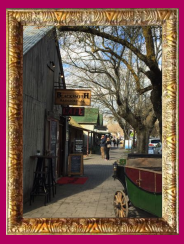
ANZIAM 2017









53rd Meeting
5-9 February, 2017
Hahndorf, South Australia

The abstracts of the talks in this handbook were provided individually by the authors. Only minor typographical changes have been made by the editors. The opinions, findings, conclusions and recommendations in this book are those of the individual authors.

We thank the organisers of the ANZIAM 2016 conference for providing their LaTeX template files.

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1 Conference Details and History

1.1 Organising Committee

- Yvonne Stokes (University of Adelaide) — Director & SIAM representative
- Barry Cox (University of Adelaide) — Treasurer
- Edward Green (University of Adelaide) — Secretary
- Bronwyn Hajek (University of South Australia)
- Michael Haythorpe (Flinders University)
- Hayden Tronnolone (University of Adelaide) — Webmaster

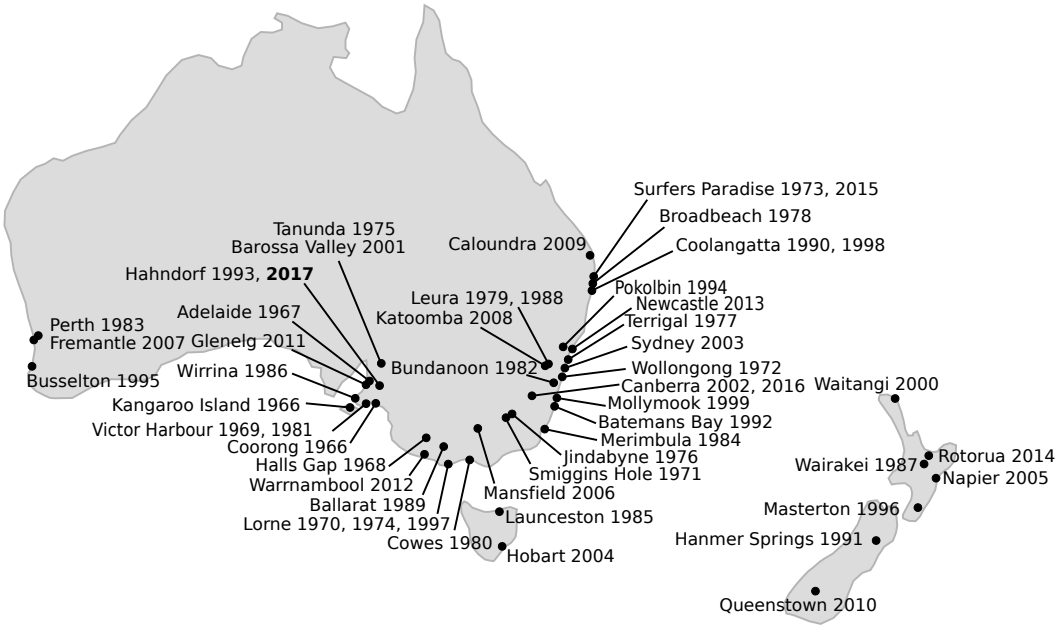
1.2 Invited Speakers Committee

- Mary Myerscough (University of Sydney) — Chair
- Gary Froyland (University of New South Wales)
- John Hearn (Royal Melbourne Institute of Technology)
- Markus Hegland (Australian National University)
- Roslyn Hickson (IBM Research)
- Alex James (University of Canterbury)
- Mark McGuinness (Victoria University of Wellington)
- Michael Small (University of Western Australia)
- Yvonne Stokes (University of Adelaide)

1.3 Invited Speakers

- Frank de Hoog (CSIRO) — 2016 ANZIAM Medallist
- Hans De Sterck (Monash University)
- Claire Postlethwaite (University of Auckland)
- Joshua Ross (University of Adelaide) — 2016 Michell Medalist
- Meinolf Sellmann (IBM Research)
- Maria Vlasiou (Eindhoven University)
- Martine Woolf (Geoscience Australia)
- Jonathan Wylie (City University of Hong Kong)
- Special Guest: John Ockendon (University of Oxford)

1.4 Past Conference Locations



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

1.5 The T.M. Cherry Student Prize

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

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

1.6 The Cherry Ripe Prize

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

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

1.7 The J.H. Michell Medal

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

1999	Harvinder Sidhu	UNSW
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

1.8 The E.O. Tuck Medal

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

2013	Shaun Hendy	VUW and Callaghan Innovation
	Geoffry Mercer	ANU
2015	Troy Farrell	QUT

1.9 The ANZIAM Medal

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

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

1.10 The A. F. Pillow Applied Mathematics Top-Up Scholarship

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

2009	Christopher Lustri	QUT
2010	Alex Badran	UoW
2011	Michael Dallaston	QUT
2012	Hayden Tronnolone	U Adelaide
2013	Lisa Mayo	QUT
2014	Audrey Markowskei	Macquarie U
2015	Pouya Baniasadi	Flinders U
2016	Alexander Tam	U Adelaide

1.11 Acknowledgements

The Organising Committee gratefully acknowledges the financial support of the following sponsors.

