#8, p27) *Chair: Matthew Simpson*				
	Maitai 2	Waimea- McNabb session	Wairau	Riwaka	Heaphy
	Chair: Mark Flegg	*Chair:* Graeme Wake	*Chair:* Luke Fullard	*Chair:* Boris Baeumer	*Chair:* Chris Green
10:00–10:20	**Gayani Tennakoon*** Collective motion with excluded-volume effects (#188, p119)	**Graeme Wake** Why are our pine trees going red? The problem of Red Needle Cast (#199, p125)	**Suha Al-Ali*** Free surface shape due to a line sink in an unconfined, vertical duct containing a porous medium (#1, p24)	**Paul Keeler** Electromagnetic signal propagation with randomness (#97, p73)	**Eduardo Altmann** Generalized entropies and the distance between scientific fields (#2, p24)
10:20–10:40	**Shawn Means** Weaving a tangled web: neurons and networks (#128, p89)	**Graham Weir** Magnetic field from a block neodymium magnet (#204, p128)	**Conway Li*** Corner rounding and roughness in dip-coating applications (#109, p79)	**Lisa Reischmann*** Extensions of the Cahn–Hilliard equation: modelling and simulation of coupled phase-separation processes (#163, p107)	**Pamela Burrage** Integrated approaches for stochastic chemical kinetics (#23, p35)
10:40–11:00	**Adarsh Kumbhari*** The importance of mitochondrial fission and fusion in a beating heart cell (#103, p76)	**Philip Laird** Simulation of reduction of train transit times and energy use from track upgrades (#106, p77)	**Harinadha Gidituri*** Dynamics of a fully wetted Marangoni surfer at the liquid-gas interface (#66, p57)	**Steve Taylor** An initial-boundary value functional differential equation problem arising in a cell division model (#186, p118)	**Markus Neuhaeuser** Pseudo-precision and rank tests (#139, p94)
11:00–11:20	Morning tea				

Wednesday morning continued

	Maitai 2	Waimea- McNabb session	Wairau	Riwaka	Heaphy
	Chair: Oliver Maclaren	*Chair:* Graeme Wake	*Chair:* Stephen Joe	*Chair:* P. Broadbridge	*Chair:* Nalini Joshi
11:20–11:40	**Alys Clark** Early pregnancy maternal-fetal interactions: Insights from an agent based model (#34, p41)	**Troy Farrell** Towards accurate real-time control of lithium ion batteries (#52, p50)	**Matthew Tam** A new descent algorithm in nonlinear optimisation (#185, p118)	**Dilruk Gallage*** Solution for 4th-order nonlinear axisymmetric surface diffusion by inverse method (#62, p55)	**Naoyuki Ishimura** On a copula-based conditional value at risk (#84, p66)
11:40–12:00	**Cailan Jeynes-Smith*** Ultrasensitivity in a reversible covalent modification cycle with positive autoregulation (#89, p69)	**Bruce van Brunt** The Cauchy problem for functional differential equations (#214, p133)	**Andrew Phair*** Image reconstruction for MRI with a rotating RF coil (#155, p103)	**Luke Bennetts** Nonlinear waves on metamaterial chains (#13, p30)	**Sean Dawson*** Quantum monodromy and symplectic invariants of the spheroidal harmonics system (#43, p45)
12:00–12:20	**Jennifer Flegg** Infection in surgical wounds: bacteria versus immune cells (#56, p52)	**John Burnell** Geothermal reservoir modelling - challenges and achievements (#21, p34)	**Ursula Weiss*** Shape optimization by homogenization of an electromagnetic emission sensor plate (#205, p128)	**Andrew Cullen*** Exploring nonlinear wave equations through a novel fast ODE solver (#42, p45)	**Diana Nguyen*** Integrable systems arising from separation of variables on S3 (#141, p95)
12:20–12:40	**Ronél Scheepers*** A compartment model of cholesterol regulation in the retina (#171, p111)	**Mary Myerscough** A structured population model for lipid accumulation in macrophages (#138, p94)	**Andrew Eberhard** A fixed point operator in discrete optimisation (#50, p49)	**Fabien Montiel** Transport equation models for water waves in ice-covered oceans (#132, p91)	**Fareeda Begum*** Counterparts of the Schwarz Lemma for univalent holoporphic functions on an annulus (#10, p28)
12:40–1:00	**Murk Bottema** Quantifying irregular shape (#17, p32)	**Robert McKibbin** Estimating airflow turbulence scales from gas tracer data (#127, p88)	**Chayne Planiden** The Moreau envelope, proximal mapping and derivative-free VU-algorithm (#156, p103)	**Scott McCue** Hole-closing problem for the Porous-Fisher equation (#126, p88)	**Christopher Green** Harmonic measure distribution functions for slit domains on spherical and toroidal surfaces (#72, p60)
1:00–2:00	Lunch				

Wednesday afternoon

2:00–2:50	**Invited: Martin Wechselberger (University of Sydney)**, Maitai 2 The geometry of excitability in multiple (time-)scale problems (#203, p127) *Chair: Adelle Coster*				
	Maitai 2	Waimea	Wairau	Riwaka	Heaphy
	Chair: Wang Jin	*Chair:* Phillip Brown	*Chair:* Richard Clarke	*Chair:* David Simpson	*Chair:* Peter Taylor
3:00–3:20	**Oleksii Matsiaka*** Mechanistic and experimental models of cell migration reveal the importance of cell-to-cell pushing (#124, p86)	**James McCaw** Metapopulation models for macroparasitic disease transmission (#125, p87)	**Alexander Tam*** A multi-phase extensional flow model for sliding motility in yeast biofilms (#184, p117)	**Sam Jelbart*** Canard explosion in two-stroke relaxation oscillators (#86, p67)	**Zhou Zhou** Transport plans with domain constraints (#212, p132)
3:20–3:40	**Jessica Crawshaw*** A computational model of vascular deformation (#40, p44)	**Robert Cope** Optimal early epidemic surveillance design for Bayesian model discrimination of novel pathogens (#37, p42)	**Jim Denier** Modelling blood flow through umbilical cord (#44, p46)	**Valerie Jeong*** Heteroclinic networks with noise and input (#88, p68)	**Edward Kim*** Backward stochastic equations and applications (#99, p74)
3:40–4:00	Afternoon tea				

Wednesday afternoon continued

	Maitai 2	Waimea	Wairau	Riwaka	Heaphy
	Chair: H. Tronnolone	*Chair:* James McCaw	*Chair:* Tim Stokes	*Chair:* Dion O'Neale	*Chair:* Bruce van Brunt
4:00–4:20	**Nathan Pages*** Multiple time scales in a calcium dynamics model. (#151, p101)	**Michael Lydeamore** Estimating epidemiological quantities for skin sores in remote Australian communities using interval-censored data (#116, p82)	**Sergey Suslov** Peculiarities of magnetic control of heat transfer in ferrofluids (#181, p116)	**Caroline Wormell*** Particle approximation of forward-backward stochastic differential equations (#207, p129)	**Angus Lewis*** Modelling electricity prices with regime switching models (#108, p78)
4:20–4:40	**Rowena Ball** Uncool CATs: Differential scanning calorimetry can overestimate critical ambient temperatures (#9, p28)	**Saber Dini** Quantifying the impact of recurrent malaria infections on hospital readmissions and death (#45, p46)	**Luke Fullard** Head in the sand: Modelling the flow of discrete grains as a continuum (#60, p54)	**Bernd Krauskopf** Excitability and feedback: to pulse or not to pulse? (#102, p75)	**Guiyuan Ma** Optimal investment and consumption under a continuous-time cointegration model with exponential utility (#118, p83)
4:40–5:00	**Wang Jin** Modelling SDF-1/CXCR4 regulated in vivo homing of therapeutic mesenchymal stem/stromal cells in mice (#90, p69)	**Steffen Docken** Quantifying the variability in the viral growth of SIV during infection (#47, p47)	**Edward Green** Connections between transversely isotropic fluids and active suspensions (#71, p60)	**Alex James** Gender and Society (#85, p67)	**Xiaoping Lu** A PDE approach for weather derivative pricing (#114, p81)
5:00–5:20	**Peter Taylor** A model for cell proliferation in a developing organism (#187, p119)	**Joshua Ross** Optimized prophylactic vaccination in metapopulations (#168, p109)	**Ravindra Pethiyagoda** Time-frequency analysis for wakes of accelerating ships (#154, p102)	**Carlo Laing** Reduced models for networks of model neurons (#105, p77)	**Song-Ping Zhu** An alternative form used to calibrate the Heston model (#213, p132)
6:30	Conference dinner: pre-dinner drinks – Riwaka Foyer and Courtyard				
7:00	Conference dinner – Maitai 1				

Thursday morning

9:00–9:50 — **Invited: Anja Slim (Monash University)**, Maitai 2
Trapped underground: the fluid dynamics of sequestered carbon dioxide (#174, p112)
Chair: Vivien Kirk

	Maitai 2	Waimea	Wairau	Riwaka	Heaphy
	Chair: R. Chisholm	*Chair:* Hyuck Chung	*Chair:* Fabien Montiel	*Chair:* Xiaoping Lu	*Chair:* Peter Johnston
10:00–10:20	**Pengxing Cao** Quantifying the *in vivo* gametocyte kinetics of *P. Falciparum* with controlled human malaria infection data (#26, p37)	**Sara Loo** Investigating selection pressure on single nucleotide polymorphisms in bacterial populations (#113, p81)	**Dimetre Triadis** An analytical solution for groundwater infiltration under ponded surface conditions (#192, p122)	**Justin Tzou** Anomalous scaling of Hopf bifurcation thresholds of localized spot patterns in 2-D (#195, p123)	**Philip Broadbridge** The partially integrable nonlinear diffusion equation with diffusivity $1/u$ (#18, p32)
10:20–10:40	**Michael Watson** A multiphase model of fibrous cap formation to investigate the effect of growth factor competition (#202, p127)	**Thi Hoai Linh Nguyen** Animal swarming models using stochastic differential equations: a brief review (#142, p96)	**Kenji Tomoeda** Appearance and disappearance of the region occupied by the flow through a boundary (#189, p120)	**Hinke Osinga** Bursting in the presence of a locally separating manifold (#149, p100)	**Frances Kuo** Application of Quasi-Monte Carlo methods to neutron diffusion and wave propagation in random media (#104, p76)
10:40–11:00	**Mike Chen** Chondrogenesis strategies in layered tissue engineering constructs (#30, p39)	**Stuart Johnston** The impact of short- and long-range perception on population movements (#92, p70)	**Kyoko Tomoeda** Toward a mathematical analysis for a model of suspension flowing down an inclined plane (#190, p120)	**Cris Hasan** Existence and stability of periodic traveling waves: who will prevail in a rock-paper-scissors game? (#75, p62)	**Thomasin Lynch** Advection problems with spatially varying velocity fields: Analytical and numerical solutions in 1D (#117, p83)
11:00–11:20	Morning tea				

Thursday morning continued

	Maitai 2	Waimea	Wairau	Riwaka	Heaphy
	Chair: Stuart Johnston	*Chair:* Alex James	*Chair:* Larry Forbes	*Chair:* Andrew Eberhard	*Chair:* Pamela Burrage
11:20–11:40	**Dietmar Oelz** Microtubule dynamics, kinesin-1 sliding, and dynein action drive growth of cell processes (#146, p98)	**Danya Rose** Who cares? Or, when does paternal care arise in primates? (#167, p109)	**Andrey Pototsky** Vertically vibrated floating drops (#159, p105)	**Daisuke Tagami** A incomplete balancing domain decomposition method for magnetostatic problems (#183, p117)	**Kenji Kajiwara** Space curve extensions of Log-aesthetic curves in industrial design by integrable geometry (#95, p72)
11:40–12:00	**Richard Clarke** Determining how the microstructure of the glycocalyx layer affects its bulk properties (#35, p41)	**Christopher Baker** Learning from optimisation to improve invasive species management (#7, p27)	**Larry Forbes** Light fluids rising through heavy ones (#59, p53)	**John Butcher** 45 years of B-series (#24, p36)	**Kevin Burrage** The Toeplitz part of a wave is the reflection-less part: an analysis based on Bessel functions (#22, p34)
12:00–12:20	**Shakti Menon** A unified mechanism for spatiotemporal patterns in somitogenesis (#129, p89)	**Matthew Holden** Can population dynamic models improve species occurrence predictions? (#80, p64)	**Tim Stokes** Unsteady free surface flows into a submerged ring sink. (#177, p114)	**Takuya Tsuchiya** Hadamard variational formulae and its applications for iterative numerical schemes (#194, p123)	**Boris Baeumer** Modelling deposition and erosion of clay in an aquifer (#6, p26)
12:20–1:10	**Invited: Ian Sloan (University of New South Wales)**, Maitai 2 Using maths to probe the maps - are the cosmic microwave background maps really random fields? (#175, p113) *Chair: Frances Kuo*				
1:10–1:20	Closing remarks – Maitai 2				
1:20–2:20	Lunch				

4 Conference Abstracts

1 Free surface shape due to a line sink in an unconfined, vertical duct containing a porous medium

Suha Al-Ali

Murdoch University

Co-authors: Graeme Hocking, Duncan Farrow

Timetable: p. 18

We consider flow of water in a homogeneous, saturated, porous medium in a vertical column that is confined horizontally, that has an air-water interface (phreatic surface) at the top and is unconfined below. The withdrawal of water with a free surface through a line sink from a two-dimensional, vertical sand column is considered using a novel spectral method. A hodograph solution with a cusp is computed and compared to the limiting steady state solutions. Unsteady solutions are computed to compare with the steady solutions and to consider the coning of the phreatic surface. A spectral method is used to solve both the steady and unsteady versions of the problem. In all cases, the mean level of the phreatic surface or interface remains approximately constant. If the flow rate is sufficiently small, the surface simply adjusts to the steady state solution, while if it is large enough the middle of the surface pulls down in a narrowing cone at an approximately linear rate until it draws into the sink. In order to determine which steady solution will evolve it is important to know the history. If the starting conditions are such that they lie above the line given by the hodograph solutions, then the surface will almost certainly draw down directly into the outlet.

2 Generalized entropies and the distance between scientific fields

Eduardo Altmann

School of Mathematics and Statistics, University of Sydney

Timetable: p. 18

Information theory provides a rigorous framework to compute the similarity between symbolic sequences. This talk will focus on sequences of written text in which the symbols are words. A distinguishing feature of these sequences is that they are mostly composed by a few words (that appear frequently in the text) but at the same time most words are rare (e.g., appear only once). This feature is described more precisely by Zipf's law, i.e., a fat-tailed distribution of word frequencies universally observed in different texts and languages. First I will show how Zipf's law affects the statistical properties of estimators of entropic-based measures (such as the Jensen-Shannon divergence) and how their slow convergence with the size of the text motivates the introduction of measures that go beyond the usual Shannon entropy. I will then show different applications of these generalized measures, including a study of the vocabulary change in English throughout the last centuries (based on millions of books from the Google n-gram database) and an investigation of the language of scientific fields in the last three decades (abstract of millions of scientific papers indexed by the Web of Science). In particular, will quantify the distance between scientific fields, show how they compare to alternative classifications (e.g., based on citations between papers), and quantify how they evolved in time.

3 Using a PDE to dissect the role of Plasmodium translocon of exported proteins during infection

Rosemary Aogo

Infection Analytics Program, Kirby Institute, UNSW Australia, Kensington NSW 2052, Australia.

Co-authors: Jasmin Akter, Deborah Cromer, Miles P. Davenport , Ashraful Haque, David S. Khoury

Timetable: p. 13

Malaria parasites infect red blood cells (RBCs). It is believed that successful maturation and replication depends upon the parasite trafficking hundreds of parasite-derived proteins into the host RBCs. This phenomenon is believed to mediate the viability and virulence of the parasite within the host. PTEX (Plasmodium translocon of exported proteins), the molecule which is located in the vacuole membrane is the trafficking machinery responsible for transport of these proteins into RBCs. The molecular role of PTEX has been characterised in vitro. Here, we are interested in understanding the importance of the PTEX for parasite survival and fitness within a host. To do this, we combined modelling with an established experimental system to track the loss and progression in life stages of PbA Ptex88 induced knockdown (Ptex88iKD) parasite in vivo. Here, we used a modelling approach that directly estimate the host rate of removal and replication rate of parasitized RBC. This showed that PTEX knockdown parasites were not more susceptible to host removal, and they produce the same number of progeny on average per successful replication cycle (PTEX-ve had a clearance half-life of 17.3h [95%CI; 13.8-27.7h] compared with 16.3h in PTEX+ve). However, using an age-structured PDE model we identified that knockdown of Ptex88 slowed parasite maturation. This implies that, Ptex88 is important for parasite maturation, more so in the early stages of the parasite life cycle. These findings provide more understanding of the importance of parasite protein export into the host RBC for parasite development and survival within an infected host.

4 Complex dynamics of a diffusive modified Holling-Tanner predator-prey model

Claudio Arancibia-Ibarra

Queensland University of Technology (QUT)

Co-authors: Michael Bode, José Flores, Graeme Pettet, Peter Van Heijster

Timetable: p. 16

In this work, we consider temporal and spatio-temporal Holling-Tanner predator-prey models with an alternative food for the predator. From our result of the temporal model, we identify regions in parameter space in which Turing instability in the spatio-temporal model are expected. Subsequently, we analyse these instabilities. We use simulations to illustrate the behaviour of both the temporal and spatio-temporal model.

5 An agent-based approach for modelling the dilution effect in plants

Jason Archer
Massey University
Co-authors: Mick Roberts
Timetable: p. 15

The dilution effect is the subject of much controversy in ecological epidemiology. It supposes that there exists a negative relationship between the biodiversity of a given ecosystem and the risk of disease transmission within it. This is an appealing prospect in theory, providing a public health incentive for conservation which is particularly relevant for infectious diseases caused by pathogens that circulate in natural reservoirs, such as influenza and Ebola virus. We explore the dilution effect mathematically in the context of plants, emulating a study by Zhu et al (2000) examining rice varieties planted in polycultures and their susceptibility to fungal rice blast disease. We accomplish this by considering an SIR-derived agent-based model that describes the spread of an infectious disease through a community of plants. To investigate the dilution effect we implement two mechanisms that might bring about a dilution effect. The first of these is a reduction in transmission between plants of different species, and the second is a reduction in the susceptibility of plants with neighbours of different species, stemming from an increased fitness through ecological complementarity or facilitation. Using this model, we determine that there are multiple competing mechanisms at play that could explain the presence (or absence) of the dilution effect. We compare this model to analogous existing continuous time models and see that the dilution effect is not universally applicable, but rather, a complex phenomenon sensitive to the scale and properties of specific systems.

6 Modelling deposition and erosion of clay in an aquifer

Boris Baeumer
University of Otago
Co-authors: Tom Blennerhasset
Timetable: p. 23

We develop a system of non-linear PDEs to model the deposition and erosion of clay in an aquifer. We use the powerful finite element package FEniCS to approximate solutions and observe the emergence of channels and lenses.

7 Learning from optimisation to improve invasive species management

Christopher Baker
University of Queensland
Timetable: p. 23

Invasive species are an important global conservation issue, with Australia and New Zealand bearing the brunt of the current impacts. In an environment of limited funding, we can use dynamic optimisation methods such as optimal control theory to understand how best to expend resources through time, spatially, and between species. However, the complexity and stochasticity of the environment make it challenging to model these systems effectively, let alone do it in a way that permits the computation of a true optimal management strategy. Different modelling approaches have strengths and weaknesses, and, in order to capitalise on all of their strengths, we need to carefully think about how they fit together. In this talk I will discuss a range of invasive species modelling approaches, going from simple models through to much more complex and tailored models, and discuss how we can learn across them to inform and improve management.

8 Mathematical and computational challenges in interdisciplinary bioscience: efficient approaches for interrogating stochastic models of biological processes

Ruth Baker
University of Oxford
Timetable: p. 18

Simple mathematical models have had remarkable successes in biology, framing how we understand a host of mechanisms and processes. However, with the advent of a host of new experimental technologies, the last ten years has seen an explosion in the amount and types of data now being generated. Increasingly larger and more complicated processes are now being explored, including large signalling or gene regulatory networks, and the development, dynamics and disease of entire cells and tissues. As such, the mechanistic, mathematical models developed to interrogate these processes are also necessarily growing in size and complexity. These detailed models have the potential to provide vital insights where data alone cannot, but to achieve this goal requires meeting significant mathematical challenges. In this talk, I will outline some of these challenges, and recent steps we have taken in addressing them.

9 Uncool CATs: Differential scanning calorimetry can overestimate critical ambient temperatures

Rowena Ball

Australian National University

Co-authors: Brian Gray, Charlie Macaskill

Timetable: p. 21

The standard method for calculation of reaction kinetic constants from differential scanning calorimetry (DSC) data assumes, firstly, that the temperature throughout the sample is spatially uniform and, secondly, that a single reaction is involved. In this talk I describe a perturbation analysis carried out by the authors to investigate the conditions under which these assumptions begin to break down. The consequent extent to which minor errors in the values of the kinetic constants are amplified and derived critical ambient temperatures (CATS) are dangerously overestimated is assayed for bulk quantities of the material. The heat conduction equation is used and the rate of reaction heat generation is accounted for explicitly, as in standard thermal ignition theory. The model includes also compensation for thermal lag that typically occurs in a DSC. The leading-order approximation that follows from this model corresponds to the classical approximation used in DSC theory. However, the present theory also allows determination of correction terms and thereby evaluates the conditions under which such corrections are negligible. Only then can the classical method of calculation of the kinetic constants be relied on. The basic result is that current practice is reasonably accurate when the Frank-Kamenetskii parameter, familiar in thermal ignition studies, is $\ll 1$. But thermally unstable substances have a propensity to self-ignite largely because their Frank-Kamenetskii parameter is of order 1 or greater! Numerical simulations using experimental kinetic and thermochemical data support the theory.

10 Counterparts of the Schwarz Lemma for univalent holoporphic functions on an annulus

Fareeda Begum

University of Canterbury

Co-authors: Ngin-Tee Koh

Timetable: p. 19

We study Schwarz lemma counterparts for univalent holomorphic functions on an annulus. Some counterexamples demonstrates that a pointwise version of the Schwarz lemma for univalent holomorphic functions on an annulus would not be possible. We also establish an integral means version of the Schwarz lemma for univalent analytic mappings of an annulus. It is determined that normalization and univalence both play a vital role.

11 An agent-based model for the spread of Wolbachia in mosquito populations

Sarah Belet
Monash University
Co-authors: Jennifer Flegg, Jonathan Keith, Kate Smith-Miles
Timetable: p. 15

The vector-borne Dengue fever poses a major health issue in tropic environments, which includes areas such as far-north Queensland. One method of suppressing the spread of Dengue fever that is currently being trialled is the introduction of bacteria called *Wolbachia* into mosquito populations, which prevents mosquitoes from passing on viruses to humans. A *Wolbachia* invasion has strong potential to completely saturate mosquito populations due to a mechanism called cytoplasmic incompatibility. Here, we will be detailing the effects and mechanisms of *Wolbachia*, including the phenomenon of cytoplasmic incompatibility. We will discuss the development and outcomes of an agent-based model for the spread of *Wolbachia* in mosquito populations.

12 Mathematical modelling of nasal high flow

Alona Ben-Tal
Massey University
Co-authors: James Revie and Stanislav Tatkov
Timetable: p. 17

Nasal High Flow (NHF) is a therapy in which humidified, warm air is delivered through the nose to spontaneously breathing patients. It has been shown that NHF affects the amplitude and frequency of breathing and that this response varies between patients and between wakefulness and disease states. To help us understand the physiological effects of NHF, we have developed a mathematical model of the respiratory system that couples the upper airway with lung mechanics, gas exchange and gas transport. The model consists of 12 ordinary differential equations and was simulated in open loop (i.e. without including the respiratory feedback mechanisms) under different physiological conditions. Our simulations show that NHF affects the oxygen (O_2) and carbon dioxide (CO_2) levels in the blood. We hypothesize that these changes in blood gas levels trigger the respiratory control system to change the breathing pattern and we show that changing the breathing pattern under certain conditions can bring the blood levels of O_2 and CO_2 back to normal. Our simulations also show that administrating NHF leads to an increase in baseline of airway pressure as well as an increase in pressure swings during breathing. These results are aligned with trends seen in previous experimental studies. Our theoretical study provides several new insights about the physiological effects of NHF and demonstrates the potential of using NHF for studies of neural control of breathing.

13 Nonlinear waves on metamaterial chains

Luke Bennetts
University of Adelaide
Timetable: p. 19

I will consider nonlinear "long" waves that are supported by a mass-in-mass metamaterial chain when nonlinear stiffness is included. The mass-in-mass chain consists of a standard mass-spring chain, but with an additional mass and spring attached to each mass on the chain. The attachments split the linear dispersion curve into two branches, so that long waves can be found at relatively high frequencies. I will show that cubically nonlinear hardening/softening in the attached springs results in bright/dark solitons and breathers in a band of high frequencies.

14 On the dynamical mechanisms governing El Niño–Southern Oscillation irregularity

Judith Berner
National Center for Atmospheric Research, Boulder, Colorado, USA
Co-authors: Prashant D. Sardeshmukh and Hannah M. Christensen
Timetable: p. 12

El Niño–Southern Oscillation (ENSO) is the dominant mode of tropical variability on interannual time scales. It consists of an irregular oscillation of sea surface temperature anomalies over the tropical eastern Pacific Ocean, with a periodicity in the 3-7 yr range. Through atmospheric teleconnections, ENSO impacts weather across the globe and is the leading source of predictive skill for seasonal and interannual forecasts. This study investigates the mechanisms by which short time-scale perturbations to atmospheric processes can affect ENSO variability in climate models.

To this end climate simulations with and without stochastic parameterizations are compared. The simulation with stochastic parameterization (STOCH) compares better with observations in having lower interannual sea surface temperature variability and more irregular transitions between El Niño and La Niña states, as expressed by a broader spectrum.

Reduced-order linear inverse models (LIMs) derived from lagged covariances of selected tropical variables yield good representations of tropical interannual variability. In particular, the basic features of ENSO are captured by the LIMs least damped oscillatory eigenmode. In STOCH, the damping time scale of this eigenmode is reduced from 17 to 11 months. This noise-induced stabilization is consistent with perturbations to the frequency of the ENSO eigenmode and explains the broadening of the spectrum.

We will derive analytically that a noise-induced stabilization and broadening of the spectrum are obtained when stochastically perturbing the frequency of a linear damped oscillator. On the other hand, perturbations to the damping rate will lead to increased variance and a narrowing of the spectrum.

15 Optimal control of irrupting pest populations in a climate-driven ecosystem

Rachelle Binny
Manaaki Whenua - Landcare Research
Co-authors: E Penelope Holland, Alex James
Timetable: p. 14

Irruptions of small consumer populations, driven by pulsed resources, can lead to adverse effects including the decline of indigenous species or increased disease spread. Broad-scale pest management to combat such effects benefits from forecasting of irruptions and an assessment of the optimal control conditions for minimising consumer abundance. We use a climate-based consumer-resource model to predict irruptions of a pest species (*Mus musculus*) population in response to masting (episodic synchronous seed production) in New Zealand beech forest, and extend this model to account for broad-scale pest control of mice using toxic bait. The extended model is used to forecast the magnitude and frequency of pest irruptions under different control intensities, and for different timings of control operations. In particular, we assess the optimal control timing required to minimise the frequency with which pests reach 'plague' levels, whilst avoiding excessive toxin use.