- University of South Australia
- University of Adelaide
- Flinders University
- Australian Research Council Centre of Excellence for Mathematical and Statistical Frontiers
- COMSOL Multiphysics
- PDE Solutions
- Professor Nalini Joshi's Georgina Sweet Australian Laureate Fellowship

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Shannon Algar
Elizabeth Bradford
Alexander Browning
Nicholas Buttle
Valerie Chopovda
Eamon Conway
Paige Davis
Linda Eitelberg
Megan Farquhar
Nicholas Gale
Alexander Gilbert
Emma Greenbank
Michael Hackney
David Harman
Eric Hester
Hilary Hunt
Md Hamidul Islam
Stuart Johnston
Laura Karantgis
Jack Keeler
Maria Kleshnina
Ashwani Kumar
Tiffany Leung
Ben Luo
Michael Lydeamore
Thomas McCallum
Claire Miller
Liam Morrow
Gene Nakauchi
Katelyn Nolan
Dilan Pathirana
Ignacio Piwonka
Attique Ur Rehman
Konstantinos Sakellariou
Wang Jin
David Warne
Alexander Zarebski

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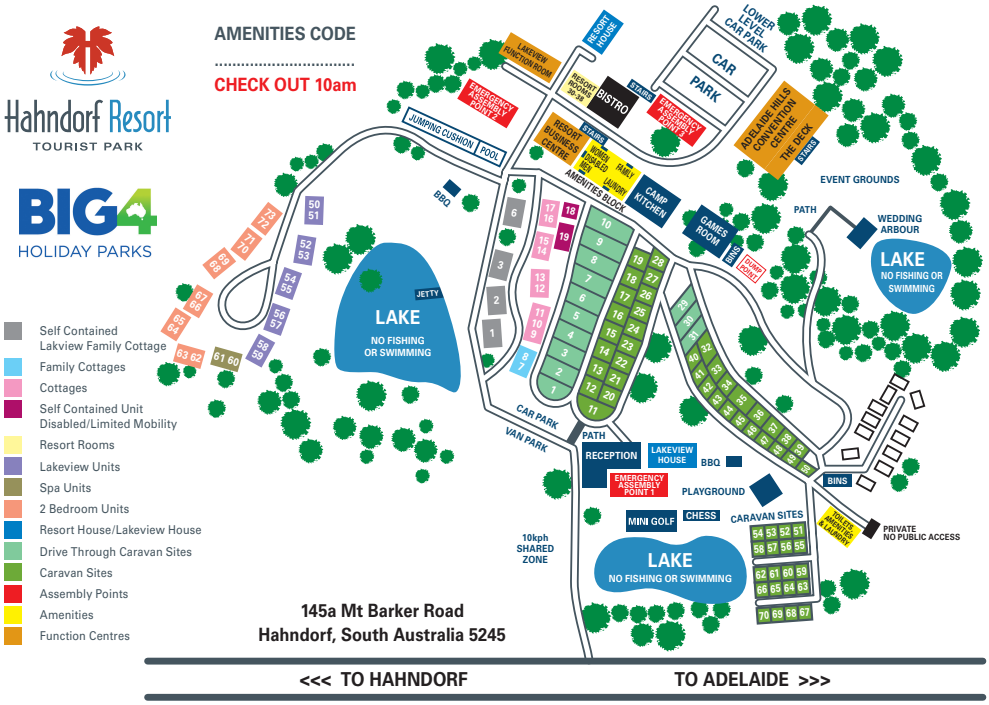
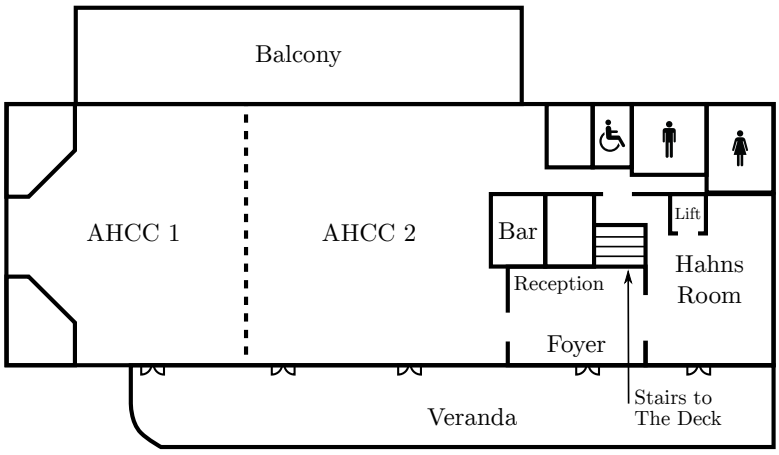
2 Conference Events, Venues and Facilities

2.1 Conference Venue

The conference is being held at the Adelaide Hills Convention Centre (AHCC) in Hahndorf, South Australia. The AHCC is located within the Hahndorf Resort Tourist Park, shown on the map below. This map shows the main AHCC building, the Lakeview Room and the Business Centre, all of which will be used for the conference.