16 A household model for vector-borne diseases

Andrew Black
University of Adelaide
Co-authors: Andrew Smith, Joshua Ross and Alun Lloyd
Timetable: p. 15

We introduce the first household model for vector-borne diseases such as Dengue and Zika. This assumes that the majority of transmission occurs within a household where both the numbers of humans and vectors are relatively small. Our model captures the impact on transmission of both the local depletion of susceptible humans and the natural turnover of the vectors due to births and deaths. We show how the within-household process can be modelled as a continuous-time Markov chain and the population level level spread modelled as a branching process. Using this framework, we can calculate a number of quantities of interest, such as the household reproduction number, and investigate how interventions can change these.

17 Quantifying irregular shape

Murk Bottema

Flinders university

Co-authors: Amelia Gontar, Hayden Tronnolone Ben Binder

Timetable: p. 19

Many biological structures are highly irregular in shape but the details of the shape are crucial to properties and function. Examples include the structure of trabeculae in cancellous bone, fat distribution in beef, and pseudohyphae of dimorphic yeast colonies. An approach to characterising shape of irregular objects based on the notion of "bag-of-shapes" is presented. A key attribute of the method is that features for representing or classifying shapes are determined automatically. The general method lends itself to modification according to prior understanding of the class of objects at hand.

18 The partially integrable nonlinear diffusion equation with diffusivity $1/u$

Philip Broadbridge

Dept. of Maths and Stats, La Trobe University

Timetable: p. 22

The nonlinear diffusion equation,

$$\frac{\partial u}{\partial t} = \nabla \cdot \left[\frac{1}{u} \nabla u \right],$$

applies to electron diffusion in plasma, and to porous media, when the dependent variable is $S = 1 - u$ $=$ degree of saturation and diffusivity $D = 1/(1 - S)$. This case of nonlinear diffusivity has special symmetry properties. In one space dimension, it is the fixed point of the same non-Lie equivalence transformation that shows equivalence of the integrable models $D = 1/u^2$ and $D = 1$. In two space dimensions, that special diffusion equation is known to have an infinite dimensional Lie point symmetry group, including a free pair of conjugate harmonic functions. Each choice of complex analytic function $f(z)$ will lead to a symmetry reduction to a non-integrable PDE in one time and one space dimension. There is some advantage in finding a direct mapping from a chosen function $f(z)$ to an infinite dimensional class of explicit solutions of the nonlinear diffusion equation. That class is given here. The solutions satisfy constant-flux boundary conditions on any contour. The increasing solutions have initial condition $u = 0$ and the decreasing positive solutions are extinguished in finite time.

19 Modelling colon cancer: Early modelling work

Phillip Brown
University of Adelaide
Timetable: p. 12

Serrated sessile polyps (SSPs) are a type of lesion found in the colon that are known to lead to colorectal cancer. They develop when there are disruptions in the processes controlling the function of colonic crypts - the test-tube shaped structures that make up the lining of colon. They are currently much harder to detect than conventional polyps, owing to their flat (sessile) appearance, and hence are less likely to be identified early, increasing the likelihood that they progress to cancer.

The term “serrated” comes from the saw-tooth appearance of the crypt walls seen in histology images. It is currently not clear what will cause a healthy crypt to become serrated, but it has been shown that SSPs are associated with mutations to the BRAF or KRAS genes which may cause resistance to apoptosis and an increase in proliferation rates.

This project hopes to shed light on the physical and mechanical processes that lead to serrations by using agent-based modelling techniques to recreate the serrated morphology. In particular, it will use the package CHASTE to achieve this.

In this talk I will give an overview of the biology of SSPs and describe the preliminary modelling work done to recreate the aspects of a healthy colonic crypt that may be important to SSP formation.

20 Travelling waves in a mathematical description of a biologically inspired smart material

Alexander Browning
Queensland University of Technology
Co-authors: Professor Matthew Simpson, Dr Francis Woodhouse
Timetable: p. 15

An area of recent interest is that of mechanical metamaterials. In their simplest sense, these materials consist of an array of interconnected elements that are tunable and produce interesting mechanical behaviours. We incorporate a biological mechanism into a previously studied one-dimensional metamaterial that is designed to transmit a simple mechanical signal. Our mechanism allows the material to automatically reset. In this talk, we present a mathematical description of the material and this new mechanism, and investigate the effect of this mechanism on the ability of the material to transmit mechanical signals. The signal is transported through the material by a travelling wave, leading to interesting mathematical analysis that draws parallels to the Fitz-Hugh Nagumo model.

21 Geothermal reservoir modelling - challenges and achievements

John Burnell
GNS Science
Timetable: p. 19

Since the 1950's, researchers in New Zealand have sought ways to reliably predict the future behaviour of geothermal systems. The DSIR Applied Mathematics Division, led by Alex McNabb, was at forefront of these efforts. Great strides have been made over that period from quasi-analytic models through to 3-dimension numerical models that capture the complexity of the reservoir geology. In this talk, I will look at some of the achievements that have been made in New Zealand and also the challenges that need to be resolved before the next advancements can be made.

22 The Toeplitz part of a wave is the reflection-less part: an analysis based on Bessel functions

Kevin Burrage
QUT
Co-authors: Pamela M. Burrage, Shev MacNamara
Timetable: p. 23

We study the reflection-less boundary condition for the wave equation in one space dimension and time, in the semi-discrete setting, where time remains continuous and space is discretized. It is known that all matrix functions of the familiar second difference matrix representing the Laplacian in this setting are the sum of a Toeplitz matrix and a Hankel matrix. The solution to the wave equation is one such matrix function. Here, we show that the Toeplitz part is reflection-less. A key part of our analysis involves properties of Bessel functions.

Our approach allows control so that it is possible to choose in advance the number of reflections in a computer simulation of the wave. An attractive result that comes out of our analysis is the appearance of the well-known shift matrix, and also other matrices that might be thought of as Hankel versions of the shift matrix. By revealing the algebraic structure of the solution in terms of shift matrices, we make it clear that the Toeplitz part, which we term the 'Toeplitz wave,' is indeed reflection-less at the boundary. Although the subject of the reflection-less boundary condition has a long history, we believe the point of view that we adopt here in terms of matrix functions is new.

23 Integrated approaches for stochastic chemical kinetics

Pamela Burrage

Queensland University of Technology (co-authors are at various institutions)

Co-authors: Manuel Barrio, Kevin Burrage, Andre Leier, Tatiana Marquez-Lago, Shev MacNamara

Timetable: p. 18

In this talk I discuss how we can simulate stochastic chemical kinetics when there is a memory component. This can occur when there is spatial crowding within a cell or part of a cell, which acts to constrain the motion of the molecules which then in turn changes the dynamics of the chemistry. The counterpart of the Law of Mass Action in this setting is through replacing the first derivative in the ODE description of the Law of Mass Action by a time-fractional derivative, where the time-fractional index is between 0 and 1. There has been much discussion in the literature, some of it wrong, as to how we model and simulate stochastic chemical kinetics in the setting of a spatially-constrained domain this is sometimes called anomalous diffusion kinetics.

In this presentation, I discuss some of these issues and then present two (equivalent) ways of simulating fractional stochastic chemical kinetics. The key here is to either replace the exponential waiting time used in Gillespies SSA by Mittag-Leffler waiting times (MacNamara et al. [2]), which have longer tails than in the exponential case. The other approach is to use some theory developed by Jahnke and Huisinga [1] who are able to write down the underlying probability density function for any set of mono-molecular chemical reactions (under the standard Law of Mass Action) as a convolution of either binomial probability density functions or binomial and Poisson probability density functions). We can then extend the Jahnke and Huisinga formulation through the concept of iterated Brownian Motion paths to produce exact simulations of the underlying fractional stochastic chemical process. We demonstrate the equivalence of these two approaches through simulations and also by computing the probability density function of the underlying fractional stochastic process, as described by the fractional chemical master equation whose solution is the Mittag-Leffler matrix function. This is computed based on a clever algorithm for computing matrix functions by Cauchy contours (Weideman and Trefethen [3]).

This is joint work with Manuel Barrio (University of Vallodolid, Spain), Kevin Burrage (QUT), Andre Leier (University of Alabama), Shev MacNamara (University of Technology Sydney) and T. Marquez-Lago (University of Alabama).

[1] T. Jahnke and W. Huisinga, 2007, Solving the chemical master equation for monomolecular reaction systems analytically, J. Math. Biology 54, 1, 126. [2] S. MacNamara, B. Henry and W. McLean, 2017, Fractional Euler limits and their applications, SIAM J. Appl. Math. 77, 2, 447469. [3] J.A.C. Weideman and L.N. Trefethen, 2007, Parabolic and hyperbolic contours for computing the Bromwich integral, Math. Comp. 76, 13411356.

24 45 years of B-series

John Butcher

University of Auckland

Timetable: p. 23

In the paper [Hairer, E. and Wanner, G. Computing 13 (1974), 1-15], the term "B-series" was introduced. Although the motivation was the analysis of numerical methods for differential equations, the Hopf algebra on which B-series are based, now has wide-ranging applications to various fields, including geometry, quantum field theory and stochastic processes. In this 45 year anniversary, some of the combinatoric and algebraic structures, on which B-series are built, will be reviewed; together with an introduction to some of the applications to the analysis of numerical methods.

25 Global instabilities in the flow around a rotating sphere

Sophie Calabretto

Macquarie University

Timetable: p. 16

The unsteady flow generated due to the impulsive motion of a sphere is a paradigm for the study of many temporally developing boundary layers. The boundary layer is known to exhibit a finite-time singularity at the equator, which manifests as the ejection of a radial jet, preceded by a toroidal starting vortex pair, which detaches and propagates away from the sphere. The radial jet subsequently develops an absolute instability, which propagates upstream towards the sphere's surface. This talk will present new results, considering the global stability of the temporally and spatially developing flow, in regimes where separation of temporal and spatial scales prohibits the use of classical techniques from hydrodynamic stability theory.

26 Quantifying the *in vivo* gametocyte kinetics of *P. Falciparum* with controlled human malaria infection data

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Co-authors: Katharine A. Collins, Sophie Zaloumis, Julie A. Simpson, James S. McCarthy, James M. McCaw
Timetable: p. 22

Malaria causes over 200 million new infections in humans and approximately half a million deaths every year (predominantly in children under 5 years old, and mainly due to *P. falciparum*). Interrupting malaria transmission represents one of the most effective strategies to achieving malaria elimination and the development of successful interventions requires a quantitative understanding of the within-human kinetics of gametocyte which is a particular stage of parasite development and responsible for transmission from human to mosquito. Here, we quantify the gametocyte kinetics in humans by fitting a mechanistic model of within-host malaria infection to the data from a controlled human malaria infection (CHMI) clinical trial. We validate the model fits against a different set of data and further investigate the potential impact of varied kinetic parameters on the transmission probability linked via the expression of gametocyte level in human blood. This work is facilitated by two advances: (1) more accurate and frequent measurements of the parasite load using qPCR; (2) adoption of mechanistic within-host modelling and Bayesian hierarchical modelling in data fitting such that kinetic parameters at both individual and population levels can be coherently quantified. The predictive model will facilitate the design of future clinical trials, optimisation of drug regimens for treatment and for development of more effective interventions to block transmission.

27 Calculating thermal diffusivity from laser flash experiments

Elliot Carr
Queensland University of Technology
Timetable: p. 14

The laser flash method for measuring the thermal diffusivity of solids involves subjecting the front face of a small sample to a heat pulse and recording the subsequent temperature rise on the opposite (rear) surface. The thermal diffusivity can be estimated from the rear-surface temperature rise history by calculating the half rise time: the time required for the temperature rise to reach one half of its maximum value. In this talk, I will present an alternative approach that expresses the thermal diffusivity exactly in terms of an appropriate integral involving the theoretical rear-surface temperature rise curve. Approximating this integral numerically leads to a simple formula for the thermal diffusivity involving the rear-surface temperature rise history. Results based on randomly-generated synthetic experimental data sets, demonstrate that the new approach produces estimates of the thermal diffusivity — for a typical test case — that are more accurate and less variable than the half-rise time approach.

28 A collective coordinate framework to study the dynamics of travelling waves in stochastic PDEs

Madeleine Cartwright

University of Sydney

Co-authors: Georg Gottwald

Timetable: p. 15

We propose a formal framework based on collective coordinates to reduce infinite-dimensional stochastic partial differential equations (SPDEs) with symmetry to a set of finite-dimensional stochastic differential equations which describe the shape of the solution and the dynamics along the symmetry group. We study SPDEs arising in population dynamics with multiplicative noise and additive symmetry breaking noise. The collective coordinate approach provides a remarkably good quantitative description of the shape of the travelling front as well as its diffusive behaviour, which would otherwise only be available through costly computational experiments. We corroborate our analytical results with numerical simulations of the full SPDE.

29 A probabilistic model for martensitic interfaces

Pierluigi Cesana

Institute of Mathematics for Industry, Kyushu University and La Trobe University

Co-authors: John M. Ball; Ben Hambly

Timetable: p. 13

A martensitic phase-transformation is a first-order diffusionless transition occurring in elastic crystals and characterized by an abrupt change of shape of the underlying crystal lattice. It is the basic activation mechanism for the Shape-Memory effect. In this talk we present a probabilistic model for the description of martensitic microstructure as an avalanche process. Our approach to the analysis of the model is based on an associated general branching random walk process. Comparisons are reported for numerical and analytical solutions and experimental observations.

30 Chondrogenesis strategies in layered tissue engineering constructs

Mike Chen
University of Adelaide
Timetable: p. 22

Chondrogenesis, the differentiation of mesenchymal stem cells (MSCs) into chondrocytes (native cartilage cells), is a key step in the tissue engineering of articular cartilage. Chondrogenesis is regulated by transforming growth factor-β (TGF-β), a short-lived cytokine whose effect is prolonged by storage in the extracellular matrix. Successful tissue engineering applications require as complete differentiation of the initial population of MSCs as possible. Recent experiments involve seeding a hydrogel construct with a layer of MSCs lying below a layer of chondrocytes, stimulating the construct from above with exogenous TGF-β and then culturing it *in vitro*. To investigate the efficacy of this strategy we develop a reaction-diffusion model to describe the interactions between MSCs, chondrocytes and TGF-β. Using this model we investigate the effect of varying the initial concentration of TGF-β, the initial cell densities and the relative depths of the two layers.

31 Domain truncation in pipeline monitoring

Pascal Cheon
University of Auckland
Timetable: p. 15

On-line pipeline process monitoring is a common problem faced in industrial applications. The aim is to reconstruct the evolution of liquid concentration inside a segment of a pipe. A typical measurement modality for this is the electrical impedance tomography (EIT). This is a non-invasive boundary measurement modality which maps from the unknown concentration distribution space to the voltage measurement space. The voltage measurements are induced by currents injected from the boundary of the pipe. Thus, when modelling the measurement process, the computational domain is designed large enough to encapsulate sufficient current flow distribution over the liquid. Consequently, the domain may include a nuisance subdomain which is not of our reconstruction interest. The nuisance domain can be artificially truncated out by constructing a boundary condition over the truncation boundary. A non-local boundary map called the Dirichlet-to-Neumann (DtN) map is introduced for this boundary condition. In this talk, we propose a way of incorporating the domain truncation in the nonstationary estimation problems. The viability of this approach in on-line pipeline process monitoring problem is demonstrated with numerical simulations.

32 Population-level effects of immunological memory contingent on multiple infection episodes

Rebecca Chisholm

University of Melbourne

Co-authors: Nikki Sonenberg, Nicholas Geard

Timetable: p. 15

Immunological memory, following infection or vaccination, enables a rapid and more enhanced immune response during subsequent infections, and impacts epidemiological dynamics at the host-population scale. For pathogens comprised of single serotypes (i.e., one immunologically-equivalent strain, such as the measles), immunological memory can inhibit transmission via herd immunity. For pathogens comprised of multiple serotypes (i.e., multi-strain pathogens), the impact is more complex. For example, infection or vaccination against a particular serotype of Streptococcus pneumoniae leads to immunological memory that is largely serotype-specific, which poses challenges for understanding its transmission and control.

Group A Streptococcus (GAS) is another multi-strain human pathogen for which our understanding of transmission and immunity are limited. A recent study showed that mice require two (skin) infections by the same strain within a three-week time window to develop enduring strain-specific immunity. It is unknown whether a similar mechanism operates in humans, nor how the three-week time window might translate to humans. The population-level effects of such a mechanism are also unclear.

I will describe how we used mathematical modelling to (i) determine population-level consequences of enduring immunological memory when it is contingent on multiple episodes of infection; and (ii) assess whether this might plausibly explain the acquisition of immunity to GAS in humans. Our results reveal a complex relationship between the pathogen, immunological memory, and the endemic prevalence and strain diversity. Furthermore, we show that this immunological mechanism can lead to patterns of transmission that are consistent with observations of GAS across different host population settings.

33 Acoustic scattering by a circular cylinder and air flow around it

Hyuck Chung

Auckland University of Technology

Timetable: p. 17

The scattering of sound wave around a circular cylinder in 2D has been well studied. Here I present a computation of sound field around an elastic cylinder when there is steady low-Mach number air flow. The air flow creates additional resonances in the down stream below the fundamental frequency of the cylinder. The circular cylinder that is elastic is centred at the origin and the steady air flow up to 15% of the speed of sound comes from the right of the cylinder. The air, sound pressure, elastic deformation of the cylinder are modelled by linear theory of elasticity, and fluid.

34 Early pregnancy maternal-fetal interactions: Insights from an agent based model

Alys Clark

Auckland Bioengineering Institute, University of Auckland

Co-authors: Rojan Saghian, Joanna James

Timetable: p. 19

At the beginning of pregnancy, a unique change occurs in the arteries of the uterus. After implantation, the placenta begins to form and needs to establish an effective nutrient supply from mother. Therefore, placental cells (trophoblasts) invade both into uterine tissue and into the maternal blood vessels nearest to the site of implantation. These trophoblast act to remodel the maternal blood vessels, transforming them from tightly coiled muscular arteries into wide open-bore conduits allowing for an increasing flow of nutrient rich blood to feed baby via the placenta. While studies of trophoblast migration in vitro have identified a number of factors (chemoattractants, mechanical stimuli) that could impact on this process, there is currently no effective means to translate these data to the in vivo scenario where the net flow of blood toward the placenta potentially impinges on invasion. Here we present a 3D agent based model that takes steps toward teasing apart the impact of chemical signals and shear stress on trophoblast invasion into the maternal arteries. Our model is parameterised to experimental data describing trophoblast migration under shear stress. The model predicts that observed 'plugging' of the maternal arteries in early pregnancy can act to promote trophoblast invasion by providing a 'low flow' environment, and postulate how localised cell death or 'weak spots' in plug structure can lead to plug degeneration and a rapid increase in blood flow to the placenta near the end of the first trimester, marking the onset of blood flow through the materno-fetal circulation.

35 Determining how the microstructure of the glycocalyx layer affects its bulk properties

Richard Clarke

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Co-authors: Tet Chuan Lee, Vinod Suresh

Timetable: p. 23

The Endothelial Glycocalyx Layer (EGL) is a thin, brush-like layer that coats the inside of the vasculature. It is believed to serve as a protective barrier against excessive fluid shear, as well as a number of other biological functions, such as mechanotransduction. In the past the EGL has been modelled as an isotropic, homogeneous porous layer. However, there is an increasing volume of experimental evidence to suggest that the EGL has a microstructural organisation that brings in to question this assumption. This study uses Homogenisation Theory, applied on a two-dimensional embedded surface, to analyse the extent to which anisotropy on the microscale can lead to anisotropy on the bulk scale.

36 How does hormone receptor phosphorylation tune the calcium signal in hepatocytes?

Ielyaas Cloete
University of Auckland
Timetable: p. 14

Variation of calcium concentration in hepatocytes (liver cells) is known to modulate diverse cellular 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 are interested in determining the effects of various types of calcium feedback mechanisms such as calcium feedback on Phospholipase C (PLC) and the calcium-mediated protein kinase C (PKC) feedback on the hormone receptor have on the whole-cell calcium signals. Recent experimental 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, it appears that there is also a negative feedback pathway, cross-coupling PLC activation to PKC, which serves to terminate calcium spikes.

This talk will discuss recent progress in construction and analysis of a model of calcium oscillations that incorporates the new experimental results about likely feedback mechanisms in hepatocytes.

37 Optimal early epidemic surveillance design for Bayesian model discrimination of novel pathogens

Robert Cope
University of Adelaide
Co-authors: Joshua Ross
Timetable: p. 20

When a novel pathogen emerges, characterizing its epidemiology is necessary to produce models and devise interventions. For example, the choice of intervention and its effectiveness may be heavily impacted by whether symptom onset coincides most closely with exposure to the disease, infectiousness, or recovery. To characterise the disease epidemiology, we require surveillance data, but when resources are limited we must choose a limited number of times at which to enact surveillance. In this talk, we demonstrate a framework for identifying pathogen epidemiology from first-few-hundred household data (under incomplete surveillance), using random forest based Bayesian model discrimination. We evaluate optimal surveillance strategy across a range of simulated scenarios, and present a heuristic that produces high-quality strategies at a fraction of the computational expense. This framework is highly effective and represents a significant advance for disease decision support.

38 Stochastic queueing models: intracellular dynamics, regulation and optimisation with data

Adelle Coster
School of Mathematics & Statistics, UNSW
Timetable: p. 15

Mammalian cells respond to insulin by redistributing their transporter proteins to express more at the surface of the cell, controlling the flux of glucose. This response is rapid to take advantage of the higher concentration of glucose in the bloodstream after a meal. When external glucose levels are low, however, the transporters need to be sequestered away from the cell surface to stop the glucose leaking out. I will present some experimental data indicating some of the dynamics of fat cells under insulin stimulation, and develop a closed, stochastic queueing model to describe the system. An exploration of the parameter space shows that the model is a feasible one to describe the data and a distance function is developed for the comparison of the time-varying distributions of the stochastic model and the stochastic data.

39 Wrinkles in nanosurfaces

Barry Cox
University of Adelaide
Co-authors: Tom Dyer and Natalie Thamwattana
Timetable: p. 13

Chemical vapour deposition is a popular technique for producing high-quality graphene sheets on a substrate. However, the cooling process causes the graphene sheet to undergo a strain-induced, out-of-plane buckling resulting in graphene wrinkles. These wrinkles often lead to undesirable effects on the properties of the graphene sheet. In this talk we construct a mathematical model to understand the conformations of these wrinkles. Initial an arch-shaped wrinkle is modelled this is then generalised to incorporate graphene self-adhesion through van der Waals interactions across the wrinkle sides. Variational techniques are utilised to determine the lowest-energy conformation for both models. We find these models predict lowest-energy structures similar to those seen in experiments.

40 A computational model of vascular deformation

Jessica Crawshaw
University of Melbourne
Co-authors: James Osborne, Jennifer Flegg
Timetable: p. 20

The term vascular remodelling describes morphological alterations to the blood vessel network to optimise and maintain the delivery of blood to the tissue. Within the microvasculature, vascular remodelling features angiogenesis, vessel wall thickening, and vascular regression. Whilst the former have enjoyed much attention from the mathematical community, the latter, vascular regression, has yet to be explored in detail. Furthermore, although it is well accepted that the forces from the blood flow (haemodynamic forces) have a necessary role in vascular regression, it is difficult to experimentally distinguish between the relative contribution of the haemodynamic forces and the various cellular signalling pathways. As such, the development of computational models to analyse the relationship between the local haemodynamic forces and the surrounding vasculature is invaluable.

We have developed a computational model to study how the capillary wall deforms when subject to haemodynamic forces. Using the open source multicellular modelling software package, Chaste, we have modelled the capillary wall as a discretised hyperelastic membrane interacting with the microcirculation, modelled using a lattice-Boltzmann simulation in HemeLB, over a long time scale. This discretised model will enable us to examine how blood vessels deform in response to the local haemodynamic environment, thus laying the foundations for future research examining the relationship between haemodynamic forces and the deformation of the vessel wall.

41 BondGraphTools: Modelling network bioenergetics

Peter Cudmore
University of Melbourne
Timetable: p. 14

Energy is the currency of physical systems, yet mathematical models of biological processes often neglect to account for energy and power. While this is not necessarily a problem when describing an individual process, capturing the flow of energy is crucial for building systems level models that avoiding pathological behavior such as perpetual motion. Following how energy is transformed also allows for increasingly physical descriptions of multi-domain processes such as cellular respiration (electro-chemical) and muscular contraction (electro-chemo-kinetic).

In many interesting cases, metabolism for example, cellular systems can be described using a network topology. These networks describe how energy is transformed from one form or location to another. It is this network topology that allows mathematical biologists to talk about distinct subnetworks (the Krebb cycle, for example) and conceptually organize a system into modules.

Here we present a new software library BondGraphTools that allows mathematical biologists to programmatically build and simulate networked models of energy systems. Implemented in Python and Julia, BondGraphTools is designed to be intuitive which will be demonstrated via some interesting applications in cross-domain cellular processes.

42 Exploring nonlinear wave equations through a novel fast ODE solver

Andrew Cullen
Monash University
Co-authors: Simon R. Clarke
Timetable: p. 19

The nonlinear forced Gardner equation is a generalised form of the Korteweg-de Vries (KdV) equation, that has applications ranging from atmospheric fluid dynamics through to quantum field theory. As such, it is important to have a comprehensive understanding of the solution spaces that are admitted by these equations. In the case of the KdV equation, we will present numerical results that unify two previously calculated and distinct regimes of the solution space - the short and long (or hydraulic) topographic limits. For the Gardner equation, we will demonstrate how the the solution space evolves as the balance of nonlinearities changes. These equations are solved using the Gegenbaeur Homotopy Analysis Method, a spectrally accurate numerical technique that wehave developed that demonstrates quasi-linear scaling with respect to the grid resolution.

43 Quantum monodromy and symplectic invariants of the spheroidal harmonics system

Sean Dawson
University of Sydney
Co-authors: Diana Nguyen, Holger Dullin
Timetable: p. 19

In 2018, Dullin and Waalkens showed that the Hydrogen atom in prolate spheroidal coordinates has quantum monodromy. This means that a global assignment of quantum numbers is impossible. By semi-classical Bohr Sommerfeld quantisation, the eigenvalues of a quantum integrable system can be approximated by action integrals. Semi-global symplectic invariants, introduced by Vu Ngoc in 2003, describe the behaviour of the actions near the Focus-Focus point. In this talk, we show that the quantum integrable system obtained by separating the Laplacian in prolate spheroidal coordinates possesses quantum monodromy around its Focus-Focus point. We call this the spheroidal harmonics system. We prove the existence of monodromy by showing that the pre-image of a critical Focus-Focus value of the energy momentum map is a doubly pinched torus in the phase space. After discrete symmetry reduction, this becomes a singly pinched torus. By computing the associated actions, we obtain a semi-classical approximation of the eigenvalues of the spheroidal wave equation. We compute the Taylor series invariants for this integrable system. We show that the reduced spheroidal harmonics system and the spherical pendulum are not equivalent integrable systems.