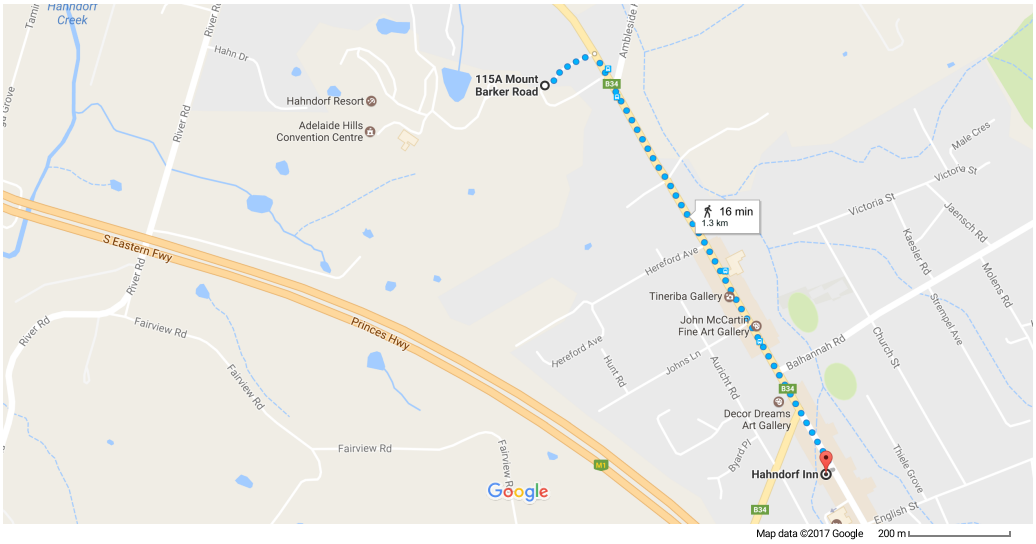


The floor plan for the main AHCC building is shown below, which includes AHCC 1, AHCC 2 and the Hahns Room. The Deck may be reached by the stairs as indicated.



Adelaide Hills Convention Centre

For those wishing to walk between the venue and Hahndorf town centre, there is a track that significantly reduces the length of the walk; see the map below.

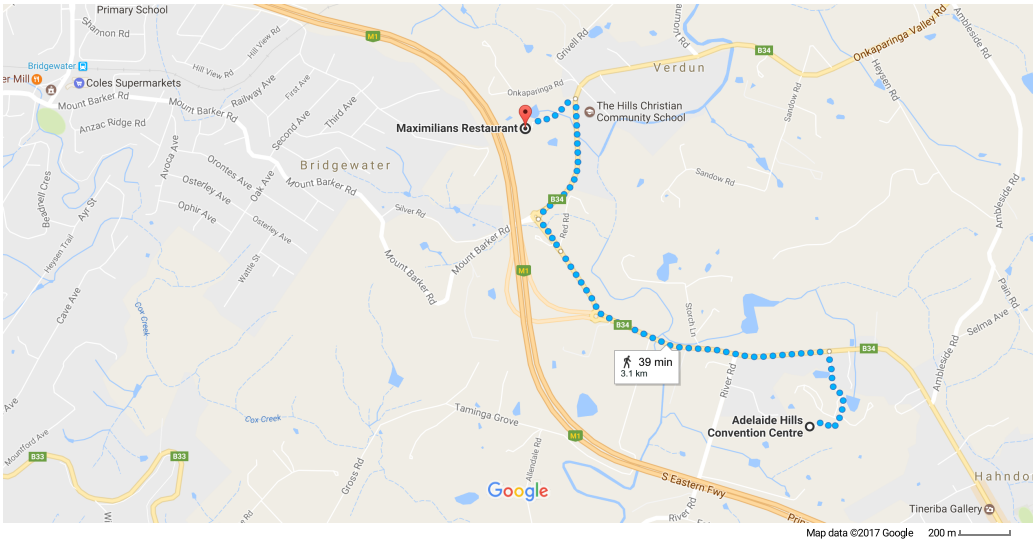


2.2 Conference Reception

The welcome reception will be held from 6–8 pm on Sunday, 5 February on The Deck at the Adelaide Hills Convention Centre. All conference delegates and registered guests are invited.

2.3 Conference Banquet

The Conference Banquet will be held at Maximillian's Restaurant in Verdun on Wednesday, 8 February beginning with pre-dinner drinks from 6:30 pm. Bus transport to and from Maximillian's will be provided to all Banquet ticket holders. Alternatively, it will take approximately 40 minutes to walk or 5–10 minutes to drive between the Adelaide Hills Convention Centre and Maximillian's via the route shown on the map below.



2.4 Refreshment Breaks and Lunches

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

2.5 Internet Access

Delegates will be provided with WiFi internet access throughout the conference. The WiFi network name is 'AHCC-GUEST' and the voucher number is 41959-28358.

2.6 Social Media

ANZIAM attendees are encouraged to use social media from their personal accounts to share ideas from the conference. The conference Twitter hashtag is #ANZIAM2017 and the conference account handle is @ANZIAM2017. 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.

2.7 Invited Lectures and Contributed Talks

All invited lectures will take place in ACHH 1–2. Contributed talks will be held in parallel sessions in AHCC 1, AHCC 2, the Lakeview Room, the Business Centre and the Hahns Room. The duration of each contributed talk will be fifteen minutes with an additional five minutes for questions and room change over.

2.8 Engagement with Japan Virtual Session

An aim of ANZIAM 2017 is to promote engagement with the Japanese Society for Industrial and Applied Mathematics (JSIAM) and we welcome to our conference a significant number of JSIAM members and Japanese students. Their talks and those arising from collaboration between researchers based in Australia or New Zealand and Japan are marked J in the programme. The speakers are listed below along with the page in the timetable on which they are scheduled.

We thank Professor Kenji Kajiwara for his initiative to promote JSIAM–ANZIAM links through conferences such as ANZIAM 2017 and we note that other similar interactions have been organized. For example, the JSIAM conference of 11–14 September 2016 in Japan featured Australian and New Zealand speakers and there will be Japanese participants in the Mathematics in Industry Study Group to be held at the University of South Australia, 13–17 February 2017.

2.9 Student Evening

All students are invited to The Deck from 6:30 pm on Monday, 6 February for the Student Evening. The Evening provides a chance to meet fellow students in an informal setting, with food provided and drinks available for purchase. This event has been organised by the ANZIAM student representative Laura Karantgis.

2.10 Women in Mathematical Sciences Lunch

The Women in Mathematical Sciences Lunch is held at national ANZIAM conferences to promote and celebrate the contribution of women to the mathematical sciences. In 2017 the event will feature the female invited speakers at ANZIAM 2017: Dr Claire Postlethwaite, Associate Professor Maria Vlasiou and Dr Martine Woolf. Conference delegates of any gender are welcome to attend and participate in the discussion, which will be chaired by Associate Professor Lesley Ward. The Lunch will be held in parallel to the main conference lunch on Tuesday, 7 February in The Three Gums Bistro. Tickets are free but must be booked through the conference registration system at maths.adelaide.edu.au/anziam2017/registration.

For information on and some advice from our female invited speakers please see the Question-and-Answer interviews at austms.org.au/ANZIAM2017-QA.

The 2017 Lunch has been organised by Gobert Lee, Giang Nguyen and Yvonne Stokes on behalf of the AustMS Women in Mathematics Special Interest Group (WIMSIG). Information on WIMSIG is available at austms.org.au/Women+in+Mathematics+group. The Lunch is supported by ANZIAM, WIMSIG and the Australian Research Council through Professor Nalini Joshi's Georgina Sweet Australian Laureate Fellowship.

3 Conference Programme

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

Monday Morning

*student talk [J]JSIAM/Japan collaboration

8:00–8:10	Registration — Entry Foyer				
8:10–8:30	Conference Opening, ACHH 1–2				
8:30–9:30	**Invited: Claire Maria Postlethwaite, (The University of Auckland)**, ACHH 1–2 **Title:** Noisy attractors: modelling using heteroclinic and excitable networks (#137, p. 95) *Chair: Hinke Osinga*				
	AHCC 1	AHCC 2	Lakeview Room	Business Centre	Hahns Room
	Chair: Edward Green	*Chair:* Andrew Black	*Chair:* Luke Bennetts	*Chair:* Frances Kuo	*Chair:* Giang Nguyen
9:40–10:00	**Rebecca Turner*** Modelling Animal Navigation (#171, p. 112)	**Thomas Alexander McCallum*** Optimal observation times and the Fisher Information (#111, p. 82)	**Eric William Hester*** New insights on dead water (#69, p. 59)	**Alexander Gilbert*** Applying quasi-Monte Carlo integration to a parametrised elliptic eigenproblem (#56, p. 52)	**Thomas Jungling** Consistency in dynamical systems subject to complex driving signals (#83, p. 67)
10:00–10:20	**Shannon Dee Algar*** The dynamics of selfish flocks (#3, p. 26)	**Alexander Zarebski*** Branching out from exponential models: an inhomogeneous model for early epidemic dynamics (#194, p. 124)	**Jack Samuel Keeler*** A Tale of Two Topographies: Exponential Asymptotics of the forced KdV equation (#88, p. 70)	**Masahisa Tabata[J]** Equivalence of upwind-element choice method and Lagrange–Galerkin method (#163, p. 108)	**Rachael Quill*** A Monte Carlo evaluation of the sensitivity of bivariate Kolmogorov–Smirnov style tests (#139, p. 96)
10:20–10:40	**Ayham Zaitouny** Shadowing Filters for Positioning and Tracking Moving Targets with Application to Flocking Birds (#193, p. 124)	**Peter Ballard*** Intervention to maximise the probability of epidemic fade-out (#8, p. 29)	**Nicholas Buttle*** Three dimensional flow over arbitrary bottom topography (#18, p. 33)	**Ryo Kobayashi[J]*** Verified quadrature for integrand with power-type singularity using partial integral (#93, p. 72)	**John Hearne** The impact on the taxi industry of improved access to Melbourne airport (#67, p. 58)
10:40–11:00	Morning tea on The Deck				