44 Modelling blood flow through umbilical cord

Jim Denier

Macquarie University

Timetable: p. 20

This talk will present some recent results on the flow in coils. The motivation for the study comes from a desire to understand the impact of coiling on the transport of blood and nutrients through the fetal umbilical cord. The vitality of the fetal umbilical cord is often measured in terms of a heuristic measure known as the umbilical cord index (UCI) which measures the number of coils in a cord per cm length. Although there have been studies on the impact of the UCI on pregnancy outcomes, with both overcoiled (hypercoiling) and undercoiling (hypocoiling) showing some correlation to adverse outcomes, it is not clear whether the UCI is a valid measure of what is happening to the blood transport in the coil.

This talk will present a combination of computational and experimental results on this problem and provides some thoughts on an alternative measure of the impact of coiling on the flow through the cord.

45 Quantifying the impact of recurrent malaria infections on hospital readmissions and death

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Co-authors: Nick Douglas, Ric Price, Julie Simpson

Timetable: p. 21

Malaria is a dynamic infectious disease associated with significant morbidity and mortality, where severe manifestations for falciparum malaria are well documented compared with vivax malaria. Without a safe radical treatment for vivax malaria, recurrent malaria episodes can occur over many months for an individual patient. This study investigates the impact of recurrent malaria infections on morbidity and mortality in Western Papua, Indonesia, an area co-endemic for falciparum and vivax malaria. A multi-state model was used to describe the progressive change in the status of patients experiencing recurrent malaria episodes. Using Cox regression for modelling the hazards of transition between the states, the important risk factors of malaria recurrence and death were identified. The results show that the risk of representation to hospital due to malaria increases following multiple recurrences, and multiple rehospitalisations (receiving inpatient treatment after presentation) can significantly increase the risk of death. Moreover, multiple recurrences from infections with vivax malaria were shown to induce a higher risk of representation to hospital compared with falciparum malaria infections, in addition to increasing the risk of death. Our results highlight the significant deleterious effect of recurrent episodes of vivax malaria and warrants increasing the priority for treatments that prevent recurrent vivax malaria episodes.

46 The dynamics of Kuiper belt objects

Nur Atiqah Dinon
University of Auckland
Timetable: p. 16

Beyond the orbit of Neptune there is a region call Kuiper Belt (KB). This region is made of possibly millions of small icy bodies known as Kuiper Belt Objects (KBOs) that revolve around the Sun. The dynamics of KBOs has been, and continues to be, a hot topic of investigation. Given that the KB is located so far away and extremely difficult to observe, the dynamics is still poorly understood. Several studies have been done to explain the formation of the KB and its structure. However, there has been little work on the long- term evolution of the KB. I will present the results of N-body simulations of the KBOs over 100 million years. My results show that despite the protecting influence of the gas giants, the orbits of some KBOs change sufficiently that they become Earth crossers and even Mercury crossers.

47 Quantifying the variability in the viral growth of SIV during infection

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Timetable: p. 21

One of the main challenges inhibiting the development of a cure for Human Immunodeficiency Virus (HIV) is our lack of understanding of HIV latency. Latency is the ability of some HIV infected cells to lie dormant in a non-virus producing state (in some cases for years), allowing them to remain undetected and unaffected by a patients immune system or conventional anti-retroviral therapies. When patients are taken off treatment, it is the reactivation of latent, HIV infected cells that drives the re-initiation of the infection within the patient. It is presumed that the mechanisms governing the reactivation rate of latently infected cells are related to the mechanisms that determine the growth of the virus during initial infection. By infecting Rhesus Macaques with genetically barcoding Simian Immunodeficiency Virus (SIV), which is related to HIV, we are able to track the early stage growth of multiple SIV clonotypes within a single Macaque. In this talk, we will discuss how we construct and estimate a distribution in the population of individual clonotypes following infection of macaques with our barcoded SIV. We will also consider the relationships between the form of this distribution and potential mechanisms that may affect viral growth during initial infection as well.

48 A data enabled model for coupling dual porosity flow with free flow

Craig Douglas
University of Wyoming
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Timetable: p. 17

In this talk, we provide a snapshot of a U.S. National Science Foundation funded project to create a working computational and data science model useful for reservoir simulation. This project carries out systematic research on the development, validation, numerical methods, data assimilation, and mathematical analysis for a dual-porosity-Navier-Stokes model. In many real world problems and industrial settings, the free flow of a liquid and the confined flow in a dual porosity media are often coupled together and significantly affected by each other. However, the existing Stokes-Darcy types of models cannot accurately describe this type of coupled problem since they only consider single porosity media. Therefore, with the support of external data, we follow the general framework of Stokes-Darcy model and dual-porosity model to develop a new coupled multi-physics multi-scale model and the corresponding numerical methods for accurately describing the coupling of the flow in dual porosity media and the free flow. The resulting coupled dual-porosity-Navier-Stokes model has higher fidelity than the Darcy, dual-porosity, Navier-Stokes, or Stokes-Darcy equations on their own. Furthermore, the field data provides the possibility to improve and demonstrate the accuracy of the model prediction through data assimilation.

49 Compressible three-dimensional boundary layers with short spanwise scales

Peter Duck
University of Manchester
Timetable: p. 16

We consider compressible three-dimensional boundary-layer (high Reynolds number) flows over a semi-infinite flat plate aligned with an oncoming uniform flow of speed U^*_∞.An arbitrary choice of reference length scale, L^*, allows for a non-dimensional Cartesian coordinate system (L^*x, L^*y, L^*z) aligned with the leading edge of the plate at $x = 0$, such that $y = 0, x > 0$ defines the plate surface. The basic boundary-layer is perturbed by (short-scale, spanwise-varying) injection through the surface of the plate. To capture short-spanwise scales we rescale in the (y, z) plane according to $(Y, Z) = Re^{1/2}(y, z)$. Here $Re = U^*_\infty L^*/\nu^*$ (for kinematic viscosity ν^*) is a global Reynolds number based on the chosen length scale. The corresponding high Reynolds number flow field is

$$u = \hat{U}(x, Y, Z, t) + \cdots, \quad (v, w) = Re^{-1/2}(\hat{V}(x, Y, Z, t), \hat{W}(x, Y, Z, t)) + \cdots,$$

with pressure

$$p = Re^{-1/2}\hat{p}(x) + Re^{-1}\hat{P}(x, Y, Z, t) + \cdots .$$

The resulting system (that has been considered previously in the incompressible regime, which is rather simpler) is often referred to as the *boundary-region equations.* This system encompasses much of the full flow physics, and is applicable to a wide variety of flow configurations, including corner

boundary layers, spanwise-periodically disturbed flows with links to transient growth and streaks. We first consider (steady) three-dimensional states driven by a finite-width injection slot and then unsteady perturbations to such flows. The methodology is asymptotically rigorous (but is considerably more efficient than computations of the full Navier-Stokes equations, particularly in the compressible regime).

50 A fixed point operator in discrete optimisation

Andrew Eberhard

RMIT University

Co-authors: Jeffrey Christiansen, Brian Dandurand and Fabricio Oliveira

Timetable: p. 19

I will discuss some duality structures that have appeared in discrete optimisation in conjunction with studies of discrete proximal point algorithm, augmented Lagrangian duality, some supporting theory for the Feasibility Pump and more recently with regard to Stochastic Integer Programming. A common theme appears involving a fixed point operator that associates the local minima of a regularised function with the feasible point of the problem. This enables the one to describe some algorithmic heuristics in terms of a related continuous optimisation problem, enabling the use of ideas from variational analysis to explain the success of these methods.

51 An accurate and efficient discretization for stochastic models of cell migration and cell proliferation

Nabil Fadai

Queensland University of Technology

Co-authors: Matthew J. Simpson, Ruth E. Baker

Timetable: p. 13

Understanding how cells proliferate, die, and migrate in various environments is essential in determining how organisms develop and repair themselves. While previous mathematical models have successfully described the salient features of these cell processes in limiting cases, they fail to accurately account for other underlying mechanisms in more general parameter regimes: specifically, when groups of cells are prone to crowding and clustering. Furthermore, the computational run-time of these models, when accounting for large numbers of cells, is high. In this talk, we propose a new computationally-efficient agent-based lattice model to accurately describe cell proliferation and cell migration, including when crowding and clustering are present. This compartment-based approach accounts for clusters of cells (modelled as agents) by determining a critical distance at which these agents influence each other's actions. We find that this compartment-based representation of lattice models not only faithfully reproduces results from previously studied limiting cases, but also provides insight into

additional parameter regimes where previous models do not accurately capture the salient features of the aforementioned cell processes.

52 Towards accurate real-time control of lithium ion batteries

Troy Farrell

Queensland University of Technology

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

Timetable: p. 19

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 the reduced model are shown to compare favourably 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 variables at all discrete locations, as is the case with the spatial discretisation methods most commonly used to implement partial differential equation models of battery operation.

53 How much money should be spent on managers vs workers?

Duncan Farrow

Murdoch University

Timetable: p. 15

This talk will describe a simple model for a company that has two classes of employee: worker and manager. The model is then used to determine how the resources of a company should be split between the two classes so as to maximise the overall production of the company. The model is built around a function $e(r)$ which characterises how effective the managers are at improving the productive efficiency of the workers. A condition for optimal overall production is derived which includes circumstances where there should be no managers at all! Some qualitative interpretations of the results will also be presented.

54 Justification of the approximate methods for solving operator equations

Alexander Fedotov
Retired
Timetable: p. 13

Until now there are only two approaches for justification of the approximate methods for solving operator equations. One is based on Banach theorem of inverse operators and the second is based on Fredholm theory of the second kind integral equations. Here we classify known results of this topic and show some new results in the theory of justification.

55 Modelling turbulence and the Anthropocene: synergetic effects reduce ocean biomass

Jody Fisher
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Timetable: p. 16

A universal scaling relationship exists between organism abundance and body size. Within ocean habitats this relationship often deviates from that typically observed, whereby marine macro-fauna display steeper size-abundance scaling than expected. This is indicative of a fundamental shift in food-web organization, but until now, a conclusive mechanism for this pattern has remained elusive. Using a novel mechanistic model, we demonstrate that ocean turbulence is responsible, whereby the energetic cost of movement within a turbulent ocean induces additional biomass losses. Exploration of this model reveals that there is an excellent correspondence between empirical observations and the theoretical properties of our ODE system. This allows us to investigate the potential for cumulative biomass losses across multiple anthropogenic impacts.

56 Infection in surgical wounds: bacteria versus immune cells

Jennifer Flegg
University of Melbourne
Co-authors: Chathranee Jayathilake, Philip K. Maini, Harriet W. Hopf, D.L. Sean McElwain, Helen M. Byrne, Mark B.Flegg
Timetable: p. 19

Infections are a common complication of any surgery, often requiring a recovery period in hospital. Infection at the site of surgery lengthens a patient's hospital stay and is a risk factor for mortality. In this work, we develop a four-species coupled set of non-linear partial differential equations that describes the space-time dependence of immune cells, bacteria and oxygen for the healing of a surgical wound. From numerical solutions of the model we observe two outcomes: bacteria domination or bacteria elimination by immune cells. In order to interpret some key features of this spatio-temporal model, we make several simplifications and proceed to analyse a reduced model for its behaviour. The analysis of the reduced model is in good qualitative agreement with the numerical solutions of the full model. Our model findings provide insight into how the nature of the contaminant and its initial density influence bacterial infection dynamics in the surgical wound.

57 Diffusion-limited enzyme kinetics

Mark Flegg
Monash University
Timetable: p. 16

The classical theory of enzyme kinetics is useful in many areas of mathematical biology and ecology in which processes occur on different time scales. In this talk we will discuss how this theory may be interpreted in agent-based simulations of reaction-diffusion processes, specifically on continuous domains.

58 Measuring the fractal dimension of aggregate clusters using the perimeter-area method

Brendan Florio
CSIRO Mineral Resources and University of Western Australia
Co-authors: Phillip Fawell, Michael Small
Timetable: p. 14

The fractal dimension is an important parameter in the modelling of flocculation (or aggregation). It determines the important relationship between an aggregate's mass and bulk radius, which in turn governs its collision and settling rates, for example. Models are particularly sensitive to the value of the fractal dimension, so empirical measurements need to be very accurate. There are many ways to measure an aggregate's fractal dimension, such as the mass-radius dimension, or the perimeter-length dimension. The perimeter-area method was derived by Mandelbrot to measure the fractal dimension of ore chips. The perimeter-area method is now commonly used in aggregation literature. Using ideal theoretical fractal objects, we show that while the perimeter-area method is effective in measuring the fractal dimension of island-type objects such as ore chips, special attention is needed when it is used on cluster-type objects, such as aggregates.

59 Light fluids rising through heavy ones

Larry Forbes
University of Tasmania
Co-authors: Emma Allwright and Steve Walters
Timetable: p. 23

We consider an axisymmetric plume, formed when a light fluid is introduced through a round hole at the bottom of a channel, that is otherwise filled with heavier fluid. As the fluid rises, it can overturn to form a "mushroom cloud", familiar from images of volcanoes or bomb blasts. We model this using Boussinesq fluid theory. This gives us some insight as to why the plume overturns, instead of just continuing on upwards as an elongating spike. The effective interface location can be retrieved from the numerical solution to the problem, and some elegant plume shapes will be explored.

60 Head in the sand: Modelling the flow of discrete grains as a continuum

Luke Fullard
IFS, Massey University
Co-authors: Daniel Holland, Clive Davies
Timetable: p. 21

Granular materials and their behaviour have fascinated mankind for thousands of years. The first storage silos were used in ancient Greece (late 8th century BC), the first use of an hourglass is depicted on a sarcophagus (350 AD), and the Egyptians were known to pour water on sand in front of their sled, reducing friction and allowing easy transport of goods (1900 BC).

In the modern day, we are interested in granular materials for their interesting, complex, and sometimes unexpected physics, and for their application in industry, for example, the storage of granular products in silo systems. In the dense flowing regime, granular behaviour is somewhere between fluid-like motion and solid-like rigid dynamics.

While the Discrete Element Method (DEM), where the motion of every particle is modelled individually, has proven itself an accurate and useful numerical tool, it is impractical for real industrial sized systems, where the particle count can range from many millions to many billions.

In this talk I will present the results of physical and numerical experiments of dense granular flow in silos. To facilitate simulation of large scale systems, an apparent viscosity is integrated into a standard Navier-Stokes incompressible fluid dynamics solver. The apparent viscosity is determined using the so-called $\mu(I)$ model for the rheology of granular “fluids”. This continuum model for granular dynamics is used to simulate the drainage of grains from silos, the results of which are compared to experimental measurements of poppy seed drainage made using Magnetic Resonance Imaging (MRI) velocimetry.

61 Structure-preserving methods based on discrete laws on Voronoi meshes

Daisuke Furihata
Osaka University
Timetable: p. 13

In these decades, we have developed a few numerical methods to inherit essential properties from the original target problems, such as PDEs/ODEs. We commonly call them structure-preserving methods, and we indicated they are efficient, reliable and durable via some numerical computations on one-dimensional problems. However, if we would like to introduce reference/mesh points located arbitrarily in two- or three-dimensional regions, it is hard to design some structure-preserving methods. The reason is that we should define some finite difference/volume operators to discretize differential operators, however, in general, it is also severe problems to find or design some discrete Gauss, Green and Stokes formulae based on them. This difficulty often prevents the design of structure-preserving methods since such formulae are an essential key for variational calculation included in the process of the design. Recently, we have found that there exist some rigorous discrete Gauss, Green and Stokes formulae among finite difference/volume operators based on Voronoi decompositions. Furthermore, we can apply them to design some structure-preserving numerical methods for some PDE problems and run numerical computations. In this talk, we would like to indicate those finite difference/volume operators, Green, Gauss and Stokes formulae and the obtained discrete variational derivative methods, which is one of the structure-preserving methods for PDEs, based on Voronoi cells.

62 Solution for 4th-order nonlinear axisymmetric surface diffusion by inverse method

Dilruk Gallage

La Trobe University

Co-authors: Philip Broadbridge, Dimetre Triadis, Pierluigi Cesana

Timetable: p. 19

We present a method for constructing similarity solutions of a fourth-order nonlinear partial differential equation for axisymmetric surface diffusion by extending an inverse method used for the second-order one-dimensional nonlinear diffusion equation by J.R. Philip. By imposing the solution profile of the linear radial model, both a feasible surface tension, and an effectively related mobility function are deduced simultaneously.

An optimization algorithm is implemented to construct a well-defined mobility function that is effectively a single-valued function of surface orientation.

It is shown that the solution of the linear model well approximates the solution of the fully nonlinear model, in which the surface tension and mobility are close to constant for a wide range of surface angles.

We provide numerical evidence that the mobility function and the corresponding energy function are not unique. In other words, there are at least two model materials that produce the surface shape in a self-consistent way.

63 State space models for long range animal movement

Emily Gentles

University of Arkansas, USA

Timetable: p. 16

In the past decade over 5.5 million bats in North America have died of white-nose syndrome, a fungal disease active during hibernation. This, coupled with increasing urbanization, threatens current keystone bat populations and consequently impedes their ability to provide important ecosystem services, such as pollination and pest control. In order to provide support for these populations we must understand their movement through the environment. In this study we used telemetry data from Indiana bat specimens to construct a continuous time state-space model of bat migration. State-space modeling is extremely useful as it allows for multivariate representations and continuous-time models are particularly useful for the representation of animal telemetry data as the true process of movement occurs in continuous time and space. By modeling in continuous-time, we were not limited to a pre-determined time interval which allowed for less manipulation of the irregular animal movement data.

64 Continuum modelling of phagocytosis based on cell-cell adhesion and prey-predator relationship

Fillipe Georgiou

University of Newcastle

Co-authors: N. Thamwattana and B.Lamichhane

Timetable: p. 17

Phagocytosis is defined as ingestion of large (≥ 0.5 μm) particles, such as unwanted cells, debris or particulate matter, into plasma membrane-derived vacuoles called phagosomes. This process is accomplished via the use of receptors on the cells surface that recognize and bind to the prey particles. Phagocytosis plays an important role in immune systems through the destruction of pathogens, old cells and the inhibiting of cancerous cells. We combine a cell-cell adhesion modelling technique with classic predator-prey modelling to generate a new model for phagocytosis which can relate the interaction between cells in both space and time. Using this model we create numerical simulations using an adaptive finite volume method in both one and two dimensions, we compare the two dimensional simulation with a video of bacteria phagocytized by a neutrophil cell. We also look at dispersion relations for both homogeneous and non-homogeneous steady states for one-dimensional model to look at the range of parameters that will lead to phagocytosis.

65 Wet chemical etching of silicon dioxide microfibres

Josef Giddings

University of Adelaide

Co-authors: Yvonne Stokes, Kyle Bachus, Heike Ebendorff-Heidepriem

Timetable: p. 15

The performance of electrospray ionisation mass spectrometry is heavily dependent on emitter tip geometry and the flow rate of the biomolecule solution being measured. This has led to the development of emitter tips that can operate at nano-flow rates with a very small outer diameter at the tip end. However, this typically results in its internal diameter being tapered which increases its susceptibility to clogging. In order to maintain the internal diameter a new fabrication process has been developed submerging silicon dioxide microfibres in hydrofluoric acid while pumping water through the centre hole. By doing so it is possible to etch the outer diameter of the microfibre down whilst maintaining a constant internal diameter. The water creates a concentration gradient around the microfibre end which controls the geometry etched. Experiments have shown that higher flow rates create wider, convex geometries, while lower flow rates create narrower, concave geometries. We model this process and validate our simulated results by comparing with experiments. We find that the water being pumped through the centre hole does not fully protect it and there is some etching there. For higher flow rates this etching is negligible, however is not at lower flow rates. By setting a tolerance on the amount of etching of the centre hole, we propose a flow rate and etch time in order to produce the geometry for optimal electrospray ionisation mass spectrometry performance.

66 Dynamics of a fully wetted Marangoni surfer at the liquid-gas interface

Harinadha Gidituri

Swinburne University of Technology

Co-authors: Mahesh Panchagnula and Andrey Pototsky

Timetable: p. 18

Marangoni flow created by the gradient of surface tension can be facilitated to transport small objects along fluid interfaces. We study lateral motion of a fully wetted self-propelled particle at a liquid-gas interface. The particle releases a surfactant at a constant rate inducing surface tension gradient. Using the Lorentz reciprocal theorem, we relate the resulting translational speed of such a particle at the interface to the self-propulsion speed of a chemically inactive particle. The dynamics of the insoluble surfactant is incorporated by taking into account advection by the Marangoni flow, surface diffusion and homogeneous decomposition reaction. We show that the translational speed of a fully wetted point Marangoni swimmer at the surface is increased as compared with the self-propulsion speed of a chemically inactive swimmer. We construct a fully-wetted Marangoni surfer from a non-motile thin rod that releases surfactant at one of its ends. In a steady state, the rod is being pushed along its length by the Marangoni flow with the source of the surfactant at the back end acting as a propulsion engine.

67 Ensemble forecasting with stochastically perturbed bred vectors

Brent Giggins
University of Sydney
Co-authors: Georg Gottwald
Timetable: p. 13

The breeding algorithm is a method of generating initial conditions for ensembles in weather and seasonal forecasts. Although breeding produces finite-size flow-adapted perturbations and is computationally inexpensive, the bred vector ensembles often lack spread and diversity, producing forecasts that tend to under-estimate the uncertainty of the future prediction. We introduce methods based on homogenisation theory to create modified bred vector ensembles that retain the advantages of the original method but increased the diversity of the initial conditions. These methods result in forecasts that have better predictive skill and are more reliable as quantified by standard meteorological diagnostics like the rank histogram. We also show that the modified bred vectors maintain their dynamical consistency by comparing them to backward and covariant Lyapunov vectors along with ETKF and DEnKF ensembles generated from data assimilation.

68 Dynamic complexity in two coupled photonic crystal nanocavities

Andrus Giraldo
University of Auckland
Co-authors: Bernd Krauskopf, Neil Broderick, Alejandro Giacomotti and Juan Ariel Levenson
Timetable: p. 13

Nonlinear optical resonators are the subject of much interest due to the plethora of effects that they may generate, including optical frequency combs and cavity solitons. In particular, introducing a small gap into a Photonic Crystal creates an optical resonator with extremely small mode volumes. Such nano-devices offer the possibility of doing nonlinear optics with very small photon numbers, threshold-less lasing and many other intriguing experiments in both classical and quantum optics.

We consider an optical device consisting of two coupled nanocavities in a Photonic Crystal that are optically driven. This experimental system has been shown to exhibit spontaneous symmetry breaking and bistable behaviour. However, its more complex dynamics have not yet been characterised. Interestingly, the overall behaviour of this type of device is captured by a four-dimensional vector field model. We conduct a bifurcation analysis to determine the dynamics that arises when the intensity and frequency of the optical input are varied, while the other parameters of the Photonic Crystal are fixed to experimental values. In particular, we find Shilnikov bifurcations of the wild type, and transitions between chaotic attractors with different symmetry properties. Hence, this four dimensional system allows us to study and visualize the consequences of higher-dimensional chaos in a concrete applied model arising from an application. We present and characterise how these global bifurcations are organised around bifurcations of higher codimension. In particular, we also discuss the transition between different types of chaotic attractors.

69 Lyapunov spectrum of Perron-Frobenius operator cocycles

Cecilia Gonzalez Tokman
University of Queensland
Co-authors: Anthony Quas
Timetable: p. 13

The Lyapunov spectrum of Perron-Frobenius cocycles contains relevant information about dynamical properties of random (non-autonomous) dynamical systems. In this talk we describe the Lyapunov spectrum for a family of expanding maps of the circle, and discuss natural perturbations which, in some parameter regimes, induce collapse (instability) of this spectrum.

70 Hysteresis and the drift to depletion: Akt under repeated insulin stimulation

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

Akt, also known as Protein Kinase B (PKB), is a major nutrient sensor in the mammalian cell. Located at the juncture of several metabolic and mitogenic signalling pathways, it regulates a number of cellular processes such as glucose metabolism, proliferation, and apoptosis. Abnormalities in Akt regulation are associated with a range of diseases, from diabetes to cancer. The signalling specificity of Akt derives from both its cellular location and its biochemical state. Initially, Akt is synthesised inside the cell. Upon insulin stimulation, it travels to the plasma membrane (PM), where it attains the fully activated conformation following phosphorylation. As phosphorylation only occurs at the PM, the translocation of Akt from cytosol to PM is a crucial step in the activation process. We have developed a simple, linear, three-pool ordinary differential equation model of Akt translocation. Using a conservation relation inherent in the model, we have shown that this system is equivalent to a heavily damped harmonic oscillator. By analysing both step increases and decreases in insulin stimulation, we have shown that the system exhibits hysteresis in all regions of parameter space. Here we present some of the ramifications of hysteresis on the system response to pulsatile and periodic forcing, both of which are ubiquitous in biological signalling networks.

71 Connections between transversely isotropic fluids and active suspensions

Edward Green

University of Adelaide

Co-authors: Gemma Cupples, Craig Holloway, Rosemary Dyson, David Smith, Richard Clarke

Timetable: p. 21

Suspensions of self-motile, elongated particles are a topic of significant current interest, exemplifying a form of 'active matter'. Examples include self-propelling bacteria, algae and sperm, and artificial swimmers. Ericksen's model of a transversely isotropic fluid treats suspensions of non-motile particles as a continuum with an evolving preferred direction; this model describes fibrous materials as diverse as extracellular matrix, textile tufts and plant cell walls. In this talk, we will look at the connections between transversely isotropic fluids and recent models for active suspensions. We then show how anisotropic effects and translational diffusion affect the stability of flows in the case of nearly-perfectly aligned and randomly oriented particles.

72 Harmonic measure distribution functions for slit domains on spherical and toroidal surfaces

Christopher Green

Macquarie University

Timetable: p. 19

In this talk, it will be shown how to generalise recent formulae for harmonic measure distribution functions, or h-functions, for multiply connected slit domains in the complex plane to two distinct compact surfaces: the sphere (genus-0) and the ring torus (genus-1). Given a domain Ω on a compact surface $\mathcal{S}$, and a fixed basepoint $z_0 \in \Omega$, the h-function is a piecewise smooth continuous function $h : [0, \infty) \to [0, 1]$ which encodes certain properties of the triple $(\mathcal{S}, \Omega, z_0)$. For $r > 0$, the value of $h(r)$ is the harmonic measure of the portion of the boundary $\partial\Omega$ that lies within a distance r of z_0, and where r is measured along the surface $\mathcal{S}$. Motivated by deriving analytical formulae, attention is restricted to domains Ω exterior to a finite number of horizontal slits of equal latitude, and the associated h-functions determined using a combination of techniques from conformal mapping and special function theory. The formulae derived hold for any finite number of slits.