Monday morning continued

*student talk J JSIAM/Japan collaboration

	AHCC 1	AHCC 2	Lakeview Room	Business Centre	Hahns Room
	Chair: Matthew Simpson	*Chair:* Andrew Smith	*Chair:* Andrew Bassom	*Chair:* Melanie Roberts	*Chair:* Petrus van Heijster
11:00–11:20	**Adrianne Jenner*** Can maths help viruses treat cancer? Exploring model parameter space to optimise therapies (#78, p. 64)	**Lewis Mitchell** Your friends are more popular than you. But your best friends are not so bad. (#118, p. 85)	**Sergey Suslov** Flow surprises in a swirling electrolyte (#161, p. 107)	**Elizabeth Bradford*** A numerical look at the inversion of linear matrix pencils (#13, p. 31)	**Ignacio Ortega Piwonka*** Generalized master equations and fractional Fokker–Planck equations from continuous time random walks with arbitrary initial conditions (#130, p. 91)
11:20–11:40	**Marianito Rodrigo** A general reaction–diffusion model for acid-mediated tumour growth (#146, p. 99)	**Katelyn Grace Nolan*** Forecasting Monthly Turnover in Cafes, Restaurants and Takeaways in Australia (#124, p. 88)	**Sharon Stephen** Effect of partial slip on boundary-layer instability (#157, p. 105)	**Geetika Verma** A recursive algorithm for inversion of linear operator pencils on Hilbert space (#176, p. 114)	**James Hannam*** Phase out of the plane (#62, p. 56)
11:40–12:00	**Pantea Pooladvand*** The Diffusion of an Oncolytic Virus within a Solid Tumour (#136, p. 94)	**Linda Miriam Eitelberg*** Predicting Sydney's Temperatures from Chemicals in our Atmosphere (#42, p. 45)	**Andrey Pototsky** Faraday instability and nonlinear patterns in a two-layer liquid films with a free upper surface (#138, p. 95)	**Phil Howlett** The Kadison–Singer Problem; tight frames for Euclidean vector spaces; and Walsh matrices (#74, p. 62)	**Naoyuki Ishimura[J]** Evolution of copulas and its application to the dependence relation between exchange rates (#76, p. 63)
12:10–12:55	**Invited: Jonathan Wylie, (City University of Hong Kong)**, ACHH 1–2 **Title:** Stretching of Viscous Threads (#186, p. 120) *Chair: Yvonne Stokes*				
12:55–1:50	Lunch on The Deck				

Monday afternoon

*student talk [J]JSIAM/Japan collaboration

1:50–2:50	**Invited: Hans De Sterck, (Monash University)**, ACHH 1–2 **Title:** Nonlinearly Preconditioned Optimisation Methods for Data Analytics (#34, p. 41) *Chair: Lewis Mitchell*				
	AHCC 1	AHCC 2	Lakeview Room	Business Centre	Hahns Room
	Chair: Catherine Penington	*Chair:* Robert Cope	*Chair:* Scott McCue	*Chair:* Tony Roberts (UoA)	*Chair:* Martin Wechselberger
3:00–3:20	**Adarsh Kumbhari*** Modelling the effectiveness of therapeutic cancer vaccines: an agent-based approach (#97, p. 75)	**David Harman*** Applying Generalised Polynomial Chaos to Epidemic Models with Individualised Parameter Distributions (#64, p. 57)	**David Matthew Skene*** Wave Reflection from an Overwashed Step (#154, p. 103)	**Henryk Wozniakowski*** Multivariate Approximation for Analytic Functions with Gaussian Kernels (#185, p. 119)	**Konstantinos Sakellariou*** Topology of Ordinal Partition Symbolic Networks: Characterising System Dynamics (#150, p. 101)
3:20–3:40	**Danya Rose*** A more realistic agent based model for the Grandmother Hypothesis (#147, p. 100)	**James Nicholas Walker*** Data augmented MCMC for early characterisation of novel pathogens (#179, p. 116)	**Luke Bennetts** Ice shelf vibrations (#10, p. 30)	**John Wormell*** Fast numerical approximation of intermittent maps (#184, p. 119)	**Robert Nawiekang Otupiri*** Pulsing Dynamics In An All-Fibre Laser With Saturable Absorber (#132, p. 92)
3:40–4:00	**Saber Dini*** Studying stripe formation in zebrafish: stochastic modelling and PDE approximation of a run-and-chase system (#36, p. 42)	**Reena Kapoor** Optimal vaccination scheme for influenza like disease with heterogeneity in infectivity and susceptibility (#85, p. 68)	**Audrey Markowskei*** The changes induced in the far-field pattern upon rounding the corners of a structure (#109, p. 81)	**Kenta Kobayashi[J]*** Error analysis of Lagrange interpolation on tetrahedrons (#92, p. 72)	**Soizic Terrien** Effect of delayed feedback on the dynamics of a self-pulsing laser (#168, p. 110)
4:00–4:20	Afternoon tea on The Deck				

Monday afternoon continued

*student talk J JSIAM/Japan collaboration

4:20–4:40 — **Special Presentation:** Nigel Bean, ACHH 1–2
Title: AMSI Industry Mathematical Sciences Engagement Task Force

	AHCC 1	AHCC 2	Lakeview Room	Business Centre	Hahns Room
	Chair: Benjamin Binder	*Chair:* Adelle Coster	*Chair:* James Murray Hill	*Chair:* Brendan Harding	*Chair:* Larry Forbes
4:50–5:10	**Nicholas Gale*** Correcting Abnormally Developed Retinotopic Maps using Transcranial Magnetic Stimulation (#55, p. 52)	**Peter Kim** Evolution of human longevity, menopause, and sex conflict with grandmothering (#90, p. 71)	**Thomas Dyer*** Wrinkle Structures formed during Graphene Growth (#38, p. 43)	**Megan Elizabeth Farquhar*** Numerical Simulation of Variable-order-in-space fractional diffusion equations (#46, p. 47)	**Gary Froyland** Optimal mixing enhancement (#53, p. 51)
5:10–5:30	**Wang Jin*** Logistic proliferation of cells in scratch assays is delayed (#79, p. 65)	**Sara Li-Yen Loo*** Evolution of male reproductive strategy as payoffs are driven by male-biased sex ratios. (#102, p. 77)	**Robert L. Dewar[J]** Recirculating Flow of an Euler Fluid (#35, p. 41)	**Peter Johnston** A Study of the Method of Fundamental Solutions Applied to the Inverse Problem of Electrocardiology (#81, p. 66)	**Matthew Cassell*** Strong-field magnetoconvection (#21, p. 34)
5:30–5:50	**Claire Miller*** How thick is your skin? The effect of cell behaviour on epidermal tissue structure (#116, p. 84)	**Jody Fisher*** Dynamical analysis of a universal, size-scale free predator prey model using Groebner Bases (#49, p. 48)	**Steve Taylor** Deformation of a large insect screen (#167, p. 110)	**Shin'ich Oishi[J]** Verified numerical computation for stationary problem of Allen–Cahn equation (#128, p. 90)	**Roger J. Hosking** Firing Up El Niño (El Niño and its relationship with the South East Asian Aerosol Plume) (#73, p. 61)
6:30	ANZIAM Student Evening on The Deck				

Tuesday morning

*student talk J JSIAM/Japan collaboration

8:30–9:30	**Invited: Joshua Ross, (The University of Adelaide)**, ACHH 1–2 **Title:** Mathematical problems in pandemic response (#148, p. 100) *Chair: Nigel Bean*				
	AHCC 1	AHCC 2	Lakeview Room	Business Centre	Hahns Room
	Chair: Bronwyn Hajek	*Chair:* Joshua Ross	*Chair:* Graeme Charles Hocking	*Chair:* Jerzy Filar	*Chair:* John Hearne
9:40–10:00	**Alexander Tam*** Nonlinear diffusion as a model mechanism for pattern formation in yeast biofilms (#164, p. 108)	**Jonathan Eade*** An ODE model for the transmission of the disease Nosema ceranae in honey bee colonies with demographic structure (#39, p. 43)	**Patrick Hassard*** A BEM formulation for doubly-periodic two-dimensional Stokes flow with pressure boundary conditions (#66, p. 58)	**Ajini Galapitage*** Optimal scheduling of trains through junctions using connected driver advice systems (#54, p. 51)	**Ali Tirdad** Modelling the Surge Beds in the Emergency Department of a Hospital by Markov Decision Process and Queueing Theory (#169, p. 111)
10:00–10:20	**Paige Nicole Davis*** Absolute instabilities of travelling wave solutions in a Keller–Segel model (#32, p. 40)	**Tiffany Ngo Nam Leung*** Out-of-phase epidemics in a model of infectious disease transmission with immune boosting and cross-immunity (#100, p. 76)	**Christopher Green** The effect of surface tension on steadily translating bubbles in an unbounded Hele-Shaw cell (#59, p. 54)	**Amie Albrecht** Energy-efficient train control: the two-train separation problem on level track (#2, p. 25)	**Ashwani Kumar*** Optimising Patient Flow and Throughput in a Surgical Suite (#96, p. 74)
10:20–10:40	**Ryusei Yoshimine[J]*** Mathematical Model of True Slime Mould Tube Network and Its Simulation (#192, p. 123)	**Michael Lydeamore*** Developing a model for the transmission of Group A Streptococcus (#106, p. 79)	**Christopher Lustri** Bubble Selection in a Hele-Shaw Cell using Stokes' Phenomenon (#105, p. 79)	**Sue Ann Chen** Characterising the performance of rooftop solar panels: A data-driven perspective (#22, p. 35)	**Debora Cristina Correa** Investigating the role of random walks on music networks (#29, p. 38)
10:40–11:00	Morning tea on The Deck				