73 Modelling Surtseyan Ejecta

Emma Greenbank
Victoria University of Wellington
Co-authors: Mark McGuinness, Andrew Fowler and C. Ian Schipper
Timetable: p. 13

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 and base surges, but the phenomenon of interest to our research is that of the Surtseyan ejecta. Surtseyan ejecta are balls of lava containing an entrained material. They occur when a slurry of previously erupted material and water washes back into the volcanic vent. This slurry is incorporated into the magma and ejected, from the volcano, inside a ball of lava. The large variation in temperature between the slurry and the lava causes the water, in the slurry, to vaporise. This results in a pressure build-up which is released by vapour escaping through the pores of the lava or the bomb exploding. This talk will focus on modelling this phenomena using a set of coupled nonlinear partial differential equations that arise from mass, momentum and energy conservation. I will also be discussing some of the results and how they compare to previous modelling.

74 The effect of inertial lift force on a spherical particle suspended in flow through microfluidic ducts

Brendan Harding
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Co-authors: Yvonne Stokes
Timetable: p. 16

Inertial lift force is a second order effect causing particles to deviate from the streamlines of a (laminar) fluid flow. The inertial lift force can be estimated via a perturbation expansion of the disturbance flow in the particle Reynolds number. In the case of flow through curved ducts the drag forces generated by the secondary motion of the fluid are also important. In recent work we have demonstrated that at low flow rates the lateral location towards which particles migrate can be approximately described via a dimensionless parameter depending only on length scales of the duct and particle. I will describe our approach and extensions to this work.

75 Existence and stability of periodic traveling waves: who will prevail in a rock-paper-scissors game?

Cris Hasan

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Co-authors: Hinke M. Osinga, Claire M. Postlethwaite, Alastair M. Rucklidge

Timetable: p. 22

We study a Rock-Paper-Scissors model that describes the spatiotemporal evolution of three competing populations, or strategies, in evolutionary game theory and biology. The dynamics of the model is determined by a set of partial differential equations (PDEs) and features travelling waves (TWs) in one spatial dimension and spiral waves in two spatial dimensions. We focus on periodic TWs and the closely-related spiral wave patterns in this model. A characteristic feature of this model is the presence of a robust heteroclinic cycle that plays a key role in the organization of periodic TWs. The existence of periodic TWs and associated heteroclinic cycles can be established via the transformation of the PDE model into a system of ordinary differential equations (ODEs) under the assumption that the wave speed is constant. We explore the bifurcation diagram of the ODE system and investigate the existence of TWs as different parameters are varied. Determining the stability of periodic TWs is more challenging and requires a study of the essential spectrum of the linear operator of the periodic TWs. We compute this spectrum and the curve of instability with the continuation scheme developed in [Rademacher et al., Physica D, 2007]. We also build on this scheme and develop a method for computing what we call belts of instability, which are indicators of the temporal expansion rates of unstable TWs. We finally show how these results compare with direct simulations of the PDE model.

76 Designing an optimal schedule for breaking the hazardous fuel continuum while maintaining habitat quality

John Hearne

RMIT University

Timetable: p. 15

Reducing fuel in the landscape is widely practiced to mitigate the increasing destruction and threat posed by wildfires. Determining a schedule for such fuel reduction is a complex problem. While the main aim is to reduce the hazard of a large wildfire it is also necessary to consider the effect on both flora and fauna. Most vegetation types in fire-dependent systems require burning within a certain frequency range. Both more and less frequent burning leads to the local loss of the species. Fauna introduce further complexity into the problem. Some species require vegetation in a specific age range. For example, the endangered Southern Brown Bandicoot requires heathland that was burnt between five and twelve years ago. Some deterministic, spatio-temporal optimisation models have been proposed to disconnect areas of high fuel as much as possible while satisfying vegetation requirements and trying to maintain habitat quality for fauna. These models have shown that better results can be achieved with longer planning horizons. Such results might be questioned in the face of many unplanned fires. This talk will explore this issue.

77 Instabilities in the melting of metal nanowires

Shaun Hendy
Te Pūnaha Matatini, Department of Physics, University of Auckland
Co-authors: Kannan Ridings
Timetable: p. 15

Nanostructured materials typically have lower melting points than that of the bulk due to their high surface area to volume ratios, which reduces their stability relative to the molten phase. Surface melting, where melting at an interface precedes complete melting, can also become important for thermodynamic stability as the surface area to volume ratio increases. Metal nanostructures with non-melting surfaces (surfaces which are not fully wet by their melt) can exhibit exotic behaviour, such as superheating, as they approach melting. Here we consider the surface melting of metal nanowires by solving a phenomenological two-parabola Landau model. The model suggests that surface melting will precede bulk melting when the melt wets or partially wets the surface as is the case for planar surfaces and sufficiently large nanoparticles. The model also shows that the simple dependence of the melting temperature on the surface to volume ratio, which is seen empirically, only emerges in the limit where the wire curvature is much greater than the thickness of the solid-liquid interface. We also consider the stability of the solid-liquid interface in partially melted wires, and examine the conditions under which Plateau-Rayleigh type instabilities can lead to break up of the solid wire prior to complete melting.

78 A straightforward geometric approach to fluid-solid interactions using the signed distance function

Eric Hester
University of Sydney
Co-authors: Dr Geoffrey Vasil
Timetable: p. 13

Fluid-solid interactions underlie many interesting phenomena, such as ship drag, melting ice and alloy solidification, or animal swimming and flight. We have previously found a simple empirical prescription to improve a common method for simulating fluid-solid interactions, the Volume Penalty Method. Controlled numerical benchmarks supported the validity of the correction. This talk will outline our progress in developing a mathematical framework to systematically derive corrections for this and other models. The utility results from the straightforward differential geometry of the signed distance function. No background in differential geometry is required.

79 Modelling hypothesised interactions during transmission dynamics of two malaria species

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Co-authors: R. Aguas, A. Devine, J.M. McCaw, L. White, and ACREME

Timetable: p. 13

Half of the global population are at risk of malaria, and there are over 200 million cases and 400,000 malaria deaths annually. The greatest threat is posed by two of the parasite species that infect humans, with 1.98 billion people at risk of both *Plasmodium falciparum* and *Plasmodium vivax*. *P. vivax* is posing a challenge to the elimination of malaria with the relative and absolute prevalence increasing in several countries, such as Papua New Guinea and India. There are several hypotheses about both the biological mechanisms for the interactions of these two species, and about the best intervention approach for *P. vivax* to enable elimination efforts to align with those for *P. falciparum*. We are developing mathematical models of population level transmission of *P. falciparum* and *P. vivax* to identify which of the hypothesised species interactions are supported by available data.

80 Can population dynamic models improve species occurrence predictions?

Matthew Holden

University of Queensland

Co-authors: Jerzy Filar

Timetable: p. 23

Where does a species occur? It is one of the most fundamental questions in ecology, yet predictions of species occurrence still remain poor. In this talk, I will discuss how incorporating dynamic population processes into species distribution models may improve predictive power. We show that newly developed methods for doing this, demographic distribution models (DDMs), do not always improve predictions over standard approaches. DDMs are built using demographic data, measured in the field, and link environmental variables to long-term population growth rate, λ, through effects on survival, growth and reproduction. Species are assumed to be present at sites if their long-term population growth rates are greater than or equal to one, and absent elsewhere. We show that predictions from DDMs can be especially inaccurate if data come from locations where the population is abundant, an aspect that is characteristic of most demographic surveys. The problem is that density dependence causes computed λ to be near or below one when population density is near carrying capacity. Therefore, DDMs can overestimate absences if the species experiences density-dependent growth, reproduction, or survival. Using a combination of simulations and a simple analytic approximation, we provide a rule of thumb for identifying the critical population density after which density dependence starts to interfere with accurate spatial projections of species occurrence. The formula for this critical density can be used as a guideline for when to use linear DDMs in a density-dependent context.

81 Transversely isotropic extensional flow

Matthew Hopwood
University of Adelaide, University of Birmingham
Co-authors: Ed Green, Rosemary Dyson
Timetable: p. 12

Many biological materials such as cervical mucus and collagen gel possess a fibrous microstructure. In order to gain more understanding of how this microstructure affects their mechanical properties, we consider the problem of the stretching of a thin sheet of transversely isotropic viscous fluid as a simplified version of the spinnability test for cervical mucus. By making a thin-film approximation, we are able to achieve a significant simplification of the governing equations. For the case of a Newtonian fluid, the approximation leads to the classical Trouton model. When the fluid is transversely isotropic, the expressions for conservation of mass and momentum are coupled to equations governing the evolution of the fibre alignment within the fluid. This model is then solved using arbitrary Lagrangian-Eulerian methods.

82 Ngā hiahia kia titiro ki te tīmata, ā, ka kite ai tātou te mutunga (you must understand the beginning if you wish to see the end)

Phil Howlett
University of South Australia
Timetable: p. 14

My NZ colleagues inspired the title of this talk—they invariably sign off their emails with a Māori phrase—and I translate these phrases by asking Mr. Google. One day I found a phrase that echoes what I want to say—Ngā hiahia kia titiro ki te tīmata, ā, ka kite ai tātou te mutunga[1] — You must understand the beginning if you wish to see the end. The ANZIAM medal is one of the highlights in my career and this is my first opportunity to thank those who helped me along the way. So I will do that—and then talk a little about my perspective on mathematics, from the beginnings in basic number theory to the endings in higher level research. I will discuss some fundamental problems with numbers that interest me and might also interest our students. I will also talk about the basic principles of optimal train control. 1. Te Puni Kōkiri (2010). Arotake Tūkino Whānau: Literature Review on Family Violence.

83 Parasite-induced shifts to a lethargic host state results in evolutionary bistability

Amy Hurford
Memorial University
Co-authors: Abdou Moutalab Fofana
Timetable: p. 13

Many parasites induce decreased host movement, known as lethargy, which can impact disease spread and the evolution of virulence. Mathematical models have investigated virulence evolution when parasites cause host death, but disease-induced decreased host movement has received relatively less attention. Here, we consider a model where, due to the within-host parasite replication rate, an infected host can become lethargic and shift from a moving to a resting state, where it can die. We find that when the lethargy and disease-induced mortality costs to the parasites are low or moderate, then evolutionary bistability can arise, and either moderate or high virulence can evolve depending on the initial virulence and the magnitude of mutation. These results suggest, firstly, the transient coexistence of strains with different virulence, which may explain the coexistence of low- and high-pathogenic strains of avian influenza and human immunodeficiency viruses, and secondly, that medical interventions to treat the symptoms of lethargy or to prevent disease-induced host deaths can result in large jumps in virulence and the rapid evolution of high virulence. In complement to existing results that show bistability when hosts are heterogeneous at the population-level, we show that evolutionary bistability may arise due to transmission heterogeneity at the individual host-level.

84 On a copula-based conditional value at risk

Naoyuki Ishimura
Chuo University
Co-authors: Andres Mauricio Molina Barreto and Yasukazu Yoshizawa
Timetable: p. 19

We introduce a new definition of copula-based conditional Value at Risk for a multivariate random vector. Compared to the previous notion due to Krzemienowski and Szymczyk (2016), our quantity is slightly simple and easy to be computed. We derive a formula in the case of Archimedean copulas. The computation shows that the difference between the independent and nonlinear relations is estimated.

85 Gender and Society

Alex James
University of Canterbury
Co-authors: Mike Plank, Rose Chisnall
Timetable: p. 21

Are our science societies diverse and representative of their communities? Are there ways to improve diversity? We explore these ideas using a mixture of data and stochastic models.

86 Canard explosion in two-stroke relaxation oscillators

Sam Jelbart
University of Sydney
Co-authors: Martin Wechselberger
Timetable: p. 20

The hallmark of van der Pol-type relaxation oscillation is an alternation between four distinct motions ('slow-fast-slow-fast') over the course of a single cycle. This is an example of 'four-stroke' relaxation oscillation, for which the onset of relaxation oscillation is facilitated by a 'canard explosion': a dynamic phenomena characterised by a rapid transition from small to large amplitude relaxation oscillations under an exponentially small motion in parameter space. In this talk we consider 'two-stroke' relaxation oscillations, which consist of only two distinct motions per cycle, and are known to occur in electrical circuits, mechanical oscillators with friction, and models for aircraft-ground dynamics. We use geometric singular perturbation theory to study canard explosion in planar systems capable of two-stroke relaxation oscillation, with an emphasis on those dynamics features which distinguish it from van der Pol-type canard explosions. Two families of canard cycles are identified, both of which have amplitudes which grow unlimitedly before terminating at infinity. Using a phase space compactification, it is shown that in one case the termination of limit cycles can be characterised as a saddle-node of periodics bifurcation at infinity.

87 Teleconnection networks of extreme weather events in Antarctica

Hamish Jelleyman
University of Auckland
Co-authors: Dr Dion O'Neale and Dr Tra Dinh
Timetable: p. 17

Teleconnections are links between meteorological events or features which can be linked by a causal or correlated relationship. These connections can be separated either temporally or spatially. We investigated 38 years of meteorological data from 1979 to 2016 to identify teleconnections across the Ross Sea Region and more generally across the entire Antarctic continent. Extreme weather events were identified at each location using seasonal and trend decomposition by Loess (a method used for estimating non-linear relationships). These events were correlated for each pair of locations to create a teleconnections network. This network was analysed with the purpose of identifying spatial and temporal structures within the weather data, with a focus on their organisation and scale across the continent of Antarctica.

88 Heteroclinic networks with noise and input

Valerie Jeong
University of Auckland
Timetable: p. 20

Heteroclinic networks are structures within dynamical systems that have a variety of applications in physical systems, including designing neural networks. The dynamics of heteroclinic networks have been studied in depth for several decades, however, the effects of noise on the networks is not well understood. In this talk, I will present how small noise and/or inputs affect a relatively simple heteroclinic cycle, called the Guckenheimer-Holmes Cycle. This cycle consists of three equilibria and the heteroclinic connections between them. As time evolves, trajectories spend longer and longer time near each equilibrium. When noise or inputs are added, this slowing down no longer occurs. Future work will include studying how the interactions between noise and input affect the cycle, and other dynamical networks.

89 Ultrasensitivity in a reversible covalent modification cycle with positive autoregulation

Cailan Jeynes-Smith
Queensland University of Technology
Co-authors: Robyn Araujo, Pamela Burrage
Timetable: p. 19

A covalent-modification cycle allows for a protein substrate to be reversibly converted into a modified form. Such a system can display a variety of behaviours. One such behaviour that is of particular interest was investigated by Goldbeter and Koshland and was coined 'ultrasensitivity'. This describes a 'switchlike' reaction whereby a protein is rapidly converted into another form over a small range of input values. Goldbeter and Koshland described a set of conditions on the system to obtain this behaviour but deviations from this can decrease sensitivity and have other effects on the conversion of the protein. We recently found the addition of positive autoregulation into covalent modification cycles strongly promotes ultrasensitivity. Our analysis of these new chemical reaction structures suggests that high levels of ultrasensitivity may be achieved and is dependent on a much more robust set of conditions when positive autoregulation is present. This work is giving us greater insight into the processing of biochemical signals within complex cellular signalling networks.

90 Modelling SDF-1/CXCR4 regulated in vivo homing of therapeutic mesenchymal stem/stromal cells in mice

Wang Jin
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Timetable: p. 21

Mesenchymal stem/stromal cells (MSCs) are a promising tool for cell-based therapies in the treatment of tissue injury. The stromal cell-derived factor-1 (SDF-1)/CXC chemokine receptor 4 (CXCR4) axis plays a significant role in directing MSC homing to sites of injury. However *in vivo* MSC distribution following intravenous transplantation remains poorly understood, potentially hampering the precise prediction and evaluation of therapeutic efficacy. In this study a murine model of partial ischemia/reperfusion (I/R) is used to induce liver injury, increase the hepatic levels of SDF-1, and study *in vivo* MSC distribution. A mathematical model-based system is developed to characterize *in vivo* homing of human MSCs in mouse models with SDF-1 levels in liver and CXCR4 expression on the transfused MSCs. The model is calibrated to experimental data to provide novel estimates of relevant parameter values. The model simulations align with the experimental data of control and hypoxia-preconditioned human MSC distribution in normal and injured mouse livers, and accurately predict the experimental outcomes with different MSC doses. The modelling results suggest that SDF-1 in organs is an effective *in vivo* attractant for MSCs through the SDF-1/CXCR4 axis and reveals the significance of the SDF-1/CXCR4 chemotaxis on *in vivo* homing of MSCs. This *in vivo* modelling approach allows qualitative characterization and prediction of the MSC homing to normal and injured

organs on the basis of clinically accessible variables, such as the MSC dose and SDF-1 concentration in blood. This model could also be adapted to abnormal conditions and/or other types of circulating cells to predict *in vivo* homing patterns.

91 A comparison of models for subendocardial and partial thickness ischaemia

Barbara Johnston
Griffith University
Co-authors: Peter Johnston
Timetable: p. 12

Elevation of the ST-segment of an ECG is commonly used to detect and localise transmural ischaemia (damage that is through the full thickness of the heart wall). However, the connection between the ECG and non-transmural ischaemia is less well understood. Mathematical models typically represent non-transmural ischaemia using an ischaemic zone that extends from the inner heart wall (endocardium) partway to the heart surface (epicardium). However, recent experimental work has suggested that ischaemia typically arises within the heart wall, rather than at the endocardium.

In this talk, I will compare two models of cardiac ischaemia, where the left ventricle is modelled as a semi-ellipsoid: one for subendocardial ischaemia (representing the first scenario) and one for partial thickness ischaemia (representing the second scenario). The comparisons will be presented in terms of the potentials and positions of the minima and maxima (the model outputs) that occur on the heart surface due to the ischaemia, and also in terms of the sensitivity of the outputs to the various inputs of the models. The talk will conclude with some remarks on the similarities and differences between heart surface potential distributions produced by these two models, and, what this potentially might tell us about the connection between non-transmural ischaemia and the ECG.

92 The impact of short- and long-range perception on population movements

Stuart Johnston
University of Melbourne
Co-authors: Kevin Painter
Timetable: p. 22

Navigation of cells and organisms is typically achieved by detecting and processing orienteering cues. Occasionally, a cue may be assessed over a much larger range than the individuals body size, as in visual scanning for landmarks. Here, we formulate models that account for orientation in response to short- or long-range cue evaluation. Starting from an underlying random walk movement model, where a generic cue is evaluated locally or nonlocally to determine a preferred direction, we state corresponding macroscopic partial differential equations to describe population movements. Under certain approximations, these models reduce to well-known local and nonlocal biological transport

equations, including those of KellerSegel type. We consider a case-study application: hilltopping in Lepidoptera and other insects, a phenomenon in which populations accumulate at summits to improve encounter/mating rates. Nonlocal responses are shown to efficiently filter out the natural noisiness (or roughness) of typical landscapes and allow the population to preferentially accumulate at a subset of hilltopping locations, in line with field studies. Moreover, according to the timescale of movement, optimal responses may occur for different perceptual ranges.

93 Assessing catheter contact during cryo-ablation

Peter Johnston

Griffith University

Co-authors: Michael Handler, Gerald Fischer

Timetable: p. 15

Atrial fibrillation is potentially a fatal heart condition if left untreated. With this condition extraneous electrical sources exist, which cause the heart to beat in an ineffective manner. One possible treatment for atrial fibrillation is cryo-ablation, where atrial cells in the neighbourhood of the extraneous sources are destroyed using extreme cold.

The freezing of the wall of the atrium is usually performed with a loop catheter, but for effective treatment the loop must be in contact with the wall along its entire circumference. To ensure this contact, a new catheter has been devised that contains unipolar electrodes. Electrodes in contact with the atrial wall are expected to record different electrograms from those not in contact with the wall.

In this talk we present realistic simulations to show the differences between the above mentioned electrograms.

94 Long-term evolution of Apollo Asteroids

Jinesh Joseph

University of Auckland

Timetable: p. 17

Asteroids whose orbits cross that of Earth as viewed from the north pole of the ecliptic are known as Earth-crossing asteroids. These asteroids are divided into Aten and Apollo asteroids. The number of known Aten and Apollo asteroid is steadily increasing as more searches are performed and observation techniques improve. The group of Apollo asteroids contains a subset known as potentially hazardous asteroids (PHAs). These are asteroids that come within 750,000 kilometres of Earth, twice the distance of the Moon from Earth, and are sufficiently large to cause regional damage if they hit Earth. As of January 2018, out of 8984 Apollo asteroids, 1601 were designated PHAs.

This talk focuses on the orbital dynamics of Apollo asteroids, for this we have performed simulations using the simulation package SSS (Solar System Simulations). Two models for the interaction between bodies are used, both based on Newtonian gravitational interactions between bodies. The simpler model, denoted as Model 1, has the massive bodies (the Sun and planets) acting on one another and on the the asteroids. The asteroids do not act upon the other asteroids or on the massive bodies. The more detailed model, denoted as Model 2, has all the bodies acting one another. We have performed simulations of the Apollo asteroids over 10 million years. We present the results of these simulations and discuss the likelihood of an asteroid hitting a planet.

95 Space curve extensions of Log-aesthetic curves in industrial design by integrable geometry

Kenji Kajiwara

Institute of Mathematics for Industry, Kyushu University

Co-authors: Jun-ichi Inoguchi, Kenjiro T. Miura and Wolfgang K. Schief

Timetable: p. 23

We discuss an extension of the log-aesthetic curves (LAC) in industrial design based on the integrable deformation theory of plane curves under the similarity geometry. In this framework, LAC is understood as an analogue of the Eulers elasticae in the sense that it allows two basic characterizations: (i) the rigid motion of integrable deformation of plane curves (ii) variational principle. Based on this formulation, our extension of LAC to the space curves is characterized by the traveling wave solution of the coupled system of the mKdV and the third order Burgers equation, which is given in terms of the elliptic function and the Lam function.

96 Relation between spatio-temporal patterns generated by cellular automata and a singular function

Akane Kawaharada

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Co-authors: Takao Namiki

Timetable: p. 12

A cellular automaton is a discrete dynamical system on a grid of cells that evolves by a transition rule given locally and uniformly. It is well known that cellular automata can create self-similar patterns. The relation between cellular automata and fractal geometry has been studied mathematically for many years. In the 1980s, it was proved that for linear cases one-dimensional linear cellular automata with a prime number of states admit a limit set under a suitable scaling. It was also studied that the dimension spectra of linear cellular automata. However, it is difficult to apply these analyses to nonlinear cellular automata, and not even a case study has been presented on this topic for some time.

In this talk, we examine the relation between the spatio-temporal patterns generated by nonlinear cellular automata and a singular function, which comprises a self-affine function on a unit interval. This result indicates that the patterns themselves are also fractal.

97 Electromagnetic signal propagation with randomness

Paul Keeler
University of Melbourne
Co-authors: François Baccelli and Bartek Blaszczyszyn
Timetable: p. 18

Electromagnetic signals from transmitters such as mobile phones travel multiple paths in cities due to the signals reflecting off obstacles such as buildings, which strengthens and weakens signals due to constructive and destructive wave interference. The increasing levels of telecommunications in cities means more electromagnetic signals undergoing such multipath propagation. Despite this, the standard statistical propagation models for signals, such as the Rayleigh model, are usually based on a free-space assumption, mostly neglecting the geometry of buildings. We present a mathematical model of a single transmitter positioned between two parallel walls. By assuming the signal travels as a plane wave and using the classical method of images, we incorporate the reflected signals into a mathematical model and derive an expression for the resulting non-random signal. This signal expression consists of two infinite series, which in a special case can be written compactly with a type of zeta function. We then consider natural ways to introduce randomness into the signal model, yielding new models for random signal fading due to multipath propagation. Future directions such as convergence results and applications are discussed.

98 Measuring drug efficacy in malaria

David Khoury
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Co-authors: Rosemary Aogo, Deborah Cromer, Ashraful Haque, Miles Davenport
Timetable: p. 13

Mortality rates from malaria have been on the decline over the past decade. However, the emergence of parasites that are resistant to our most effective antimalarials has prompted urgent global efforts to replace these antimalarials with more effective regimes. In the search for more effective antimalarials, our metrics of drug-efficacy are critical. They determine, which drugs are advanced in the development pipeline and which are not. Therefore, we need to ensure our metrics allow us to select the most effective drugs. Here we use a differential equation model of parasite dynamics after drug treatment to highlight an important nuance in interpreting a prolific metric of antimalarial efficacy. The predictions of the model are explored mouse models of malaria. This work highlights that this common measure of

antimalarial drug efficacy is confounded, and could bias our drug development pipeline so as to exclude highly effective antimalarials.

99 Backward stochastic equations and applications

Edward Kim
University of Sydney
Timetable: p. 20

During the past 20 years the theory of backward stochastic differential equations (BSDEs) have been widely used as a mathematical tool to address nonlinear problems in a wide range of probabilistic problems including (super-)replication of financial derivatives in market models with trading constraints, stochastic optimal control and nonlinear stochastic stopping games or optimal stopping problems.

The aims of this talk are to provide both the intuition and the well-definedness result for a specific class of BSDEs where the stochastic noise is driven by a general martingale. We then show that the solutions of these equations characterise the value of a nonlinear optimal stopping problem. Finally, we look at a specific application in a super-replication problem for American options in financial markets with trading frictions.

100 The circumradius condition and its application

Kenta Kobayashi
Graduate School of Business Administration, Hitotsubashi University
Timetable: p. 15

The analysis of the interpolation error is particularly important for the error analysis of the finite element methods. In the previous research, we proved that the finite element solution converges to an exact solution if the maximum circumradius of the triangular elements converges to zero. We call such situation circumradius condition and claimed that the circumradius condition is more essential than the well-known maximum angle condition. It is considered that the better finite element solution can be obtained by using the mesh division consists of "good" triangles. However, the generation of such mesh division is time consuming task within the simulation process of the finite element method. On the other hand, the efficient algorithm is known for computing Delaunay triangulation. In the presentation, we will introduce "circumradius condition" and show that the efficient error estimate can be obtained by the circumradius condition with Delaunay triangulation.

101 Static and dynamic self-assembly of a pair of microscopic magno-capillary disks

Lyndon Koens

Macquarie University (LK), Max Planck Institute for Intelligent Systems (WW & MS), University of Cambridge (LK & EL)

Co-authors: Wendong Wang, Metin Sitti, Eric Lauga

Timetable: p. 15

Control on microscopic scales depends critically on our ability to manipulate interactions with different physical fields. The creation of micro-machines therefore requires us to understand how multiple fields, such as surface capillary or electro-magnetic, can be used to produce predictable behaviour. Recently, a spinning micro-raft system was developed that exhibited both static and dynamic self-assembly [Wang *et al.* (2017) Sci. Adv. **3**, e1602522]. These rafts employed both capillary and magnetic interactions and, at a critical driving frequency, would suddenly change from stable orbital patterns to static assembled structures. In this talk, I explain the dynamics of two interacting micro-rafts through a combination of theoretical models and experiments. This is achieved by considering sequentially the governing physics of the orbital patterns, the assembled structures, and the collapse. Surprisingly, we find that the orbital patterns are determined by the short range capillary interactions between the disks, while the other behaviours only require the capillary far field. Finally we combine the models from each section to predict the dynamics of a new micro-raft experiment.

102 Excitability and feedback: to pulse or not to pulse?

Bernd Krauskopf

Department of Mathematics and The Dodd-Walls Centre for Photonic and Quantum Technologies, University of Auckland

Co-authors: Soizic Terrien, Neil Broderick, Anirudh Pammi and Sylvain Barbay

Timetable: p. 21

Excitability is a very common phenomenon in the dynamics of many natural and engineered systems; examples are neurons, certain chemical reactions and laser systems. Being at equilibrium, an excitable system reacts to a sufficiently large perturbation by suddenly releasing a pulse of stored energy. Then the system needs some time to recover its level of stored energy. When excitable systems are coupling to themselves or to each other, they receive feedback with a delay time that is considerably larger than the pulse length. This may lead to very interesting pulsing dynamics. We demonstrate this here with an excitable micropillar laser with a feedback loop, or external cavity, generated by a regular mirror, which has been shown experimentally to be able to sustain trains of optical pulses. These can be triggered largely independently by optical perturbations injected into the laser, and they are then sustained simultaneously via feedback from the external cavity. A bifurcation analysis of a rate-equation model shows that the system has a number of periodic solutions with different numbers of equally spaced pulses as its only attractors. Hence, although coexisting pulse trains can seem independent on the timescale of the experiment, they correspond to very long transient dynamics. We determine the switching dynamics by studying the associated basins of attraction, which demonstrates that timing is everything when it comes to triggering or erasing pulse trains.

103 The importance of mitochondrial fission and fusion in a beating heart cell

Adarsh Kumbhari
University of Sydney
Co-authors: Vijay Rajagopal, Peter S. Kim
Timetable: p. 18

Mitochondria are specialised organelles that produce adenosine triphosphate (ATP) a molecule used by cells as an energy source. Owing to their unique energetic demands, cardiomyocytes have evolved to have a high mitochondrial density. These mitochondria form dynamic networks that are constantly undergoing fission and fusion events in response to a variety of stressors such as increased ATP demand or oxidative stress. However, the precise bioenergetic roles that mitochondrial fission and fusion play are unknown. This is further complicated by a lack of high-resolution data tracking the reorganisation mitochondrial networks in a beating heart cell. Previously, it was shown that mitochondria may split in an attempt to minimise the propagation of local dysfunction. Here, we use a hybrid agent-based-PDE model to quantify how different fission and fusion rates impact the distribution of ATP. We find that in normoxic regimes, varied fusion and fusion rates do not result in substantial changes in ATP production. By contrast, increased rates of mitochondrial fusion in hypoxic regimes are associated with more homogenous but reduced levels of ATP. Our findings suggest that the role of mitochondrial fission and fusion might be to assist in ensuring ATP homogeneity in hypoxic regimes.

104 Application of Quasi-Monte Carlo methods to neutron diffusion and wave propagation in random media

Frances Kuo
UNSW Sydney, Australia
Timetable: p. 22

Quasi-Monte Carlo (QMC) methods offer tailored point constructions for solving high dimensional integration and approximation problems by sampling. By exploiting the smoothness properties of the underlying mathematical functions, QMC methods can achieve higher order convergence rates than standard Monte Carlo sampling, and moreover, QMC error bounds can be independent of the dimension under appropriate theoretical settings. In recent years the modern QMC theory has been successfully applied to PDEs with random coefficients in computational physics and uncertainty quantification. This talk will showcase some of the ongoing works where we take QMC methods to new territories such as neutron diffusion as a high dimensional PDE eigenvalue problem, and high frequency wave propagation in random media. This includes joint work with Ivan Graham (University of Bath), Robert Scheichl (University of Heidelberg), Alexander Gilbert (University of Heidelberg), Ian Sloan (UNSW Sydney), and Mahadevan Ganesh (Colorodo School of Mines).

105 Reduced models for networks of model neurons

Carlo Laing
Massey University
Timetable: p. 21

Directly simulating large networks of neurons is time-consuming and does not provide much insight. However, for large networks of "theta neurons" it is possible to derive reduced models that are valid under some weak assumptions. I will show how to derive several such models of differing complexity and accuracy, and how these models can be used to efficiently investigate the effects of a network's structure on its dynamics.

106 Simulation of reduction of train transit times and energy use from track upgrades

Philip Laird
University ofWollongong
Timetable: p. 18

The paper will outline various applications of computer simulation of freight or passenger train movements over existing track and potential upgraded new track to generate estimates of the reduction of transit time of the train and the energy use (fuel or electric power). Various comparisons are given, including for various sections of the Main South railway of NSW where realignment could give savings of 25 per cent in both transit times and fuel use by freight trains. The paper will also note various problems in railways studied by Mathematics in Industry Study Groups over the years, and some railway projects with a mathematics component supported by the Australian Research Council and two rail Co-operative Research Centres.

107 Perlin noise for automatic generation of complex spatial patterns: an application to cardiac fibrosis

Brodie Lawson

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Co-authors: David Jakes, Kevin Burrage, Pamela Burrage, Christopher Drovandi, Alfonso Bueno-Orovio

Timetable: p. 13

Simulations of many physical and physiological phenomena require accurate representation of the heterogeneous spatial environments in which they take place. For example, the impacts of cardiac fibrosis on electrical signalling in the heart, and the corresponding consequences with regard to potential arrhythmias, depend heavily on the localisation and patterning of fibrotic obstructions. When data regarding the structure of these environments is difficult to acquire, *in silico* experiments have two options. On one hand, they may use available environment data with a low sample size, offering little opportunity to study variability and the robustness of their predictions. On the other hand, they may use computationally-generated environments, that offer near-unlimited sample size but typically at the cost of crude, heuristically-generated patterns that do not fully capture the complex spatial heterogeneity. We here present a methodology that marries the benefits of the two approaches, constructing a flexible pattern generator using computationally-cheap Perlin noise that, when appropriately tuned, can produce the very complex and highly varied patterns seen in cardiac fibrosis on the microscopic scale. We demonstrate the use of particle-based approximate Bayesian computation to perform such tuning, and point out that the use of similar generators with our techniques for pattern quantification and matching remain applicable to many other physical and physiological situations.

108 Modelling electricity prices with regime switching models

Angus Lewis

University of Adelaide

Co-authors: Nigel Bean, Giang Nguyen

Timetable: p. 21

A popular model for electricity prices is the independent-regime MRS model whereby multiple, independent AR(1) processes are interweaved by a Markov Chain. These models can be viewed as an extension of Hidden Markov Models (HMMs) or regime-switching time series. We can think of these models as multiple independent AR(1) processes evolving, but at each time we only observe one of them, and which process is observed is determined by a (hidden) Markov chain. In the context of electricity price modelling, parameter inference for these models has not been well-studied. We have developed novel maximum likelihood methods and also applied Bayesian methods to these models. In this talk I will discuss practical issues that we encountered when estimating these models and some lessons learned.

109 Corner rounding and roughness in dip-coating applications

Conway Li
University of Western Australia
Timetable: p. 18

The shape of the surface of a liquid in a vessel is governed by the highly nonlinear Laplace-Young capillary equation, with applications in industrial dip-coating. When a solid object is dipped into a coating liquid, the liquid profile arches near the corners, which is undesirable. Practical ways to control arching include rounding off the corners and applying roughness to the object. Whilst a conventional approach would involve directly seeking numerical solutions in a rounded corner domain, here a reverse strategy is used: starting from a given numerical solution in a sharp corner, the boundary condition is used to seek new rounded corner shapes which admit the same solution.

110 Modelling of reporting behaviour in the FluTracking surveillance system

Dennis Liu
University of Adelaide
Co-authors: Lewis Mitchell, Sandra Carlson, Joshua V. Ross
Timetable: p. 12

Modelling the spread of influenza across Australia is of substantial public health concern. However, there are many challenges in verifying the accuracy of models, given that disease transmission in the general population is largely unobserved. Online participatory health surveillance systems attempt to address this challenge by providing a convenient and near real time platform for self-reporting of symptoms. FluTracking is one such platform for monitoring influenza-like-illness (ILI) in Australia, where participants are requested once a week to respond to an online survey, detailing any ILI symptoms experienced. Due to the voluntary nature of the platform, individuals reporting behaviour may vary over time. This leads to implications for modelling ILI incidence from the FluTracking system. For example, individuals may be more likely to participate if they are currently experiencing symptoms. Not considering this participation behaviour may lead to bias in models of ILI spread. In this work, we analyse weekly reports from the FluTracking system from May 2011 to October 2017 and use Bayesian logistic regression to model the probability of an individual reporting in a given week and estimate ILI prevalence in Australia for a given week. We then compare this to conventional naive estimates of ILI and show that consideration of the voluntary nature of this data should be considered when deriving estimates from the dataset.

111 Computational singular perturbation method for nonstandard slow-fast systems

Ian Lizarraga
University of Sydney
Co-authors: Martin Wechselberger
Timetable: p. 12

This talk concerns the computational singular perturbation (CSP) method, an algorithm which iteratively approximates slow manifolds and fast fibers in multiple-timescale dynamical systems. The CSP method has been analyzed thoroughly for slow-fast systems in so-called standard form, where the separation between fast and slow components of the vector field is made explicit globally. Our purpose is to extend the CSP method to systems with nonstandard timescale splitting, where slow and fast directions can mix throughout the phase space, and a separation into slow and fast variables typically can be achieved only locally. We give a detailed description of the iteration step in the nonstandard case by using a geometric approach, and work out several examples to demonstrate the method. This has applications for dynamical systems modelling frictional stick-slip oscillators and complex chemical reactions.

112 Nonparametric approach to weak signal detection in the search for extraterrestrial intelligence (SETI)

Robert Lodder
University of Kentucky
Co-authors: Anne Brooks
Timetable: p. 17

In a recent paper in The Astrophysical Journal, researchers at MIT argue it is easy for intelligent extraterrestrial civilizations to be found if they mark their position with a bright laser beacon. Given the possible distances involved, however, it is likely that weak signal detection techniques would still be required to identify even the brightest SETI beacon. In near-infrared multivariate statistical analyses, ETI emitters with similar spectra produce points that cluster in a similar region of spectral hyperspace. These clusters can vary significantly in shape and size due to variation in signal modulation, bandwidth, and Doppler shift. These factors, when combined with discriminant analysis using simple distance metrics, produce a test in which a result that places a particular point inside a particular cluster (the training data are typically noise collected in a specific region of sky) does not necessarily mean that the point is actually a member of the cluster. Weak signal strength may be insufficient to move a data point beyond 3 or 6 SDs of a cluster. An extension of the Bootstrap Error-adjusted Single-sample Technique can be used to set probability-density contours inside spectral clusters as well as outside at an assigned significance level. The detection of candidate ETI signals both within and beyond 3 SDs of the center of the noise training set is therefore possible with this method. Near-IR spectra from the vicinity of AT2018ivc, a supernova discovered in M77 on Nov. 24, 2018, are analyzed successfully using the BEST to identify unusual signals.

113 Investigating selection pressure on single nucleotide polymorphisms in bacterial populations

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Timetable: p. 22

In recent years, technological advances have led to the availability of unprecedented amounts of genome sequence data, particularly in the context of bacterial infections. These genomic data have enabled the identification of variable sites, or single nucleotide polymorphisms (SNPs). These variables sites may evolve under natural selection or neutrally and may contain key information regarding the evolutionary dynamics of bacteria. However, while methods to estimate evolution rates exist, it is not obvious how to identify the strength and direction of selection in local bacterial populations by observing counts of non-synonymous and synonymous SNPs. It is especially difficult to tease apart counteracting effects of positive and negative selection. In this study, we investigate how SNP counts are distributed under a variety of assumptions regarding selection and mutation. By simulating the dynamics of non-synonymous and synonymous mutations in a population we aim to observe the patterns relating to the effects of positive and negative selection. We then collate empirical data from whole genome sequencing studies and consider the classification of counts of SNPs to identify the effects of positive and negative selection. We present a new way to visualise this SNP data and compare these reports to a model that assumes that mutations have no effect on fitness. Further, using these methods we find that positive selection can be seen in serial isolates collected from persistent infections, while negative selection is evident in isolates collected from outbreaks of acute infection.

114 A PDE approach for weather derivative pricing

Xiaoping Lu
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Co-authors: Peng Li and Song Ping Zhu
Timetable: p. 21

We propose a PDE (partial differential equation) based approach to price weather derivatives with the market price of risk (MPR) extracted from the utility indifference valuation. The PDE system is solved numerically using a one-sided finite difference scheme. The solution procedure is validated by comparing the numerical results calculated using our approach with those from the utility indifference future prices, and then applied to price more complicated weather derivatives such as options.

115 Localising nonlocal singular perturbations in the Benjamin-Ono wave equation

Chris Lustri

Macquarie University

Timetable: p. 14

Burger's equation is a partial differential equation that causes initial data to evolve and eventually become multivalued,. Various methods have been applied for resolving this multivaluedness; the most common is to introduce a small viscosity term (known as regularization), which causes the solution to exhibit a smooth front in the multivalued region. A related approach is to introduce a small dispersion term, obtaining a singular KdV equation that produces dispersive shock waves.

In this talk, we will look at a nonlocal regularization, which produces a singular Benjamin-Ono equation. The Benjamin-Ono equation describes the behaviour of internal waves in deep water in terms of a Hilbert transform, producing an integro-differential equation. I will show that the effect of this regularization can be described in terms of Stokes' Phenomenon; a fact which is already known for diffusive and dispersive regularization. I will also show that, even though the behaviour is governed by an integro-differential equation, the Stokes' structure can be determined using purely local information.

116 Estimating epidemiological quantities for skin sores in remote Australian communities using interval-censored data

Michael Lydeamore

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Timetable: p. 21

Prevalence of impetigo (skin sores) remains high in remote Australian Aboriginal communities, Fiji, and other areas of socio-economic disadvantage. Skin sore infections, driven primarily in these settings by Group A Streptococcus (GAS) contribute substantially to the disease burden in these areas. Despite this, estimates for the force of infection, infectious period and basic reproductive ratio — all necessary for the construction of dynamic transmission models — have not been obtained. By utilising three datasets each containing longitudinal infection information on individuals, we estimate each of these epidemiologically important parameters. With an eye to future study design, we also quantify the optimal sampling intervals for obtaining information about these parameters. We verify the estimation method through a simulation estimation study, and test each dataset to ensure suitability to the estimation method. We find that the force of infection differs by population prevalence, and the infectious period is estimated to be between 12 and 20 days. We also find that optimal sampling interval depends on setting, with an optimal sampling interval between 9 and 11 days in a high prevalence setting, and 21 and 27 days for a lower prevalence setting. These estimates unlock future model-based investigations on the transmission dynamics of GAS and skin sores.

117 Advection problems with spatially varying velocity fields: Analytical and numerical solutions in 1D

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Timetable: p. 22

The advection equation is one of the most commonly used models in environmental fluid dynamics. Despite this there exist very few analytical solutions to this equation for the case when the velocity field is spatially varying. In this work we define a class of solutions to the conservation form of the 1D advection equation using a particular change of variables. Example solutions are developed for constant, varying, and discontinuous initial density profiles, as well as for continuous and discontinuous velocity fields. The accuracy of three finite-volume numerical methods are evaluated for several test cases and compared to the exact solutions. The first and second order upwind methods, and the upwind method with the van-Leer slope limiter are used. It is found that the upwind method with the van-Leer slope limiter is well suited to numerically solving the advection equation with spatially varying velocity fields for most test cases, while the first and second order upwind methods have some serious drawbacks.

118 Optimal investment and consumption under a continuous-time cointegration model with exponential utility

Guiyuan Ma
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Timetable: p. 21

In this paper, we study the effects of cointegration on optimal investment and consumption strategies for an investor with exponential utility. A Hamilton-Jacobi-Bellman (HJB) equation is derived first and then solved analytically. Both the optimal investment and consumption strategies are expressed in closed form. A verification theorem is also established to demonstrate that the solution of the HJB equation is indeed the solution of the original optimization problem under an integrability condition. In addition, a simple and sufficient condition is proposed to ensure that the integrability condition is satisfied. Financially, the optimal investment and consumption strategies are decomposed into two parts: the myopic part and the hedging demand caused by cointegration. Discussions on the hedging demand are carried out first, based on the analytical formula. Then numerical results show that ignoring the information about cointegration results in a utility loss.

119 Accelerating the solution of geothermal inverse problems using the adjoint method

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Timetable: p. 14

Computational modelling plays a key role in understanding, managing and predicting the behaviour of geothermal reservoirs. The usual ‘forward’ simulation problem consists of generating observable data given input parameters. Here we are instead concerned with the so-called ‘inverse problem’ - inferring the underlying input parameters and boundary conditions given observable data. This allows models to be calibrated against available real world data and hence improve predictions and uncertainty quantification under new scenarios.

Mathematically, inverse problems are ill-posed and require regularisation. While in principle there are well-defined methods for solving ill-posed inverse problems, for realistic problems these approaches typically require extensive simulator runs of large, computationally expensive models. The adjoint method provides a means of accelerating the solution of inverse problems, via efficient objection function derivative calculations, provided that model Jacobian information is available. Given this information, the cost of this method is effectively independent of the number of parameters and it is hence particularly appealing for very large simulation models.

In this talk I will discuss our progress in implementing the adjoint method alongside our new geothermal simulator Waiwera, and present preliminary results from test cases. These include both 12-parameter and 640-parameter parameter problems, as well as recent work on extending our approach to models with order $10^4 - 10^5$ parameters. We find for these problems that the adjoint method provides significant speed-ups, of factors of at least 10 (for smaller problems) and often much more (for larger problems), compared to standard finite differencing methods.

120 Modelling dye-sensitized solar cells by nonlinear diffusion

Benjamin Maldon

University of Newcastle

Timetable: p. 15

Dye-Sensitized Solar Cells (DSSCs) maintain high research interest, owing to their potential as a viable solution to the renewable energy problem. While ample nanomaterials have been suggested to improve their efficiency, mathematical modelling and analysis remains noticeably sparse. The dominant model in this area remains the electron diffusion equation, which has been extended to include time-dependence and nonlinear characteristics since its introduction 24 years ago. In this talk, we analyse this diffusion equation by Lie Symmetry and numerical solutions to obtain the conduction band electron density of a DSSC.

121 Modelling task-switching with heteroclinic networks.

Gray Manicom
University of Pretoria
Timetable: p. 13

Heteroclinic networks are special solutions of dynamical systems in which trajectories cycle between various states, such as saddle type equilibrium solutions or periodic orbits. The deterministic behaviour of these systems is, in some cases, well-understood. However, with the addition of noise to the system its behaviour can change significantly. The noisy system may exhibit dynamics such as switching between the networks subcycles, a change in the residence times of trajectories near the aforementioned states, lift off and memory. In this presentation I demonstrate some of these effects on the dynamical system resulting from the addition of noise to a simple heteroclinic network and consider the application to a cognitive model of task-switching.

122 Hedging for cellular persistence in stress response

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Timetable: p. 13

Stochastic stress of different intensities is exploited in variety of ways in living cells. Initially cells may trigger the response to defend against stress. But they cannot afford the energy costs if the extreme stress is not resolved after a certain time period. In such situations, cells follow either cell death by apoptosis, necrosis and autophagy or persistence through minimal energy consumption. To capture how cells perform such trade offs leading to persistence through extreme stress, we construct a stochastic model of two coupled genes, one is constitutive (G1) and the other is facultative (G2). G1 regulates the transcription of G2 and the coupling factor (M(t)) between the genes is a time dependent control that is designed in terms of optimal stochastic control. The extrinsic noise permeates into the model in terms of a jump-diffusion mixture of Wiener process and Poisson jumps. As gene regulation through promoter binding is subject to the expense of nucleotide energy currency, the control variable must possess a threshold in energy consumption. Our objective is to minimise the fluctuations in the expression levels of the two genes and to maintain robust expression levels even during extreme stress. We use Hamilton Jacobi Bellman optimality theory to maximise the expectation of our objective and present a number of simulation results.

123 A fast semi-analytical homogenization method for block heterogeneous media

Nathan March
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Co-authors: Dr. Elliot Carr, Prof. Ian Turner
Timetable: p. 12

Direct numerical simulation of flow through heterogeneous media can be difficult due to the computational cost of resolving fine-scale heterogeneities. One method to overcome this difficulty is to coarse-grain the model by decomposing the domain into a number of smaller sub-domains and homogenizing the heterogeneous medium within each sub-domain. In the resulting coarse-grained model, the fine-scale diffusivity on each sub-domain is replaced by an effective diffusivity, calculated from the solution of an appropriate boundary value problem over the sub-domain. However, in simulations in which the heterogeneous sub-domain geometries evolve over time, the effective diffusivities need to be repeatedly recomputed and may bottleneck a simulation. In this presentation, I will present a new semi-analytical method for solving the boundary value problem and computing the effective diffusivity for block heterogeneous media. I will compare the new method to a standard finite volume method and show that the equivalent accuracy can be achieved in less computational time for several standard test cases. I will also demonstrate how the new method can be used to homogenize complex heterogeneous geometries represented by a grid of blocks.

124 Mechanistic and experimental models of cell migration reveal the importance of cell-to-cell pushing

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Co-authors: Matthew Simpson, Ruth Baker
Timetable: p. 20

Moving fronts of cells are essential for development, repair and disease progression. Therefore, understanding and quantifying the details of the mechanisms that drive the movement of cell fronts is of wide interest. Quantitatively identifying the role of intercellular interactions, and in particular the role of cell pushing, remains an open question. In this work, we report a combined experimental-modelling approach showing that intercellular interactions contribute significantly to the spatial spreading of a population of cells. We use a novel experimental data set with PC-3 prostate cancer cells that have been pretreated with Mitomycin-C to suppress proliferation. This allows us to experimentally separate the effects of cell migration from cell proliferation, thereby enabling us to focus on the migration process in detail as the population of cells recolonizes an initially-vacant region in a series of two-dimensional experiments. We quantitatively model the experiments using a stochastic modelling framework, based on Langevin dynamics, which explicitly incorporates random motility and various intercellular forces including: (i) long range attraction (adhesion); and (ii) finite size effects that drive short range repulsion (pushing). Quantitatively comparing the ability of this model to describe the experimentally observed population-level behaviour provides us with quantitative insight into the roles of random motility and intercellular interactions. To quantify the mechanisms at play, we calibrate the stochastic model to

match experimental cell density profiles to obtain estimates of cell diffusivity, D, and the amplitude of intercellular forces, f_0. Our analysis shows that taking a standard modelling approach which ignores intercellular forces provides a poor match to the experimental data whereas incorporating intercellular forces, including short-range pushing and longer range attraction, leads to a faithful representation of the experimental observations. These results demonstrate a significant role of cell pushing during cell front movement and invasion.

125 Metapopulation models for macroparasitic disease transmission

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Co-authors: Dominic Delport

Timetable: p. 20

Macroparasitic infections are characterised by long generation times and a complex life cycle often involving two or more host species. An individual human host's disease burden and transmission potential are an increasing function of their parasite count. A host with a low parasite count is likely to be asymptomatic and contribute a negligible amount to overall community transmission, while hosts with high parasite count are the major contributors to transmission. Accordingly, the usual approach to studying macroparasitic infection and transmission is to use intensity models. In contrast to the susceptible-infectious-recovered (SIR) model, intensity models do not compartmentalise the population. Rather they model the mean parasite burden in the community as a whole, and make an auxiliary assumption that the distribution of parasite burden over hosts follows some probability distribution. Empirical studies suggest high over-dispersion of parasite burden, so the use of a negative-binomial distribution is common.

While dominant in the literature, intensity models have two potential drawbacks. Firstly, imposing a negative-binomial distribution may not be valid when the system is not at equilibrium. Secondly, when attempting to extend these models to account for interactions among well-mixed communities, it is not clear how to couple these communities.

In this presentation I will describe an approach to model macroparasitic infections that overcomes both these issues. We begin by returning to the early literature that established intensity models as a framework for the study of macroparasites. We enumerate all possible infection-states of an individual, based on the total number of adult macroparasites contained in the body. By doing so, we maintain the "standard" compartmental model structure and hence avoid the need to make assumptions on the functional form of parasite burden across hosts in a community. Furthermore, coupling of communities becomes straightforward, mirroring the well established processes for patch modelling using SIR models.

I will finish by presenting some numerical simulations from coupled compartmental macroparasitic models, demonstrating that they provide different quantitative results to intensity models. Potential application areas and possible implications will be discussed.

126 Hole-closing problem for the Porous-Fisher equation

Scott McCue
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Co-authors: Wang Jin, Matthew Simpson
Timetable: p. 19

Models for collective cell motion often involve reaction-diffusion equations with a linear diffusion term to describe cell motility and a logistic term to describe cell proliferation. A significant drawback for this family of models is that they are not able to capture the moving fronts that arise in cell invasion applications such as wound healing and tumour growth. This talk is concerned with an alternative approach, which is to include nonlinear degenerate diffusion via the Porous-Fisher equation, allowing for sharp-fronted solutions with compact support. We study a hole-closing problem, which is a model for cells initially seeded outside of a 'hole' that closes as cells migrate and proliferate. The hole-closing limit gives rise to interesting similarity solutions of the second kind. Other solutions that are not self-similar are also explored. We compare our results with experiments from a new two-dimensional wound healing assay (a "sticker" assay), demonstrating how nonlinear degenerate diffusion is able to capture certain experimental behaviour whereas linear diffusion is not.

127 Estimating airflow turbulence scales from gas tracer data

Robert McKibbin
Massey University at Albany, Auckland, New Zealand
Timetable: p. 19

Gas concentration data collected downwind of tracer releases are used to estimate the dominant length scale L of the near-ground atmospheric turbulence. Recorded concentrations are compared with those predicted by a simplified mathematical model. Here a tracer gas is released steadily from a fixed height into a wind with a near-uniform speed w but which veers (changes direction) during the experiments. The turbulence near the ground is assumed to be isotropic; the dispersion coefficient in the model is written $D = wL$ where L is the dominant length scale associated with the turbulence. The formula used for comparison with the experimental data is the steady-state solution of an advection-dispersion equation for a uniform wind over an impervious surface.

Results show that the computed values for the dominant turbulence length scale fall in a relatively small range. Considering the variety of wind speeds and day-time/night-time experiment times, this gives a closely-constrained estimate for L. The effects of the assumption of a uniform wind are also investigated. Differences in computed concentration values between the uniform and non-uniform wind cases are only a few percent. The assumption of a uniform wind seems justified.

[Part of this work was done by a graduate student, Aimee Harris, as a summer project.]

128 Weaving a tangled web: neurons and networks

Shawn Means

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Co-authors: Carlo Laing, Christian Blasche

Timetable: p. 18

Dynamical processes on networks are relevant to numerous systems ranging from communications, infectious diseases, social interactions and the central nervous system. Neuronal networks are vastly complex with numbers of neurons in the human brain on order 10^{11} and numbers of connections between them are even more staggering. We are investigating statistical properties of these network systems such as correlations of input and output connections for an individual neuron, and assortativities or propensities of linkages between, say, high-input and low-output neurons. Additional concerns such as the uni-directional aspect of neuronal information flow, addition or removal of auto-stimulation or multiple linkages between two neurons further complicate the process. We present various methods of assembly for these networks, and some of the techniques for optimising and reducing the overall computational difficulties encountered enroute to our investigations of emergent behaviours in networks and implications for physiological systems.