Tuesday morning continued

*student talk J JSIAM/Japan collaboration

	AHCC 1	AHCC 2	Lakeview Room	Business Centre	Hahns Room
	Chair: Robert Marangell	*Chair:* Peter Kim	*Chair:* Mark Nelson	*Chair:* Ryan Loxton	*Chair:* Eduardo G. Altmann
11:00–11:20	**Hilary Hunt*** Spatial modelling of calcium signals in heart cells (#75, p. 62)	**Paul Allen Roberts** Resistance is futile: Predictive modelling of a novel anti-adhesion bacterial therapy (#144, p. 98)	**Gene Nakauchi*** A simple geometric flow model for fire propagation (#121, p. 87)	**Jerzy Filar** Hospital's Instability Wedge (#48, p. 48)	**Carlo Laing** Chimeras in networks with purely local coupling (#98, p. 75)
11:20–11:40	**Bronwyn Hajek** Calcium waves on the surface of amphibian eggs (#61, p. 55)	**Catheryn Gray*** Getting Ready to Jump: Being in the right place at the right time (#58, p. 53)	**Harvinder Sidhu** Phase Change Material: The future of firefighting suits? (#152, p. 102)	**John Boland** Probabilistic Forecasting of Solar Radiation (#12, p. 30)	**Valeriia Chopovda*** The Caledonian symmetric four-body problem: a Schubart-like family of periodic orbits and its stability (#24, p. 36)
11:40–12:00	**Tatsuya Yamaguchi[J]*** Biologically inspired dynamical frequency separation technique (#188, p. 121)	**David James Warne*** Multilevel Monte Carlo for likelihood-free Bayesian inference of rate parameters for stochastic models of biochemical reactions (#180, p. 116)	**Melanie Roberts** Bushfire characteristics and the ember risk of a property. (#142, p. 97)	**Maryam Alavi** Microenvironment population estimation using Markov model and land-use information at high spatial resolution (#1, p. 25)	**Attique Ur Rehman*** Coupled Orbital and Thermal Evolution of Major Uranian Satellites (#173, p. 113)
12:10–12:40	**Invited: John Ockendon, (University of Oxford)**, ACHH 1–2 **Title:** Industrial Mathematics and Wave Propagation (#127, p. 90) *Chair: Troy Farrell*				

	Tuesday afternoon and evening
12:40–1:40	Lunch on The Deck Women in Mathematical Sciences Lunch in **The Three Gums Bistro**
1:40–7:30	Free time
7:30–9:30	ANZIAM AGM, AHCC 1
9:30–11:30	ANZIAM Executive Meeting, AHCC 1

Wednesday morning

*student talk [J]JSIAM/Japan collaboration

8:30–9:30	**Invited: Maria Vlasiou, (Eindhoven University of Technology)**, ACHH 1–2 **Title:** Error bounds and approximations for heavy-tailed stochastic systems (#177, p. 115) *Chair: Peter Gerrard Taylor*				
	AHCC 1	AHCC 2	Lakeview Room	Business Centre	Hahns Room
	Chair: Alys Rachel Clark	*Chair:* Michael Small	*Chair:* Stanley Miklavcic	*Chair:* Barry Cox	*Chair:* Amie Albrecht
9:40–10:00	**Md Hamidul Islam*** Insights from a novel PDE model of early atherosclerosis (#77, p. 64)	**Martin Wechselberger** Neural Excitability and Singular Bifurcations (#182, p. 117)	**Graeme Charles Hocking** Withdrawal from a stratified fluid in a porous medium. (#72, p. 61)	**Takahiro Yano[J]*** Control of a robot acting autonomously using a mathematical model of the action of a unicellular organism (#191, p. 122)	**Peter Gerrard Taylor** How much does dynamic scheduling improve queueing performance? (#166, p. 109)
10:00–10:20	**Hugh Ford*** PDE Models of Cytotoxin Biomagnification in Inflammation: Applications to Atherosclerosis and Infection (#52, p. 50)	**Petrus van Heijster** Localized patterns in a three-component FitzHugh–Nagumo model via an action functional (#174, p. 113)	**Laura Karantgis*** Modelling rainfall induced landslides with a combined analytical and computational approach (#86, p. 69)	**Yasumasa Nishiura** How geometric constraints affect the 3D morphology of di-block copolymer[J] (#123, p. 88)	**Vanessa Glenny*** A methodology for predictive topic modelling (#57, p. 53)
10:20–10:40	**Ishraq Uddin*** Multiphase modelling of atherosclerotic plaque growth (#172, p. 112)	**Robert Marangell** Absolute Instabilities in a Chemotaxis Model (#108, p. 80)	**Xin An*** Optical dispersive shock waves in defocusing colloidal media (#6, p. 28)	**Eamon Conway*** Scan rate dependent ion transport through nanopores (#27, p. 37)	**Maria Kleshnina*** Evolutionary Games Under Incompetence: A New Approach to Adaptation Dynamics (#91, p. 71)
10:40–11:00	Morning tea on The Deck				