129 A unified mechanism for spatiotemporal patterns in somitogenesis

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Timetable: p. 23

Somitogenesis is the process by which body segmentation occurs during embryonic development in all vertebrates. One of the most enduring frameworks proposed for explaining it is the Clock and Wavefront mechanism, which assumes that the presomitic mesoderm (PSM) comprises autonomous cellular oscillators, or clocks, that are arrested upon encountering a wave of gene expression. Their temporal state at the instant of arrest determines their eventual fate. Hence, temporal activity provides a blueprint for spatial order. While subsequent studies have investigated the dynamics of gene expression in the PSM, there are important unanswered questions regarding the role of inter-cellular communication on synchrony, travelling wave behaviour and the eventual arrest of oscillations leading to an inhomogeneous steady state. We propose a mathematical model for somitogenesis that describes the collective activity of a network of genetic oscillators coupled with their neighbours through Notch receptors and Delta ligands. As the PSM expands along the anteroposterior axis during somitogenesis, all the features of this process can effectively be captured in 1D. Furthermore, as there are gradients of morphogen concentration along this axis that effectively change over time, it is intuitive to describe this process using a reference frame that co-moves with the growing cells. We find that the system, which is initially synchronised, subsequently exhibits travelling waves, a homogeneous steady state, and finally a pattern reminiscent of somite-somite boundary formation. Our results suggest that all the dynamical transitions expected to occur during somitogenesis can be explained using a single mechanism.

130 Mechanistic control of epidermal tissue height

Claire Miller
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Co-authors: Edmund Crampin, James Osborne
Timetable: p. 13

The epidermis is the outer-most layer of our skin, and protects our bodies from the environment. The height of the epidermis varies both between people and by location on the body. Maintaining this height requires a careful balance between cell proliferation, which occurs at the base of the tissue, and cell loss to the environment, occurring at the top of the tissue. In this talk we investigate this balance using a 3-dimensional multicellular model of epidermal tissue, which we built based on underlying biological mechanisms. Using this model, we show that we are able to 'tune' the height of the epidermis through control of proliferation rate, degradation of cell-cell adhesion, and force required for cell removal. This analysis unlocks future model-based investigations of the epidermis, including investigating tissue recovery from perturbation, and the effect of cell mutations.

131 Reducing the effect of discretization errors in estimating ODE models by iteratively reweighted least squares

Yuto Miyatake
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Timetable: p. 12

When estimating ordinary differential equation (ODE) models, we usually fit numerical solutions to observations. However, this approach often suffers from discretization errors, which could substantially affect the estimation accuracy. Therefore, the uncertainty induced by the discretization should be carefully quantified to improve the estimation accuracy, and in fact, these kinds of attempts have attracted attention in the last few years in the communities of Bayesian inference and machine learning. In this talk, regarding the discretization error as a probabilistic noise and using reweighted least squares with isotonic regression, we propose an iteratively reweighted least squares for estimating ODE models. Numerical experiments show that our method improves the estimation accuracy for several problems.

132 Transport equation models for water waves in ice-covered oceans

Fabien Montiel
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Timetable: p. 19

Transport equation models are broadly used to forecast wave climate around the globe. Such models evolve a scalar and phaseless field called the wave action density (closely related to the wave energy spectrum) in space and time, with group speed given by the properties of the homogeneous background medium. Inhomogeneities, e.g. variable bathymetry or ocean currents, are introduced as source terms in the transport equation. In particular, in polar oceans the scattering of ocean waves by an inhomogeneous sea ice cover has been introduced in transport equation models based on phenomenological considerations, which cause the wave action density to decay and redistribute wave energy to other directional components, such that total energy is conserved. The relationship between non-homogeneous transport equation models and the first principles of continuum mechanics remains unclear, however. Here we demonstrate how such a transport equation can be derived for ocean wave packets in one horizontal dimension being scattered by a continuous ice cover with spatially varying thickness.

133 Controlling viscous fingering patterns in a Hele-Shaw cell through geometry manipulation

Liam Morrow
Queensland University of Technology
Co-authors: Scott McCue
Timetable: p. 12

A commonly used tool for studying interfacial instabilities is the Hele-Shaw cell, which is an experimental apparatus made of two parallel plates separated by a narrow gap. When an inviscid fluid is injected into a Hele-Shaw cell which is otherwise filled with a viscous fluid, the interface normally is unstable and forms distinct patterns. In recent years, there has been interest in determining how manipulating the physical geometry of the Hele-Shaw cell can be used to control the development of these fingers. Examples of these manipulations include lifting the plates as the bubble is injected, tapering the plates, or allowing the plates to bend. Here, we present fully nonlinear numerical simulations of some of these flows using a robust scheme based on the level set method and investigate the effectiveness of various control strategies.

134 Real-time assessment and prediction of influenza severity

Robert Moss
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Timetable: p. 12

Infectious disease forecasting is becoming a useful decision-support tool for public health preparedness and response activities, particularly for seasonal influenza. To date, the primary focus has been to predict key features of observed disease (e.g., when disease activity will exceed an "epidemic onset" threshold, and the timing and size of the epidemic peak). But this focus is now shifting to predicting outcomes that are more relevant to public health activities, such as hospital burden (which comprises a small proportion of all observed disease, but exerts the largest impact on the healthcare system). Two quantities are of particular relevance: the number of expected hospitalisations in each future week, and the proportion of these hospitalisations to all observed disease ("proportional severity").

A major complication is that the primary measure of observed disease — laboratory-confirmed influenza case notifications — is typically available only as count data (i.e., without testing denominators), and the testing rate can change markedly from one year to the next. This is primarily due to changes in (a) healthcare-seeking behaviours of people with mild symptoms; and (b) clinician testing practices.

In this talk, I will show how we can use weekly survey data collected by the Flutracking surveillance system to characterise healthcare-seeking behaviours and clinical testing practices at each week of the influenza season, in order to estimate proportional severity in near-real-time and ultimately to predict future hospital burden.

135 Developing methods to improve the accuracy of classification based crowdsourcing

Julie Mugford
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Co-authors: Alex James, Elena Moltchanova
Timetable: p. 17

Crowdsourcing is a widely used method to classify large amounts of images or objects. However, due to the openness of crowdsourcing, participants may contribute low quality responses. To improve the accuracy of classifications multiple participants identify each object and consensus methods are used to decide the classification of the object. Commonly, simple consensus methods, e.g. majority vote, are used. However, majority vote weights the contributions from each participant equally but the participants may vary in accuracy with which they can label objects. We show that using Bayes Rule to classify images based on participants responses, participants accuracies and relative frequencies of classes improves the accuracy of classifications compared to using majority vote. We show methods for estimating participants accuracies for varying levels of prior information about true image identities and participant characteristics.

136 An individual-based mechanical model of cell movement in heterogeneous tissues

Ryan Murphy
Queensland University of Technology
Co-authors: Pascal Buenzli, Ruth Baker, Matthew Simpson
Timetable: p. 15

Mechanical heterogeneity in biological tissues, in particular stiffness, can be used to distinguish between healthy and diseased states. However, it is often difficult to explore relationships between cellular-level properties and tissue-level outcomes when biological experiments are performed at a single scale only. To overcome this difficulty we develop a multi-scale mathematical model which provides a clear framework to explore these connections across biological scales. Starting with an individual-based mechanical model of cell movement, we subsequently derive a novel coarse-grained system of partial differential equations governing the evolution of the cell density due to heterogeneous cellular properties. We demonstrate that solutions of the individual-based model converge to numerical solutions of the coarse-grained model, for both slowly-varying-in-space and rapidly-varying-in-space cellular properties. We discuss applications of the model, such as determining relative cellular-level properties and an interpretation of data from a breast cancer detection experiment.

137 A surface of heteroclinic connections in a 4D slow-fast system

Elle Musoke
University of Auckland
Timetable: p. 15

Slow-fast dynamical systems are systems in which some variables change faster than others. From chemical reactions to electric circuits, examples of slow-fast systems are found in a wide variety of disciplines. By reason of their ubiquity, phenomena that arise from the multiple-time-scale nature of slow-fast dynamical systems are of great interest.In particular, we study mixed-mode oscillations (MMOs), periodic orbits that have segments of low amplitude oscillations and segments of high amplitude oscillations. Mechanisms for generating MMOs in four-dimensional slow-fast systems are largely unexplored. We consider the prototypical four-dimensional Olsen model that has an MMO. Near the MMO, Fenichel theory guarantees the existence of two one-dimensional, so-called saddle slow manifolds. One saddle slow manifold has a three-dimensional stable and a two-dimensional unstable manifold and the other has a two-dimensional stable and a three-dimensional unstable manifold. Numerical continuation methods are used in conjunction with appropriately defined boundary-value problems and Lins method to compute a two-dimensional surface of heteroclinic connectionsformed by the intersection of the two three-dimensional manifolds.Thissurface of heteroclinic connectionsis animportant ingredient for the formation of the MMO.

138 A structured population model for lipid accumulation in macrophages

Mary Myerscough
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Co-authors: Hugh Ford, Helen Byrne
Timetable: p. 19

Macrophage foam cells are typically seen in atherosclerotic plaques. These cells have accumulated so much internalised lipid that they take on a foamy appearance under the microscope. Macrophages acquire lipid, both from the cholesterol on modified low density lipoprotein (LDL) particles (bad cholesterol) but also from ingesting other macrophages which have become apoptotic via a process of controlled cell death. We present an advective PDE model for the populations of macrophages and apoptotic cells, structured by their internalised lipid content, find steady state solutions analytically and use this model to explore the factors that contribute to plaque progression.

139 Pseudo-precision and rank tests

Markus Neuhaeuser
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Timetable: p. 18

Nonparametric, or distribution-free, methods can be applied in many areas including statistical process control problems. For example, the Wilcoxon rank-sum statistic is used, see e.g. Mukerjee and Chakraborti (Qual. Reliab. Engng. Int. 2012; 28: 335-352). When a variable is measured by automated equipment, or when values are computed, the data are usually stored with pseudo-precision, that is with many more decimal places than justified by the precision of the respective measurement. This pseudo-precision matters when assigning ranks which is a necessary step when the Wilcoxon or any other rank-based statistic is applied. The resulting artificial reduction in the number of ties is a disadvantage because mean ranks give more efficient tests in comparison to randomly broken ties. This finding is demonstrated using asymptotic results and simulations, and illustrated using example data.

140 A random process model for laying out HF antenna arrays

Garry Newsam
University of Adelaide
Timetable: p. 14

The receiver arrays in Australias Jindalee Over-The-Horizon Radar network are large, kilometre-long structures containing hundreds of individual HF antennae. Existing arrays are linear but next generation arrays will have two-dimensional layouts. In practice array layouts are the product of many considerations; the purpose of this talk is to present a simple model for the signals impinging on the array and a corresponding metric for optimising array layout that nevertheless reproduces many of the features observed in existing layouts. In particular, if the signals of interest are modelled as a white noise process of point sources in the far field, then the resulting RF field induced over the array itself is a continuous stationary random process whose correlation function is the Fourier transform of the density of signal sources. The antennae effectively sample this field at fixed points, so the signal recorded by the antenna is a random vector whose correlation matrix is determined by the antennae locations and the continuous correlation function. Choosing the locations to maximise the log of the determinant of this matrix will optimise the information content of this signal, and thus of the array. The talk will note some important further conclusions that can be drawn from this model, and provide some numerical calculations of optimal layouts for simple approximations to signal densities observed in practice.

141 Integrable systems arising from separation of variables on S3

Diana Nguyen
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Co-authors: Holger Dullin
Timetable: p. 19

Inspired by Schöbel's work on the classification of separable coordinates on S^3 as well as Vu Ngoc's classification of semitoric systems, we study the separation of variables of the geodesic flow on S^3 and the resulting integrable systems. This talk presents a variety of interesting preliminary results about these systems. The geodesic flow on the 3-sphere S^3 is a superintegrable system with a global Hamiltonian S^1-action. The quotient of $T * S^3$ by this action is isomorphic to $S^2 \times S^2$. We obtain an explicit parametrisation of this symplectic manifold in terms of the angular momenta L_{ij} . The Hamiltonian-Jacobi equation of the geodesic flow on S^3 separates in the general spherical-elliptical coordinates as well as the 5 degenerate coordinates: prolate, oblate, Lame-subgroup reduction, spherical and cylindrical coordinates. These six distinct Stackel's systems give rise to six integrable systems on S^3 and consequently six integrable systems on $S^2 \times S^2$. We produce the image of the integral map (for a fixed energy) for all six systems, with the general elliptical case consisting of four lines and a quadratic curve. Resounding similarities are found between the momentum maps of our systems and those from the geodesic flow on an ellipsoid and the Neumann problem. We also show that image of the corresponding action map for the general elliptical coordinates is the equilateral triangle given by the intesection of the plane $I_1 + I_2 + I_3 = 1$ with the positive quadrant. With an appropriate projection

of this triangle onto R^2, we show that the image of the action map has the boundary being a Delzant triangle with critical curves on the interior of this polygon.

142 Animal swarming models using stochastic differential equations: a brief review

Thi Hoai Linh Nguyen
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Co-authors: Viet Ton Ta, Atsushi Yagi
Timetable: p. 22

We give a brief review of our work on stochastic differential equation (SDE) models describing swarming behavior of animals. We firstly introduce a general model constructed from individual-individual interaction rules which include attraction, repulsion and the individual-environment interaction rules. The external factors include moving environment, obstacles, food resource, etc. In addition, a noise factor, which models the degree of uncertainty in the individual's behavior that reflects both the imperfect information-gathering ability of an individual and the imperfect execution of the

individual's actions, is also taken into account. The specific models (free space model, avoiding obstacle model, foraging model) can be obtained easily just by choosing an appropriate external force in the general model. Numerical study on the models shows that the swarming behavior according to the models agrees well with the observation study on animals behavior in the real world. For example, fish enjoy foraging advantage while forming school, fish schooling performs different patterns when avoiding obstacles. More precisely, we observe four behavioral patterns of a group of individuals while avoiding a circle obstacle, which we call Together, Back, Reunion and Separation. Specifically, all the four patterns can be achieved just by tuning one parameter while keeping all the others constant. Furthermore, we discover the relationship between model parameters, school cohesiveness and behavioral patterns.

143 Modelling the role of the environment in the initial stages of multicellular evolution

Matthew Nitschke
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Co-authors: Andrew Black and Paul Rainey
Timetable: p. 17

The evolution of multicellular entities from unicellular ancestors signalled the emergence of a new level of biological organization. It is one of the major transitions in evolution. Despite its importance, there are many open questions surrounding the start of this transition. We investigate how this transition could have occurred by constructing mathematical models. These models describe a process, called Ecological Scaffolding, by which specific ecological conditions can cause individual cells to form groups and endow them with Darwinian properties; this means the groups show variation in character, differences in reproductive output, and heritability. The models can be used to understand

the conditions that promote this phenomena, and hence the start of the transition from unicellular to multicellular life. Some initial results will be presented that show the effect of a key environmental condition on this transition: bottleneck size.

144 Satellite orbits: Newtonian, post-Newtonian and Einsteinian

Joseph O'Leary
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Co-authors: James M. Hill
Timetable: p. 16

Einstein's highly non-linear and fully covariant general theory of relativity (GR) provided the answer to the early 20th century cardinal problem of celestial mechanics; the anomalous precession of Mercury's perihelion. Newton's instantaneously acting, inverse square law of gravitation was superseded by GR where gravity is perceived as a consequence of the geometric properties of spacetime. However, the field equations of GR are a system of ten, non-linear, coupled partial differential equations. Hence, known exact solutions are limited and modelling of realistic astrophysical situations is restricted to problems with high degrees of symmetry.

The post-Newtonian approximation to the field equations of GR has been successfully developed over the past century and allows for the accurate accounting of the departure of Newtonian gravitation due to GR and is relied upon heavily in fields such as space-geodetic techniques, astrometry, navigation and interplanetary missions. In this talk, we present new results on the characterisation of satellite and planetary orbits for near-Earth objects and solar system bodies respectively. We show the new formalism more accurately resembles the orbits in classical GR and generalises the well known Newtonian and post-Newtonian formulae for elliptical and precessing orbits respectively.

145 Bipartite networks for fun and profit

Dion O'Neale
University of Auckland
Timetable: p. 17

"All the world's best represented as a bipartite network, and all the men and women merely agents in it" — Shakespeare, if he'd been a network scientist.
Networks are a powerful and increasingly common way of representing structures and systems of interacting entities in areas as diverse as ecology, economics, finance, and urban planning. The majority of networks that have been studied to date consist of relationships between entities from a single class – so called one-mode networks. However, I will argue that many of these networks are actually projections of bipartite networks; networks with two distinct nodes types and edges only between nodes of different types.

I will introduce some of the consequences of considering (or ignoring) the underlying bipartite structure of such systems and will show how it helps to resolve an apparent paradox related to the distribution and correlation of node degrees in networks. I will also present some examples of applied bipartite networks from recent projects I have worked on, including social networks from archaeology, student-course networks, and networks of technological specialisation across geographic regions.

146 Microtubule dynamics, kinesin-1 sliding, and dynein action drive growth of cell processes

Dietmar Oelz

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Timetable: p. 23

Recent experimental studies of the role of microtubule sliding in neurite outgrowth suggested a qualitative model, according to which kinesin-1 motors push the minus-end-out microtubules against the cell membrane and generate the early cell processes. At the later stage, dynein takes over the sliding, expels the minus-end-out microtubules from the neurites, and pulls in the plus-end-out microtubules that continue to elongate the nascent axon. To understand this process in more detail, we combine computational modeling of a network of elastic dynamic microtubules and kinesin-1 and dynein motors with measurements of the process growth kinetics and pharmacological perturbations in Drosophila S2 cells. The results verify quantitatively the qualitative model of the microtubule polarity sorting and suggest that dynein-powered elongation is effective only when the processes are longer than a threshold length, which explains why kinesin-1 alone, but not dynein, is sufficient for the process growth. Furthermore, we show that the mechanism of process elongation depends critically on microtubule dynamic instability. Both modeling and experimental measurements show, surprisingly, that dynein inhibition accelerates the process extension. We discuss implications of the model for the general problems of cell polarization, cytoskeletal polarity emergence, and cell process protrusion.

147 Analysis of spherical data with applications to CMB studies

Andriy Olenko
La Trobe University, Australia
Timetable: p. 13

In this talk we will present some recent progress in studies of spherical data. These data can be modeled as realizations of a random field defined on the unit sphere. The main research problems are strongly motivated by cosmological applications. In particular, we discuss mathematical applications in Cosmic Microwave Background (CMB) radiation studies. We plan to present the following three directions. (1) Modelling CMB using SPDE. Infinite series spectral representations of SPDE's solutions must be truncated to a finite number of terms. It introduces approximation errors that must be properly estimated. (2) Muntifractal analysis of CMB using Renyi functions. Nonlinearity of Renyi functions provides testing procedures for non-Gaussianity. (3) Comprehensive numerical tools realised in a new R package rcosmo. This is the first R package for handling and analysing spherical, Healpix and CMB data on a HEALPix grid. This research was supported under ARC Discovery Projects DP160101366. The talk is based on joint results with V. Anh (QUT and Swinburne University), P.Broadbridge, D. Fryer, M.Li (La Trobe University), N.Leonenko (Cardiff university) and Y.Wang (UNSW).

148 A network approach for finding the right amount of topics in topic modelling

Adrian Ortiz-Cervantes
University of Auckland
Timetable: p. 16

Topic models are statistical models used to analyze collections of documents in order to reveal the "topics" that are discussed in them. These "topics" are also called latent themes and in the context of topic models each of these latent themes can be associated with a multinomial distribution of words. Each document in the corpus can be associated with these topics in different proportions. Latent Dirichlet Allocation (LDA) is the most widely used method for topic modelling. One of the open questions when it comes to applying LDA on topic modelling is how to choose the "right" number of topics. In this study, we present a network based heuristic for solving this problem. This works by transforming the hard problem of choosing the right number of topics into the easier problem of identifying the optimal number of communities in a network of topics generated under different parameters. We have applied this method to study the content of the documents issued by the Antarctic Treaty System (ATS). This reveals some interesting insights about their priorities, interests and geopolitical alignments. We also study the evolution of the topics with time in order to see which topics have been consistent during the 50 years of the ATS and which other have appeared or disappeared depending on the international context.

149 Bursting in the presence of a locally separating manifold

Hinke Osinga

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Co-authors: Saeed Farjami and Vivien Kirk

Timetable: p. 22

The mechanism underlying multi-spike bursting of neurons is typically explained with models that exhibit different time scales with a single slow variable. The bursting patterns observed in such slow-fast systems are periodic orbits that successively track different coexisting attracting states associated with the so-called fast subsystem, for which the slow variable is viewed as a parameter. In particular, the threshold that determines when bursting occurs is identified as the basin boundary between two attractors associated with the active and silent phases. In reality, however, the bursting threshold is a more complicated object. We develop and algorithm based on the continuation of two-point boundary value problems to compute an approximation of the bursting threshold as a locally separating stable manifold of the full slow-fast system. As a representative example, we use a three-dimensional Morris-Lecar model that has one slow and two fast variables. We compute the locally separating stable manifold and investigate how the bursting periodic orbit interacts with this manifold. We also explain how this manifold organises the number of spikes in the bursting periodic orbit and illustrate its role in a spike-adding transition as we vary a parameter.

150 Dynamics of an all-fibre laser with saturable absorber

Robert Otupiri

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Co-authors: Broderick, N. G. R. , Krauskopf, B.

Timetable: p. 13

We report on a detailed experimental and numerical study of self-pulsations in an all-fibre laser with saturable absorber. By a commonly known technique called Q-switching, a continuous stream of pulsed light intensities can be generated. We show where these pulses are born and how the pulsing behaviour is influenced by parameters including the pump power and gain and absorber sections. To this end, we consider a system of three differential equations, initially developed by Yamada and adopted here to our experimental laser system. It 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 and how it influences the pulse profile of generated light pulses. We achieve this by studying the system for different absorber lengths and increasing pump power. We demonstrate good agreement between a bifurcations analysis of the model and experimental measurements.

151 Multiple time scales in a calcium dynamics model.

Nathan Pages
University of Auckland
Timetable: p. 21

In classical slow-fast systems, there is an explicit separation between slow and fast variables, and ideas from bifurcation theory and geometric singular perturbation theory (GSPT) can be used to analyze such systems. In this talk, I will present a three-dimensional ODE model, derived from a calcium dynamics model of hepatocytes, that does not have a clear separation of slow and fast variables; one variable can be either fast or slow, depending on the location in phase space. I will discuss two complementary approaches we have used for analysing this model.

152 A hinged linkage mechanism that follows discrete integrable equations

Hyeongki Park
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Co-authors: Shizuo Kaji, Kenji Kajiwara
Timetable: p. 17

We consider a family of linkage mechanisms which consist n-copies of a rigid body joined together by hinges to form a ring. Each hinge joint has its own axis of revolution and rigid bodies joined to it can be freely rotated around the axis. The family includes a special family of linkages called the Kaleidocycles which exhibit a “turning over” motion. We can represent the Kaleidocycles as discrete closed space curves with a constant torsion up to sign, where Kaleidocycle motion preserves arc length at each pair of curve points. We present particular paths in the configuration space of the Kaleidocycles, which are governed by the semi-discrete mKdV and sine-Gordon equations.

153 Graded resonator arrays for spatial frequency separation and amplification of water waves

Malte Peter
University of Augsburg, Germany
Co-authors: Luke G. Bennetts (Adelaide), Richard V. Craster (Imperial College)
Timetable: p. 17

Wave-energy converters extracting energy from ocean waves are known to suffer from poor efficiency. We propose a structure capable of substantially amplifying water waves over a broad range of frequencies at selected locations, with the idea of enhanced energy extraction. The structure consists of a small number of C-shaped cylinders arranged in a line array, with the cylinder properties graded along the array. Using linear potential-flow theory, it is shown that the energy carried by a plane incident wave is amplified within specified cylinders, for wavelengths comparable to the array length, and for a range of incident directions. Transfer-matrix analysis is used to attribute the large amplifications to excitation of local Rayleigh–Bloch waves and gradual slowing down of their group velocity along the array.

This is joint work with L. G. Bennetts (Adelaide) and R. V. Craster (Imperial College).

154 Time-frequency analysis for wakes of accelerating ships

Ravindra Pethiyagoda
Queensland University of Technology
Co-authors: Timothy J. Moroney, Scott W. McCue
Timetable: p. 21

Spectrograms have recently emerged as a useful method of visualising ship wakes from surface height measurements taken from a single location, with potential applications in ship detection and coastal management (coastal erosion). Previous studies have formulated a linear dispersion curve that predicts the location of colour intensity in a spectrogram for a ship moving in a straight line with a rudimentary extension given to include acceleration. In this talk we will further extend the linear dispersion curve to account for a ship moving along an arbitrary path with arbitrary speed. We provide examples for a ship accelerating in a straight line and a ship travelling in a circle with constant angular velocity. Additionally, an example of nonuniqueness of the dispersion curve is presented, which sheds some light on potential difficulties for applications involving detection.

155 Image reconstruction for MRI with a rotating RF coil

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Co-authors: Dr Michael Brideson, Prof. Larry Forbes

Timetable: p. 19

To achieve higher resolution images in Magnetic Resonance Imaging (MRI) there has been a trend towards scanners operating with increasingly strong magnetic fields. At these higher field strengths, the traditional birdcage design for a Radio Frequency (RF) coil is no longer capable of generating a homogeneous RF field over the imaging region. An alternative approach is to use a surface coil, which is only sensitive to a limited part of the whole imaging region, and then mechanically rotate the coil about the object being imaged. The resultant data, acquired on a radial trajectory in Fourier space, now corresponds to multiple different sensitivity-weighted images dependent upon the angular position of the rotating coil. In this talk I will discuss a new approach to reconstructing images from data acquired in this non-conventional manner. The method reconstructs pixel values directly as a weighted sum of the acquired data, avoiding the inherent approximation of gridding used in existing methods. However, calculating the appropriate weights is an ill-conditioned and computationally expensive problem. A Tikhonov regularisation is applied to improve the conditioning and reduce the sensitivity to noise in the data. Reconstructions from simulated and real datasets are presented and compared with reconstructions from existing methods.

156 The Moreau envelope, proximal mapping and derivative-free VU-algorithm

Chayne Planiden

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Co-authors: Warren Hare, Claudia Sagastizbal

Timetable: p. 19

One method of optimising a nonsmooth function is that of regularisation: smoothing the function while safeguarding the minimisers and minimum value. The Moreau envelope is one such regularising function, and the associated proximal mapping is a powerful presence in nonsmooth analysis. We use these tools to further the scope of the VU-algorithm, which is a nonsmooth minimisation algorithm that enjoys a superlinear convergence rate. The main goal of this work is to provide a derivative-free version of the VU-algorithm, for use in situations where gradients and Hessians are either not available or too costly to calculate.

157 Mitigating fisheries-induced evolution

Michael Plank
University of Canterbury
Co-authors: Richard Law
Timetable: p. 14

A size-structured PDE has been used to model the dynamics of a multi-species fish community. The evolutionary selection pressure generated by fishing has been calculated using an adaptive dynamics framework, which separates the ecological and evolutionary timescales. The outcomes from different harvesting patterns are compared and it is found that protecting the largest fish in the population from fishing is crucial for reducing the pressure towards maturation at smaller sizes. This can be achieved without loss of fisheries yield by catching smaller fish but protecting large ones.

158 Spiral waves and heteroclinic cycles in Rock-Paper Scissors

Claire Postlethwaite
University of Auckland
Co-authors: Alastair Rucklidge
Timetable: p. 17

The RockPaperScissors game, in which Rock blunts Scissors, Scissors cut Paper, and Paper wraps Rock, provides an appealing simple model of cyclic competition between different strategies or species in evolutionary game theory and biology. When spatial distribution and mobility of individuals is taken into account, waves of Rock can invade regions of Scissors, only to be invaded by Paper in turn. The dynamics is described by a set of partial differential equations that has travelling wave solutions in one (spatial) dimension and spiral wave solutions in two (spatial) dimensions. In this talk, I will describe how we can understand what governs the wavespeed and wavelength of the travelling waves, by considering the dynamics near a robust heteroclinic cycle that arises when the PDEs are considered in a travelling frame. We find three new types of heteroclinic bifurcations, none of which have been seen in the literature before. I will finish by proposing some ideas on how to extend our work to understand what governs similar properties of the spiral wave solutions.

159 Vertically vibrated floating drops

Andrey Pototsky
Swinburne University of Technology
Timetable: p. 23

We study dynamic shape transformation of a vertically vibrated liquid drop supported by a more heavier immiscible fluid. The disjoining pressure is introduced to account for partial wettability of the carrier fluid by the drop. Navier-Stokes equation is reduced in the long-wave approximation to yield a simple hydrodynamic model that is valid for a finite Reynolds number flow regime. Numerical simulations reveal that the drop is unstable beyond a certain vibration amplitude in agreement with earlier floating drops experiments.

160 Mathematical modelling of property variation in the southern pines

Steven Psaltis
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Co-authors: Ian Turner, Elliot Carr, Troy Farrell
Timetable: p. 15

In this talk I will discuss aspects of a large collaborative project between the timber and forestry industry, Qld Department of Agriculture and Fisheries, University of the Sunshine Coast, and QUT. This work focuses on the commercial southern pine estates of southeast Queensland and northern New South Wales. They are one of the most important groups of commercial timbers due to the scale of forests, both natural and plantations, which are utilised for wood and paper products.

Here I will focus on modelling of property variation in the southern pines to develop predictions of wood properties of sawn timber boards. The wood properties are intrinsically linked to the value of the resource, and are therefore of critical importance to the forestry industry. To develop our models of wood properties we utilise measurements taken from a set of destructively-sampled trees to construct distributions of wood properties, mapped to the geometry of the tree. To obtain a continuous property distribution from the discrete measurements, we consider an approach based on radial basis functions (RBFs), which allows us to generate surfaces describing the variation of the wood properties. We consider approaches based directly on the geometry of the tree, and in terms of the cambial and apical ages of the tree to generate a 'virtual log'. We then apply industry-supplied sawing patterns to extract virtual boards, calculate their properties and validate against measured values.

161 Mathematical modelling to aid fabrication of components for medical devices

Gagani Ranathunga
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Co-authors: Yvonne Stokes, Michael Chen, Heike Ebendorff-Heidepriem
Timetable: p. 15

Micro structured optical fibres (MOFs) are revolutionary optical fibres with one or more channels running along their length. These fibres have highly useful optical properties which enable their use in medical appliances for advanced sensing. Recently, interest has arisen in the production of hollow-core tapers for use in Whispering gallery sensors and emitter tips for Mass spectrometer. These tapers need to have uniform internal structures of micro or nanoscale. In this talk, I will describe how the internal structures of tapers can be altered during drawing through active channel pressurization and temperature/viscosity control in order to oppose stretching and surface tension effects that would otherwise act to close the holes during the production process. I will also discuss the need for mathematical modelling to determine the draw parameters to obtain a specific geometry, which cannot be practically achieved through laboratory experiments.

162 Modelling antimalarial treatment in drug-resistant malaria

Georges Ferdinand Randriafanomezantsoa Radohery
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Co-authors: David Khoury
Timetable: p. 12

Malaria is caused by infection with the Plasmodium parasites, and the parasite has developed resistance towards artemisinin combination therapies (ACT), which are currently our most effective treatments for malaria. Artemisinin resistance was first detected by slower declines in parasite concentrations in infected individuals after treatment with an ACT. However, a question remains as to why parasite concentrations decline more slowly after treatment with an ACT? It has been proposed that artemisinin-resistant parasites take longer to be cleared by the host after they are killed, but the most common mathematical models of drug treatment in malaria do not separately consider the process of drug killing parasites, and the process of host removing parasites.

Here I develop a model of drug treatment in malaria and explore how different parameters in the model might change as drug resistance emerged. I compare this model to the observations in the literature to see how well it recapitulates the observations of slower declines in parasite concentrations in people infected with artemisinin-resistant infections.

163 Extensions of the Cahn–Hilliard equation: modelling and simulation of coupled phase-separation processes

Lisa Reischmann

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Co-authors: Malte Peter

Timetable: p. 18

The Cahn–Hilliard equation, which describes the process of phase separation of a binary system, is a purely phenomenological model. Considering more general phase-separation processes, e.g. observed in lipid monolayers in film-balance experiments, it is natural to ask which further effects can be reproduced with models of Cahn–Hilliard type.

We consider extended models, which result from coupling the Cahn–Hilliard equation with the Stokes equations and/or the Poisson equation to take into account flow and electrostatic charge effects. Further, we present a unified simulation approach based on the finite-element method, which allows to handle these extensions straight forwardly, and we showcase a number of numerical simulations illustrating their effects.

164 Red and grey squirrels, SQPV and the dilution effect

Mick Roberts

Massey University

Timetable: p. 15

The Eastern gray squirrel was first introduced to the UK in the 1870s, where it outcompetes the native red squirrel for resources. In addition, squirrel parapox virus (SQPV) is fatal for the red squirrel, but not the grey. Pine martens are being reintroduced in Scotland and prey preferentially on grey squirrels. We present a model for the dynamics of red and grey squirrel populations in the presence of SQPV. Using the grey squirrel death rate as a distinguished parameter we obtain a bifurcation diagram that summarises the qualitative behaviour of the system. Using parameter values taken from the literature, the model does not support the notion that the grey squirrel acts as a reservoir of infection for SQPV in red squirrels, it appears that SQPV could persist in either species in isolation. The dilution effect is the paradigm that increased biodiversity reduces the risk of infection transmission. The model demonstrates that increasing the mortality of the grey squirrel increases the population density of red squirrels, and the density of infected red squirrels. However, it reduces the proportion of the red squirrel population that is infected, and reduces the basic reproduction number $\mathcal{R}_0$. Hence the dilution effect needs to be defined in context.

165 Towards a process based model of gully erosion for improved Great Barrier Reef water quality

Melanie Roberts

Australian Rivers Institute - Griffith University

Timetable: p. 15

The Great Barrier Reef (GBR) is under threat. After climate change, water quality is recognised as the greatest stress on the GBR. Sediments eroded from the GBR catchment are transported to the marine environment, leading to poor water quality in the GBR lagoon. Suspended sediment reduces light availability, impeding seagrass growth and affecting the coral's algal symbiont, ultimately leading to coral death. Sedimentation can bury coral polyps, cause tissue necrosis, and reducing the recruitment and survival of coral larvae. Sediment can also promote the transportation of nutrients into the lagoon, leading to eutrophication, algal blooms, and Crown of Thorns starfish outbreaks. Gullies in grazing areas have been identified as leading contributors to sediment reaching the GBR lagoon, despite occupying a small proportion of the landscape. Reducing gully erosion is critical to improving water quality on the GBR, however the current pace of restoration is insufficient to achieve water quality targets. To guide investment, mathematical models of gully erosion are sought for integration with catchment-scale models used for large-scale assessments. A preliminary process based model is presented for the erosion of an idealised alluvial gully. The model is suitable for localised investment decisions that, when scaled up, can be used to assess the scale of restoration required to improve water quality of the GBR.

166 Artificial intelligence for autonomous driving

Raúl Rojas

Freie Universität Berlin

Timetable: p. 16

In my talk, I will give an overview of a new iteration of the architecture and algorithms for the autonomous cars which have been developed at the Dahlem Center for Machine Learning and Robotics, Freie Universität Berlin. I will explain how we mix reactive with deliberative control. Sensor input is collected in a series of virtual sensors which trigger different behaviors. I will explain how we have experimented with 3D-features-based localization and the ideas we have for localization and driving under tough weather conditions. Our sensors are self-calibrated and the hardware architecture provides levels of safety. I will mention some new projects, such as extending the life of the batteries in electric vehicles by using an energy buffer. In another project we are investigating swarm behavior in traffic. At the end, I will present some ideas about the evolution of the commercial introduction of autonomous vehicles in the near future.

167 Who cares? Or, when does paternal care arise in primates?

Danya Rose
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Co-authors: Sara Loo, Kristen Hawkes, Peter Kim
Timetable: p. 23

Paternal care is a rare trait among primates, with males of most species preferring a competitive approach to gaining paternities and spending little time interacting with or protecting their own young. Males who care for their young risk foregoing opportunities to compete with other males for extra paternities. Affecting the costs and rewards of either strategy are biological issues such as lactational amenorrhea, pregnancy duration, and life history, which we include in a new model of the interplay between care and competition. We explore this model in an effort to characterise some conditions under which paternal care might arise.

168 Optimized prophylactic vaccination in metapopulations

Joshua Ross
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Co-authors: Nigel Bean, Mingmei Teo
Timetable: p. 21

A highly effective method of infectious disease control is vaccination. However, there are many situations where vaccine supply is limited. The ability to determine, under this constraint, a vaccination strategy which minimises the number of people that become infected over the course of a potential epidemic is essential. Two questions naturally arise: when is it best to allocate vaccines, and to whom should they be allocated? We address these questions in the context of metapopulation models of disease spread. We discover that it is optimal to distribute all vaccines prophylactically, rather than withholding until the infection is introduced. For small metapopulations, we provide a method for determining the optimal allocation. As the optimal strategy becomes computationally intensive to obtain when the population size increases, we detail an approximation method to determine an approximately optimal vaccination strategy. Through comparisons with other strategies in the literature, we find that our approximate strategy is superior.

169 Arbitrary rotationally symmetric doubly-connected conductors: potential theory problems

Martin Sagradian

Macquarie University

Co-authors: Dr Elena Vinogradova

Timetable: p. 12

The accurate design of 3D electrostatic lenses used in microwave electronics, mass spectrometers and electrostatic accelerators depends heavily on the accuracy of the mathematical modelling of the electrostatic fields generated by the charged tubular conductors. These structures may be described as doubly-connected axially symmetric surfaces with an arbitrary profile. This paper extends the Method of Regularisation to the analysis of such conductors and complementary structures. The Laplace equation subject to Dirichlet boundary conditions is rigorously solved. After separating the integration kernel in the equivalent integral formulation into two parts, one singular and a sufficiently smooth remainder, the technique of solving triple series equations, involving properties of the Jacobi polynomials, transforms the system of functional equations to a second kind Fredholm matrix equation. It is a well-conditioned system by which the instability of the solution is eliminated. Any desired accuracy level can be stably achieved, by taking sufficiently large truncation number of the infinite system before numerical inversion of the matrix. The results are illustrated for various shapes of screens.

170 Numerical scheme for solving Hele-Shaw problems based on the method of fundamental solutions

Koya Sakakibara

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Co-authors: Shigetoshi Yazaki

Timetable: p. 12

The classical Hele-Shaw problem describes a motion of fluids sandwiched between two parallel plates with a narrow gap, and it has been studied by many researchers as a fundamental model of viscous fingering phenomena. The classical Hele-Shaw problem has curve-shortening (CS), area-preserving (AP), and barycenter-fixed (BF) properties. In this talk, we construct a numerical scheme for this problem based on the method of fundamental solutions. Under our numerical scheme, a discrete version of CS-, AP-, and BF-properties holds, while simple boundary element method does not satisfy these properties in general.

171 A compartment model of cholesterol regulation in the retina

Ronél Scheepers
Queensland University of Technology
Co-authors: Graeme Pettet, Robyn Araujo, Petrus van Heister
Timetable: p. 19

Currently age-related macular degeneration (AMD) is an untreatable disease causing loss of central vision due to pathology of the macula, a small area in the center of the posterior retina. Various hypotheses on the factors involved in the etiology of AMD exist within the field of Ophthalmology and related medical fields, yet it remains poorly understood and only a limited number of therapies are available. It is now clear that AMD should be viewed as a collection of perturbations from homeostasis, each of which could contribute to the characteristic progressive loss of central vision. In particular, there is a need to fully understand the maintenance of cholesterol homeostasis in the retina to prevent normal ageing processes from being perturbed towards maculopathy.

Here we present a novel mathematical model of the retina that represents both the homeostatic as well as the diseased state. This new model integrates the various disparate hypotheses on AMD etiology reported in the literature in the form of a hierarchy of process schematics from which a compartmental ODE model was constructed, encompassing all key species and physiological processes, such as nutrients, waste and lipoprotein management. As cholesterol management is a key issue for AMD development, we also developed a reduced mathematical model which focuses on the cholesterol management pathways in the parent model. These new mathematical approaches may contribute to a prototype clinical tool for interpreting the underlying deficit and hidden dynamics that lead to the diseased state.

172 Optimal control of acute myeloid leukaemia

Jesse Sharp
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Co-authors: Alexander Browning, Tarunendu Mapder, Kevin Burrage, Matthew Simpson
Timetable: p. 16

Acute myeloid leukaemia (AML) is a blood cancer affecting the haematopoietic stem cells of the myeloid cell line. AML is routinely treated with chemotherapy, incurring significant health and financial cost, so it is of great interest to develop optimal chemotherapy treatment strategies. In this talk, we incorporate an immune response into a stem cell model of AML, since we find that previous models lacking an immune response are inappropriate for predicting optimal control strategies. Using optimal control theory, we can produce continuous controls and bang-bang controls, corresponding to a range of objectives and parameter choices. We provide a practical discussion of the implementation of optimal control to the AML model. In particular, we describe and explore factors that impact numerical convergence. We then discuss future aims, such as mathematical modelling of drug holidays and stochastic controls.

173 Stability in piecewise-smooth maps: Fixed points, fractals, and friction.

David Simpson
Massey University
Timetable: p. 15

Fixed points are the simplest steady-states of discrete-time dynamical systems and we can expect a system to settle to a fixed point if and only if the fixed point is asymptotically stable. For piecewise-smooth maps the stability of a fixed point is not determined by eigenvalues in the usual way. Indeed the set of parameter values for which a fixed point is stable may be fractal. I'll present new ergodic theory results that provide some explanation for this fractal structure. The results can be used to obtain practical conditions for the existence of an attractor, and I'll illustrate these with a model of a mechanical oscillator experiencing stick-slip friction.

174 Trapped underground: the fluid dynamics of sequestered carbon dioxide

Anja Slim
Monash University
Timetable: p. 22

Storage of carbon dioxide deep underground is one of several technologies being considered to reduce greenhouse gas emissions to the atmosphere and mitigate climate change. The idea is to capture CO_2 from point sources such as power stations, purify it, compress it and inject it underground. The most ubiquitous potential storage location is in so-called "saline aquifers", permeable rocks at 1 to 3km depth containing a very salty brine. Here, the sequestered CO_2 passes through several stages of storage: structural trapping, capillary trapping, solubility trapping and in some cases mineral trapping. This talk will describe what fluid dynamics (and perhaps a live demonstration) can tell us about the fate of injected CO_2.

175 Using maths to probe the maps - are the cosmic microwave background maps really random fields?

Ian Sloan
University of New South Wales
Timetable: p. 23

According to cosmological theory, the cosmic microwave background (CMB) should be to a good approximation a realisation of a Gaussian random field. In this project, joint with Robert Womersley, Thong Le Gia and Yu Guang Wang, we develop a computational tool to probe the CMB temperature maps published by the Planck collaboration. We show that some of the maps, as judged from their Fourier coefficients, depart very significantly from random fields. In the case of the "SEVEM" map we show that the field can be modelled as a random field plus a localised needlet-like structure situated at the galactic centre, with the non-random part being large enough to affect significantly the angular power spectrum.

176 Propagation dynamics on multiplex (i.e. duplex) networks

Michael Small
University of Western Australia
Timetable: p. 16

Propagation dynamics in heterogeneous populations, when the population is not well-mixed, or for emerging infections, are typically not well modelled without understanding the contact network. In this talk I will review some of the significant modifications to standard compartmental disease propagation rise from modelling the contact process as a complex network. The probable can then be complicated further by considering information exchange between individuals as a seperate propagation process on a seperate network layer. Implications for design of control strategies and practical consequence will be discussed.

177 Unsteady free surface flows into a submerged ring sink.

Tim Stokes
University of Waikato
Co-authors: Graeme Hocking, Larry Forbes
Timetable: p. 23

The unsteady free-surface flow of a fluid induced by a submerged ring sink in an ideal fluid of arbitrary depth is considered. In the steady case, there are transitions between “point-like” and “line-like” behaviour of the free surface as the ring radius is increased from zero, with a ring radius of the square root of 2 proving to be a key transitional value. After first reviewing these earlier findings, we present new results on critical drawdown values in the unsteady case. Similar transitions are observed, although at a rather smaller ring radii than for the steady case.

178 Drawing of microstructured optical fibres: modelling and validation.

Yvonne Stokes
University of Adelaide
Timetable: p. 17

Microstructured optical fibres, containing patterns of air channels, have revolutionised optical fibre technologies, with a virtually limitless range of fibre designs for a wide range of applications, including communication networks, medical devices and sensing. Determining the initial preform geometry and draw parameters to make a desired fibre is, however, challenging and mathematics has played a key role in solving this inverse problem. One-dimensional models, derived using asymptotic methods, have been used with considerable success for the last five decades or so to model the drawing of textile and optical fibres as well as film blowing and the Vello process for manufacture of capillary tubes. In this talk I will show that this approach remains important today for microstructured optical fibres, and how the one-dimensional flow model may be coupled with a two-dimensional Stokes-flow model to describe the deformation of the complex structure in the cross-section. I will also discuss the coupling of the flow model with a temperature model to obtain additional information. The validity of the model will be demonstrated by comparison of results with experiments and some avenues for future work will be indicated.

179 Application of Helmholtz-Hodge decomposition to the construction of Lyapunov functions

Tomoharu Suda

Graduate School of Human and Environmental Studies, Kyoto University

Timetable: p. 14

The Helmholtz-Hodge decomposition (HHD) is a decomposition of vector fields whereby they are expressed as the sum of a gradient vector field and a divergence-free vector field. It is often used as a tool to extract information on the behaviour of the vector field. The HHD is not unique, which should lead to studies on the criteria for choosing the decomposition . However, the mathematical foundation is not satisfactorily explored in this respect. In this talk , we will discuss the connection between HHD and Lyapunov functions and give a class of vector fields where the HHD-based analysis succeeds. We will first show that local Lyapunov functions can be constructed using HHD if certain stability conditions are given. We will also discuss a strictly orthogonal HHD. Vector fields with such decomposition are a generalization of gradient vector fields, and much information on the behaviour is obtained via the HHD.

180 Spatial structure arises from chase-escape interactions with crowding effects

Anudeep Surendran

Queensland University of Technology, Brisbane, Australia

Co-authors: Michael Plank, Matthew Simpson

Timetable: p. 16

Movement of individuals, mediated by localised interactions, plays a key role in numerous processes including cellular biophysics and ecology. In this work, we propose an individual based model (IBM) of multispecies motility that accounts for various intraspecies and interspecies interactions in a community that is composed of an arbitrary number of distinct species. This framework allows us to explore how individual-level directional interactions scale up to generate spatial structure at the macroscale. To focus exclusively on the role of motility and directional bias in determining spatial structure, we consider conservative communities where the number of individuals in each species remains constant. We derive a mathematically tractable deterministic approximation of the IBM using an approach based on describing the dynamics of the spatial moments. An important objective of this study is to use the general IBM and spatial moment dynamics frameworks to investigate the impact of interactions in stereotypical community consisting of two distinct species. We explore how different features of interactions including interaction strength, spatial extent of interaction, and relative density of species influence the formation of the macroscale spatial patterns.

181 Peculiarities of magnetic control of heat transfer in ferrofluids

Sergey Suslov
Swinburne University of Technology
Co-authors: Khanh G. Pham
Timetable: p. 21

Ferrofluids are synthetic magneto-polarisable nanofluids. Their flows can be controlled by applying an external magnetic field. One of their prospective applications is as a heat carrier in thermal management systems operating in conditions where natural convection is suppressed due to extreme confinement (e.g. microelectronics). Keeping this application in mind we develop a weakly nonlinear flow stability analysis that reveals an intricate interplay between thermogravitational and thermomagnetic mechanisms of convection acting in non-isothermal ferrofluids. Solutions of the obtained dynamical system of Landau equations demonstrate that the application of a magnetic field can trigger convection in regimes where natural convection cannot exist, thus enhancing heat transfer. At the same time in regimes where both magnetic and gravitational buoyancy mechanisms are active the competition between the two may suppress the overall heat exchange, which has to be kept in mind in designing practical heat management systems.

182 Periodic orbits with four masses

Winston Sweatman
Massey University
Timetable: p. 16

The gravitational few-body problem is both beautiful and challenging. We present a family of orbits that are composed from four point masses. This family is generated from the one-dimensional periodic Schubart orbit. The new orbits are also periodic in the sense that the masses repeatedly pass through their initial configuration.

183 A incomplete balancing domain decomposition method for magnetostatic problems

Daisuke Tagami
Kyushu University
Timetable: p. 23

A incomplete Balancing Domain Decomposition (BDD) method is considered as a preconditioner for the iterative procedure in the Hierarchical Domain Decomposition Methods (HDDM) for magnetostatic problems.

HDDM has enabled us to execute large-scale computational models of magnetic field problems whose numbers of Degrees Of Freedom (DOF) are about 10^7–10^9; see, for example, Kanayama, et al. (2002) and Sugimoto, et al. (2017). BDD originally proposed by Mandel (1993) is the appropriate preconditioner for HDDM, and succeeds in applying into HDDM for structural problems; see, for example, Ogino, et al. (2008). The coarse grid problem to balance indeterminate DOF on subdomain problems plays a key role in BDD. In case of 3-D magnetostatic problems, its number of DOF is equal to the sum of the numbers of DOF of the conventional piecewise linear tetrahedral finite element space in the subdomains. This fact implies that it takes much more time to solve the coarse grid problem.

In this talk, to avoid raising the computational costs, VE (see, for example, Beirão da Veiga (2018)) is incorporated into HDDM. In case of 3-D magnetostatic problems, indeterminated DOF consists of the conventional piecewise linear tetrahedral finite ement space among the subdomains. Now the indeterminate DOF is approximated by VE in each subdomain. Owing to the approximation of the indeterminate DOF by VE, it is expected to reduce the computational costs as well as to accept polyhedral interfaces. In the presentation, some mathematical/numerical results are shown.

184 A multi-phase extensional flow model for sliding motility in yeast biofilms

Alexander Tam
University of Adelaide
Co-authors: Benjamin J. Binder, J. Edward F. Green, Sanjeeva Balasuriya, Ee Lin Tek, Jennifer M. Gardner, Joanna F. Sundstrom, Vladimir Jiranek
Timetable: p. 20

Most bacteria and fungi exist in biofilm colonies, consisting of adherent cells embedded in a fluid extracellular matrix. Yeast biofilms can form on indwelling medical devices, making them a leading cause of bloodstream infection. As biofilms are highly resistant to anti-fungal treatment, the mortality rate of these infections can approach 50% for patients in intensive care units. Due to this, yeast biofilms have attracted significant research attention. However, although inducing biofilm formation in the laboratory is possible, less is known about the physics governing their expansion.

Based on similar observations in bacteria, one hypothesis is that yeast biofilms expand by sliding motility. This involves a sheet of cells spreading as a unit, enabled by weak adhesion to the substratum. We construct a multi-phase fluid model for a biofilm growing in a nutrient-limited environment. We assume that the biofilm consists of two viscous fluid phases: living cells and an extracellular matrix.

As the width of a biofilm significantly exceeds its height, we employ an extensional flow thin-film approximation to simplify the governing equations. This gives rise to a one-dimensional axisymmetric model for the biofilm height, cell volume fraction, nutrient concentration, and fluid velocity.

To test the sliding motility hypothesis, we compare numerical solutions with yeast biofilm formation experiments. We find good agreement in expansion speed between numerical solutions and data from multiple experiments. The model also reproduces the ridge-like structure that is observed in experiments. From these findings, we conclude that sliding motility is a possible mechanism for yeast biofilm formation.

185 A new descent algorithm in nonlinear optimisation

Matthew Tam

University of Goettingen

Co-authors: Yura Malitsky

Timetable: p. 19

The gradient descent algorithm for minimising a differential function is a workhorse of nonlinear optimisation. Each iteration of this algorithm generates a new point by taking a step in the direction of the negative gradient of the current point. In its simplest realisation, this stepsize parameter is constant and the convergence theory requires cocoercivity of the gradient operator. In this talk, I discuss a simple modification of the method which allows the cocoercivity assumption to replaced with merely Lipschitz continuity. The computational cost of the modified method, in terms of gradient evaluation per iteration, is same as gradient descent. The case of variable and adaptive stepsizes will also be discussed.

186 An initial-boundary value functional differential equation problem arising in a cell division model

Steve Taylor

Mathematics Department, University of Auckland

Timetable: p. 18

We study the approximation of solutions of a functional partial differential equation model for size-structured cell growth and division. The approximations are generated by solving closely related first order partial differential equations. In this model, the density of cells, $n(x,t)$, relative to cell size x at time t evolves subject to growth, death and splitting. A cell of size x is assumed to divide into two daughter cells of size $\frac{x}{\alpha}$ and $\frac{x}{\beta}$. The natural space for solutions to the model is $L^1(0,\infty)$ because the total number of cells should be finite; $\int_0^\infty n(x,t)dx < \infty$. The aim of this paper is to compute a sequence of approximations that converges rapidly to the actual solution. We give convergence rates in L^1 and, with some restrictions, in L^p for $p > 1$.

187 A model for cell proliferation in a developing organism

Peter Taylor
University of Melbourne
Co-authors: Phil Pollett and Laleh Tafakori
Timetable: p. 21

In mathematical biology, there is a great deal of interest in producing continuum models by scaling discrete agent-based models, governed by local stochastic rules. We shall discuss a particular example of this approach: a model for the process that leads to Hirschprung's disease. Our starting point is a discrete-state, continuous-time Markov chain model proposed by Hywood, Hackett-Jones and Landman for the location of the neural crest cells that make up the enteric nervous system.

We exploit the relationship between the above-mentioned Markov chain model and the well-known Yule-Furry process to derive the exact form of the scaled version of the process. We use this to provide expressions for features of the occupancy process, such as the expected value and variance of the marginal occupancy at a particular site, the expected mass of domain agents located up to any given point in the domain and a distributional limit for the mass of domain agents located up to any given point.

188 Collective motion with excluded-volume effects

Gayani Tennakoon
University of Auckland
Co-authors: Stephen Taylor
Timetable: p. 18

Many physical and biological systems consist of individuals with collective behaviour. In reality, these individuals have a finite size, and many living organisms tend to keep others at a distance; hence, they exclude a volume in space. Volume exclusion can be considered as the simplest possible interaction within a population. From small-scale systems such as interior cell motion or ion channels to large-scale systems such as pedestrian motion or animal swarms, it plays a significant role in determining transport properties in the diffusion of particles through crowded environments. Stochastic models describe how interacting individuals give rise to collective behaviour. For large systems, particle-based models become computationally intractable. This difficulty can be avoided by replacing these high dimensional stochastic models with continuum population-level models based on partial differential equations for the population density. The goal of our research is to develop mathematical models that involve volume excluded by sizes of particles. The method is based on developing a matched asymptotic expansion to establish the link between the stochastic model and the population-level model. We begin by considering finite-sized particles travelling at the same speed in one dimension. The result is a coupled system of partial differential equations (PDE) for the distribution function of position, velocity and time. Due to size exclusion, the PDEs are nonlinear in the transport term.

189 Appearance and disappearance of the region occupied by the flow through a boundary

Kenji Tomoeda

Graduate School of Informatics, Kyoto University

Timetable: p. 22

Numerical experiments suggest interesting properties in the several fields of fluid dynamics, plasma physics and population dynamics. Among such properties, we may observe the interesting phenomena; that is, the *repeated appearance and disappearance phenomena of the region penetrated by the fluid* in the flow through a porous media with absorption. The model equation in two dimensional space is written in the form of the initial-boundary value problem for a nonlinear diffusion equation with the effect of absorption:

$$\begin{cases} v_t(t,x,y) = \Delta(v^m) - cv^p & \text{in} \quad (0,\infty)\times\Omega, \\ v(t,x,y) = \psi(t,x,y) & \text{on} \quad (0,\infty)\times\partial\Omega, \\ v(0,x,y) = v^0(x,y) & \text{on} \quad \Omega, \end{cases}$$

where Ω is a bounded domain in $\mathbf{R}^2$, $v(\geq 0)$ denotes the density of the fluid, $m > 1$, $0 < p < 1$, $c > 0$, $m + p \geq 2$, and $v^0(x,y)$ and $\psi(t,x,y)$ are non-negative continuous functions. This equation is also used to describe the propagation of thermal waves in plasma physics.

From analytical points of view, the existence and uniqueness of a weak solution and the comparison theorem are proved by Bertsch.

In this talk we show some numerical examples and prove such phenomena stated above.

190 Toward a mathematical analysis for a model of suspension flowing down an inclined plane

Kyoko Tomoeda

Faculty of Science and Engineering, Setsunan University

Co-authors: Kaname Matsue

Timetable: p. 22

In this talk we deal with the suspension flowing down an inclined plane which is a kind of solid-liquid two-phase flow. The dynamic models for suspension are formulated as transport equations for the liquid and the particles. From the dynamic transport equations, the following dilution approximate equation is obtained.

$$\begin{cases} \partial_t h + \partial_x \left(\frac{1}{3} h^3 \right) = 0, \\ \partial_t n + \partial_x \left(\sqrt{\frac{2}{9C}} (nh)^{3/2} \right) = 0, \end{cases}$$

where C is the constant, h is the total suspension thickness and $n = \phi h$ with the particle volume fraction $0 \leq \phi \leq 1$. This system is derived by the dilute approximation from the full model of the suspension, in which the particles settle to the solid substrate and the clear liquid film flows over the sediment. The authors solve the initial value problem of the equations and numerically observe that this behavior with small volume fraction is due to rarefaction waves for h and n.

We consider the Riemann problem of the conservation laws with initial data :

$$U(x,0) = \begin{cases} U_L = (h_L, n_L) & x < 0 \\ U_R = (h_R, n_R) & x > 0 \end{cases},$$

where U_L and U_R are given constants and represent the left and right states of U, respectively. We show that the weak solution is connected by 2-rarefaction wave from U_L to U_R when $h_L < h_R$, and connected by 2-shock wave when $h_L > h_R$. Following the result obtained here, we mathematically explain the relationship between the shock waves, rarefaction waves and the behavior of suspension.

191 Analysis of arbitrary polygonal waveguides: TM and TE modes

Turker Topal

Macquarie University

Co-authors: E. Vinogradova, Y. A. Tuchkin

Timetable: p. 13

A qualitative analysis of arbitrary polygonal waveguides for TE and TM modes is considered. The method of analytical regularisation ([1]-[3]) provides a mathematically rigorous and numerically efficient tool for boundary value problems of electromagnetic wave diffraction. The method has been successfully applied to arbitrary canonical waveguide problems with open and closed contours. Using the standard Green formulae technique, a first kind Fredholm integral equation can be obtained. Then an analytical semi-inversion technique is employed for the regularization procedure. This transforms the initially ill-posed equation of the first kind into a well-conditioned second kind Fredholm equation in matrix formulation. The resulting system of infinite linear algebraic equations can be solved effectively using the truncation method, which produces an algebraic system with uniformly bounded condition number. Bounding contours of various canonical waveguide cross-sections can be described by analytical expressions including for example generalised super-ellipse equation. For waveguide cross-sections of arbitrary profile, the method of spline interpolation is employed. By incorporating mollifier functions, we successfully applied the method to waveguides with arbitrary polygonal cross section.

[1] Y. A. Tuchkin, Wave scattering by open cylindrical screens of arbitrary profile with Dirichlet boundary conditions, in Soviet Physics Doklady, vol. 30, 1985, p. 1027. [2] E. Vinogradova, Electromagnetic plane wave scattering by arbitrary two-dimensional cavities: Rigorous approach, Wave Motion, vol. 70, pp. 4764, 2017. [3] S. S. Vinogradov, P. D. Smith, and E. D. Vinogradova, Canonical problems in scattering and potential theory Part II: Acoustic and Electromagnetic diffraction by canonical structures. CRC Press, 2002.

192 An analytical solution for groundwater infiltration under ponded surface conditions

Dimetre Triadis
La Trobe University and Kyushu University
Timetable: p. 22

The current most general integrable model for unsaturated one-dimensional groundwater infiltration governed by the Richards equation has been known since the 1980s. However, exact solutions for many simple, physically relevant boundary conditions have yet to be derived. We present an exact series solution for infiltration subject to ponded water at the soil surface, by decomposing the soil body into saturated and unsaturated regions separated by a moving interface. The use of efficient, iterative, symbolic-computation algorithms removes restrictions on the number of terms that can be obtained in the final infiltration series. We are also able to consider behaviour in the popular but subtle nonlinear 'delta-function diffusivity' limit within a wider class of exact solutions.

193 Growing yeast off the grid

Hayden Tronnolone
University of Adelaide
Co-authors: Benjamin J. Binder
Timetable: p. 15

Dimorphic yeasts grown on a solid substrate are able to alter their growth pattern in response to the surrounding nutrient level. When nutrient is readily available, cells separate from their mother cell to produce colonies that appear close to circular when viewed from above. When nutrient is limited, cells reproduce via the pseudohyphal growth pattern, which is characterised by distal unipolar budding (budding opposite to the birth scar), the elongation of cells, and a persistent connection between mother and daughter cells. This change results in the growth of filaments directed away from the colony, producing an irregular shape. The factors that influence this growth are studied using an agent-based off-lattice model that accounts for nutrient diffusion, cell size and the angle at which cells bud. In agreement with previous work using lattice-based models, the off-lattice model indicates that the growth mode depends strongly upon the nutrient concentration and diffusivity, while also better capturing the behaviour of individual cells and thus providing a greater understanding of the relationship between microscopic and macroscopic features. It is found that the change in cell size that occurs during pseudohyphal growth is critical to the production of filaments, while the cell budding angle influences the characteristics of the filaments produced.

194 Hadamard variational formulae and its applications for iterative numerical schemes

Takuya Tsuchiya
Ehime University
Co-authors: Takashi Suzuki
Timetable: p. 23

To compute numerical solutions of free boundary problems, the problem domain is sometimes perturbed and quantities defined on the domain vary. Derivatives of a quantity with respect to the domain perturbation is called Hadamard variation. In this talk, we show some newly obtained Hadamard variational formulas. Furthermore, we propose an iterative numerical scheme for a free boundary problem define with the Hadamard variational formula.

195 Anomalous scaling of Hopf bifurcation thresholds of localized spot patterns in 2-D

Justin Tzou
Macquarie University
Co-authors: Michael Ward, Juncheng Wei
Timetable: p. 22

For a singularly perturbed two-component activator-inhibitor reaction-diffusion system in a bounded 2-D domain admitting localized multi-spot patterns, we provide an anomalous scaling threshold for the reaction-time constant τ that determines stability to temporal oscillations of the spot amplitudes. In the limit of large inhibitor diffusivity, the linear stability is determined by the spectrum of a class of nonlocal eigenvalue problems (NLEPs). In a certain parameter regime, we show from a new parameterisation of the NLEP that no Hopf bifurcations leading to temporal oscillations in the spot amplitudes can occur for any $\tau \sim \mathcal{O}(1)$. Instead, by deriving a new modified NLEP appropriate to the regime $\tau \gg 1$, we show that a Hopf bifurcation will occur at some $\tau = \tau_H \gg 1$, where τ has an anomalous scaling law in the activator diffusivity $\varepsilon^2 \ll 1$.

196 Structure and dynamics of social bipartite and projected networks

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Univeristy of Auckland

Timetable: p. 17

Despite their importance for the analysis of complex systems, bipartite networks are often neglected. In general, one-mode versions of the bipartite network are created using the preferred node type. However, such versions (one-mode projected networks) inherently present a loss of information, which would most likely result in impaired analysis. Our goal is to provide further knowledge about the structure of bipartite networks and, more importantly, how it affects the structural properties of projected networks. First, we show the causality between the degree distributions of bipartite networks and the resulting degree distribution of projected networks. Also, we find that the bipartite degree distributions are not the only feature driving topology formation in projected networks. Thus, we move forward to another network structural feature: small cycles. They represent types of clustering in bipartite networks and directly affect the projected network structure. We use empirical and synthetic networks to show that while four-cycles indicate recurrence of links between a pair of nodes in the projections, six-cycles (representation of transitivity) affect clustering levels. Third, we introduce the dynamics of network growth. We use extensive datasets to study the evolution of the structure of scientific collaboration networks. We create a comprehensive mapping of how several network structural properties evolve over time. Finally, we propose a generative model for bipartite networks. It is a bipartite extension of a model previously designed for one-mode networks. We show that the model can assess the fundamental bipartite structural properties, reproducing both bipartite and projected network features.

197 Effect of individual heterogeneity on emergent population characteristics

Giorgia Vattiato

University of Canterbury

Timetable: p. 16

There is a growing recognition that, like humans, animals show consistent variation in behaviour among individuals, often described as ‘personality’. This individual heterogeneity can lead to significant behavioural differences between members of the same species that can have important consequences for population-level processes and ecological interactions.However, it is not clear how these behavioural variations contribute to the emergent dynamics of a population and there are critical knowledge gaps around the consequences of this heterogeneity on population responses to disturbance, success of reintroductions, harvest and control, and resource selection.By using a stochastic, spatially-explicit, individual-based model, I am exploring how consistent inter-individual heterogeneity in behaviour, i.e. different ‘personalities’, affects the emergent behaviour of a population, my first case-study being the effect of these ‘personality’ differences on the control of invasive pest-mammals in New Zealand.

198 Mathematical models of cell proliferation in experiments with synchronised cells

Sean Vittadello

Queensland University of Technology

Co-authors: Scott W. McCue, Gency Gunasingh, Nikolas K. Haass, Matthew J. Simpson

Timetable: p. 15

A population of cells is synchronised when the cells are all in the same phase of the cell cycle. In cell proliferation experiments, it is often desirable to avoid synchronisation and have the cells randomly distributed throughout the cell cycle. Here we present new cell proliferation experiments which display cell synchronisation, despite using standard experimental procedures to produce unsynchronised cell populations. The synchronised cells produce oscillations in the subpopulations of cells corresponding to the phases of the cell cycle. In order to identify these subpopulations we utilise fluorescent ubiquitination-based cell cycle indicator, or FUCCI, which allows the visualisation of the G1, eS and S/G2/M cell cycle phases of individual cells. We present new multi-stage mathematical models of cell proliferation which can capture the oscillatory nature of the cell subpopulations when cells are synchronised.

199 Why are our pine trees going red? The problem of Red Needle Cast

Graeme Wake

Natural and Mathematical Sciences, Massey University Auckland, New Zealand

Co-authors: Nari Williams, Rebecca Turner (Scion Research), Penelope Bilton (Proteus), Tony Pleasants (Al Rae Centre, Massey University@Hamilton)

Timetable: p. 18

Red needle cast was first detected in New Zealand in 2008 but it was probably present in forests for a few years before that. It is caused by a strain of phytohthora that results in pine needles turning red and being shed prematurely. A tree without needles does not grow very much. The disease can cause up to forty percent growth loss in a year. The origin of red needle cast in New Zealand has been traced to Oregon in the United States. It was transported here in plant material and on forestry machinery. A simple systems model has been proposed to understand and quantify the onset and epidemiology of red needle cast in radiata pine. This disease is impacting much of the New Zealand forestry estate being driven through the production of self-replicating spores which are dispersed with water. The first model is deterministic, not spatially or age-structured, and initially not including seasonal or environmental effects. This model showed the clear existence of calculable thresholds for disease proliferation and elimination. It is to be used to identify thresholds for infection to spread or to disappear. In this paper the established model which previously had neglected the effects of the environment, is generalised to include seasonal effects. The weather cycle drives the solution to produce in some cases quite different long-term outcomes, depending on the external parameters. The system is now non-autonomous, with weather imposed, almost yearly periodicity. Coexisting stable long-term solutions are also then driven to exhibit this periodicity. Supported by MBIE contract No. C04X1305 Healthy Trees, Healthy Future Enabling Technologies programme.

200 Bayesian model selection in epidemiology

James Walker
University of Adelaide
Timetable: p. 13

The ability to effectively mitigate the spread of diseases is a constant challenge for public health authorities. A first step is to understand how the disease spreads; specifically, information about transmission rates, latent periods and infectious periods are important aspects of understanding disease dynamics and making predictions. In practice, at times, a model is assumed appropriate and its parameters are inferred without validation. In the absence of supporting information model choice should be informed by the data, rather than convention. In this talk I present a Bayesian method based on efficient Importance Sampling for state space models. This method allows exact Bayesian model selection to be performed, with estimates of uncertainty, in cases where the likelihood function is intractable. A simulation study using this method is presented to determine scenarios in epidemiology in which one can effectively distinguish the model that generated the data.

201 Bayesian inference and information criteria for selection of reaction-diffusion models of collective cell behaviour

David Warne
Queensland University of Technnology
Co-authors: Ruth E. Baker, and Matthew J. Simpson
Timetable: p. 12

Spatial models of collective cell behaviour are often based on reaction-diffusion models that describe a population of motile cells that proliferate and die. Various flux and source terms within the reaction-diffusion framework can be used to model different mechanisms. For example, motility may involve random motion (diffusion), adhesion, haptotaxis, chemokinesis and chemotaxis. In many applications, such as wound healing, it is not always clear which motility mechanisms are most important. As a result, heuristic choices are often made without quantitative validation against real data. Those studies that do perform model validation and model comparison typically base decisions on the minimisation of residual errors. Unfortunately, this approach is known to favour over-parameterised models. We demonstrate the utility of Bayesian methods and information criteria for robust model selection that accounts for model complexity, model consistency and residual error. Our approach also provides insights into the current limitations with in vitro cell culture experimental protocols to inform model selection in practice.

202 A multiphase model of fibrous cap formation to investigate the effect of growth factor competition

Michael Watson
University of Sydney
Co-authors: Helen Byrne, Charlie Macaskill, Mary Myerscough
Timetable: p. 22

Atherosclerosis is characterised by the growth of complex, fat-filled plaques in the inner artery wall. In advanced disease, chemical signals stimulate smooth muscle cells (SMCs) to migrate into the plaque and deposit a cap of fibrous tissue at the luminal surface. This cap stops the leakage of thrombogenic plaque material into the bloodstream and protects against the dangerous clotting cascade that causes heart attacks and strokes. Despite the important role of the cap in preventing these grave clinical outcomes, the biochemical mechanisms that regulate cap formation are remarkably poorly understood. In particular, it remains unclear why certain caps develop to be thick and stable, while others become thin and vulnerable to rupture.

We develop a multiphase model to investigate the remodelling of plaque extracellular matrix (ECM) by SMCs in response to diffusible platelet-derived growth factor (PDGF) and transforming growth factor (TGF)-β signals. Consistent with experimental observations, we assume that PDGF promotes SMC chemotaxis, proliferation and ECM degradation. TGF-β, on the other hand, promotes ECM synthesis and potently inhibits the action of PDGF. Considering these competing factors, we study the model behaviour with a range of parameters to assess the likely consequences for plaque stability. Model simulations suggest that TGF-β is crucial to successful cap deposition and that plaque PDGF levels can be a critical determinant of cap thickness. This model represents the first detailed computational study of cap formation in atherosclerotic plaques and future work will investigate the mechanisms of long-term cap erosion that can ultimately lead to plaque rupture.

203 The geometry of excitability in multiple (time-)scale problems

Martin Wechselberger
University of Sydney
Timetable: p. 20

Many physical and biological systems consist of processes that evolve on disparate time- and/or length-scales and the observed dynamics in such systems reflect these multi-scale features as well. It is the interplay of the dynamics on different temporal and spatial scales that creates complicated patterns and rhythms. Transient dynamics observed in neural models of *excitability* are a prime example. This presentation is concerned with such multi-scale dynamics and focuses on the geometric approach to singular perturbation theory pioneered by Neil Fenichel in the 1970s. I will highlight peculiar and counter-intuitive dynamical features observed in such multi-scale models and provide the tools of *geometric singular perturbation theory* to explain them.

204 Magnetic field from a block neodymium magnet

Graham Weir
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Co-authors: George Chisholm, Jerome Levenue, GNS
Timetable: p. 18

Neodymium magnets were independently discovered in 1984 by General Motors and Sumitomo. Today they are the strongest type of permanent magnet commercially available. They are the most widely used industrial magnet, with many applications, including in hard disk drives, cordless tools and magnetic fasteners. We derive a mathematical model of the 3D magnetic field for a neodymium magnet, assuming an idealised block geometry and uniform magnetisation. For each field or observation point, the 3D solution involves twenty four non-dimensional quantities, arising from the eight vertex positions of the magnet, and the three components of the magnetic field. The only unknown in the model is the value of magnetisation, with all other model quantities defined in terms of field position and magnet location.

205 Shape optimization by homogenization of an electromagnetic emission sensor plate

Ursula Weiss
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Timetable: p. 19

In shape optimization, one is interested in the optimal distribution of two materials (of fixed volume) in a given region, called optimal 0-1-design, minimizing a given criterion. In general, this optimization problem does not admit a solution in the set of admissible 0-1-designs. Minimizing sequences of nearly optimal designs have the tendency to generate increasingly finer mixtures of the two materials leading to effective material parameters escaping from the set of admissible 0-1-designs. In order to overcome this problem, the relaxation-by-homogenization procedure relaxes the original problem formulation by introduction of a new admissible set of designs including the possible limits of the minimizing sequences by means of composite designs.

We investigate the problem of shape optimization by homogenization in the conductivity setting in the context of EME (electromagnetic emission) sensoring, where the underlying partial differential equation models the electric potential in the time-harmonic setting. We extend existing works by considering the complex-valued (as opposed to real-valued) material parameter input reflecting permittivity and conductivity of the material, which leads to several complications.

206 Topology-dependent density optima for efficient simultaneous network exploration

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Timetable: p. 17

From the foraging strategies of large organisms, to T-cells hunting pathogens, to proteins examining strands of DNA, carefully optimised search processes are a phenomenon that pervades throughout nature at many scales. Often these search processes do not proceed in isolation, but instead many instances proceed in parallel, competing for space and resources. In this talk I shall discuss optimisation of search processes on networked topologies where the searchers interact with each other through competition for space. Taking the simple exclusion process as the fundamental model for spatial interactions, I consider search strategies that seek to minimise the average cover time for individuals that search in parallel. We will see that the optimal strategy is to implement parallel searching at an optimal density of searchers that depends heavily on the given network topology, and that the optimal density can be well predicted by the spectral gap of the network. These results are verified over a broad class of networks, as well as real-world transport networks such as the London tube network. I will conclude by considering an asymmetric search process that reveals unexpected changes in efficiency between classes of networks.

207 Particle approximation of forward-backward stochastic differential equations

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Timetable: p. 21

Forward-backward stochastic differential equations reformulate second order semilinear hyperbolic PDEs, and are closely related to optimal control. These problems consist of a forward SDE driving a backward SDE, which respectively explore the phase space of the PDE and return its solution. In this talk we present a rigorously justified numerical algorithm that solves forward-backward SDEs by constructing a discrete Markov chain of samples of the forward process. We show that this algorithm out-performs existing numerical methods such as empirical regression techniques, especially in settings that are high-dimensional.

208 Estimation of reactivation frequency of latent HIV and the impact of fluctuating frequencies

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Timetable: p. 13

The most effective treatment currently taken by HIV patients is anti-retroviral therapy (ART), which is currently a lifelong treatment as it cannot completely eliminate the latent viral reservoir. Interruption of ART may incur viral recrudescence. However, the frequency at which latent virus reactivates after ART interruption is poorly understood. In this talk, I will discuss two methods used to estimate the reactivation frequency. One method determines the average frequency of reactivation by using the experimental data on the time of first detecting viral reactivation after ART treatment interruption. Another method is to calculate the frequency of reactivation using experimental data from multiple consecutive reactivations by looking at the ratios of different clone types in a patient. I will use results from analysis of real data sets to show that the reactivation frequency estimated using only the first reactivation event is usually lower than that using multiple events. By using stochastic models to simulate the viral reactivation under different types of non-constant frequencies, and comparing them to the case of constant reactivation frequency in the behaviours of survival curves and time delays between consecutive reactivations, I will show that fluctuating frequencies may result in a significantly later occurrence for the first reactivation, but more frequent reactivation for the subsequent events, compared with the steady case. This work will provide new insights into the design of treatments to slow down viral reactivation.

209 Singularly-perturbed linear-quadratic zero-sum stochastic differential games

James Yang
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Timetable: p. 12

In this talk, we discuss a class of a zero-sum linear-quadratic games, in which the state dynamics are governed by singularly-perturbed stochastic differential equations. Our interests lie in the asymptotic properties of the equilibrium and value of this stochastic differential game. We approach this problem by considering the associated Riccati equation of indefinite nature and reformulate it as a classical and deterministic singular perturbation problem. As a result, Tikhonov's Theorem can be applied. Finally, we give some intuition to the limiting results and draw connections with a decoupled pair of reduced-order zero-sum stochastic optimal control problems.

210 Reduced dynamics for the Kuramoto-Sakaguchi Model Through Collective Coordinates

Wenqi Yue

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Timetable: p. 13

The Kuramoto-Sakaguchi Model is a common model that describes the interactions of ensembles of coupled oscillators, which has a wide range application in many different natural and artificial systems. It is an extension of the paradigmatic Kuramoto model including the effect of a phase offset. The model exhibits intriguing dynamical behaviour such as multi-stability, chimera states, and chaos. We attempt to arrive at a reduced description of the model through collective coordinates. This method has been successfully applied to the standard Kuramoto model capturing partial synchronization, standing waves as well as the transition between different dynamic regimes. The additional complexity of the phase offset in the Kuramoto-Sakaguchi model requires a modification of the collective coordinate approach, by including the non-entrained oscillators. We present analytical results and corroborate them with numerical simulations.

211 Multivariate transitions detection method: Applications to geological boundaries analysis

Ayham Zaitouny

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Timetable: p. 13

Transitions detection methods are used to locate tipping points in signals in various applications. In addition to the important applications of detecting transition points in time series of dynamical systems, such detection algorithms can also be used for non-temporal signals such as image analysis and spatial data. In this research, we introduce a new transitions detection approach based on recurrence plot and quadrant scan methodologies. The key motive of proposing this approach is its applicability to multivariate data. This advantage over other methods, that can be applied to univariate data only, is that it enables dimensionality reduction of the problem by integrating the multivariate data into a single profile. Additionally, this proposed method is computationally cheap and fast. To demonstrate the performance and versatile utilisation of the method, we implement it on spatial data from geological applications for the purpose of assigning lithological boundaries. We test the algorithm using examples from mineral exploration bore-holes and a deep offshore gas exploration well.

212 Transport plans with domain constraints

Zhou Zhou
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Timetable: p. 20

Let Ω be one of $X^{N1}, C[0,1], D[0,1]$: product of Polish spaces, space of continuous functions from $[0,1]$ to $\mathbb{R}^d$, and space of RCLL (right-continuous with left limits) functions from $[0,1]$ to $\mathbb{R}^d$, respectively. We first consider the existence of a probability measure P on Ω such that P has the given marginals α and β and its disintegration P_x must be in some fixed $\Gamma(x) \subset kP(\Omega)$, where $kP(\Omega)$ is the set of probability measures on Ω. The main application we have in mind is the martingale optimal transport problem in mathematical finance when the martingales are assumed to have bounded volatility/quadratic variation. We show that such probability measure exists if and only if the α average of the so-called G-expectation of bounded continuous functions with respect to the measures in Γ is less than their β average. As a byproduct, we get a necessary and sufficient condition for the Skorokhod embedding for bounded stopping times. Second, we consider the optimal transport problem with constraints and obtain the Kantorovich duality. A corollary of this result is a monotonicity principle which gives us a geometric way of identifying the optimizer.

213 An alternative form used to calibrate the Heston model

Song-Ping Zhu
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Co-authors: Xin-Jiang He
Timetable: p. 21

In this talk, we present an alternative form of the Heston model that preserves an essential advantage of the Heston model, its analytic tractability, by imposing the necessary and sufficient conditions for the existence of a solution in affine form, while it is in a different form so that it offers certain advantages in parameter determination. To demonstrate this, we conducted some empirical studies, exploring if this new form does have certain advantages over the original version under certain market conditions.

214 The Cauchy problem for functional differential equations

Bruce van Brunt
Massey University, Palmerston North
Timetable: p. 19

We study the Cauchy problem

$$\begin{aligned} \frac{dy}{dx}(x) &= f(x, y(x), y(g(x))) \\ y(0) &= 0, \end{aligned}$$

where f and g are known functions. This problem involves a functional differential equation owing to the nonlocal term $y(g(x))$. The qualitative features of solutions depends strongly on the nature of g near the initial value. Generically, these problems have an infinite number of solutions for the advanced case when $|g(x)| > |x|$ near 0. In 1985, however, McNabb and Fradkin showed that the assumption of analyticity, however, leads to uniqueness. Building on this work, we review the progress on this paper since 1985.

5 Registered Conference Delegates

Name	Affiliation
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Ruth Baker	University of Oxford
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Fareeda Begum	University of Canterbury
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