Wednesday morning continued

*student talk J JSIAM/Japan collaboration

	AHCC 1	AHCC 2	Lakeview Room	Business Centre	Hahns Room
	Chair: Mary Myerscough	*Chair:* Graeme Wake	*Chair:* Duncan Farrow	*Chair:* Judith Bunder	*Chair:* Silvio Tarca
11:00–11:20	**Dilan Pathirana*** Modelling the effect of treatments for Coarctation of the Aorta on blood flow (#134, p. 93)	**Alexander Paul Browning*** Estimating parameters in a discrete model of cell proliferation assays (#15, p. 32)	**Emma Greenbank*** Modelling Steaming Surtseyan Ejecta I (#60, p. 55)	**Naoya Yamanaka[J]** Verified Algorithm for the Gamma Function using Double Exponential Formula (#189, p. 121)	**Song-Ping Zhu** On the pricing of European options with discrete dividend payments (#196, p. 126)
11:20–11:40	**Alys Rachel Clark** Modelling the interactions between the uterine blood vessels and the placenta in pregnancy (#26, p. 37)	**Kazushige Endo[J]*** Asymptotic behavior of stochastic cellular automata with conserved quantities (#43, p. 45)	**Mark Joseph McGuinness** Modelling Steaming Surtseyan Ejecta II (#114, p. 83)	**Pablo Soto-Quiros*** New Computational Methods for Compression and Recovery of Random Signals (#156, p. 104)	**Abdulrahman Nasser Alossaimy*** Network Communities identify Sectors within Financial Markets — A Scale-Free Network Model (#4, p. 27)
11:40–12:00	**Satoshi Yamada[J]*** Mathematical Model on Change in Oxygen Concentration in Blood Vessels (#187, p. 120)	**Stuart Johnston*** A new and accurate continuum description of moving fronts (#82, p. 66)	**Liam Morrow*** Melting crystals in space (#119, p. 86)	**Sunyoung Bu** A stiffness detection technique for selecting adaptive step size in the parareal algorithm (#16, p. 32)	**Angus Hamilton Lewis*** Modelling electricity prices with regime switching models (#101, p. 77)
12:00–12:20	**Pouya Baniasadi*** Can we assemble DNA without oversimplifying our mathematical models? (#9, p. 29)	**Tertius Ralph*** Hard-core interactions in one-dimensional velocity jump models (#140, p. 96)	**Brendan Florio** Mathematical modelling of phase change in nanowires (#50, p. 49)	**Joe O'Leary*** Satellite orbit prediction using structure preserving geometric numerical integrators (#126, p. 89)	**Ben Luo*** Nonlinear Time Series Analysis using an Ordinal Partition Metric (#104, p. 78)
12:20–12:40	**Pengxing Cao** Artemisinin-induced parasite growth retardation in blood-stage Plasmodium falciparum infection (#19, p. 33)	**Satoru Koda[J]*** Statistical gene analysis to develop techniques of artificial heterosis in plants (#94, p. 73)	**Minsup Lee[J]*** Well-posedness for the Keller–Segel system coupled with the Navier–Stokes fluid in the critical Besov spaces (#99, p. 76)	**Yuuka Yanagisawa[J]** Fast verification method for solving matrix equations by QR factorization (#190, p. 122)	**Bernd Krauskopf** Why be afraid of state-dependent delays? (#95, p. 73)
12:40–1:40	Lunch on The Deck				

Wednesday afternoon

*student talk J JSIAM/Japan collaboration

1:50–2:50	**Invited: Meinolf Sellmann, (General Electric)**, ACHH 1–2 **Title:** Intelligent Decisions (#151, p. 102) *Chair: Phil Howlett*				
	AHCC 1	AHCC 2	Lakeview Room	Business Centre	Hahns Room
	Chair: Peter Johnston	*Chair:* John Boland	*Chair:* Timothy Marchant	*Chair:* Garry Newsam	*Chair:* Thomas Jungling
3:00–3:20	**Barbara Johnston** Quantifying the effect of input uncertainty in a cardiac tissue model (#80, p. 65)	**Andrew Black** Stochastic models of multi-level Darwinian populations (#11, p. 30)	**Kenji Kajiwara**[J] Construction and Simulation of Discrete Integrable Model for Soil Infiltration Problem (#84, p. 68)	**Elliot Joseph Carr** Using volume averaging to correct the boundary conditions in macroscale models of multilayer diffusion (#20, p. 34)	**Andrew Keane** The importance of being chaotic: Bifurcations in an El Niño model (#87, p. 69)
3:20–3:40	**Catherine Penington** Quantifying rates of cell migration and cell proliferation in coculture barrier assays reveals how skin and melanoma cells interact during melanoma spreading and invasion (#135, p. 94)	**Andrew Smith** A Stochastic Environment for Metapopulation Models (#155, p. 104)	**Philip Broadbridge**[J] Exact 3D solutions for unsaturated water content through a web of plant roots (#14, p. 31)	**Hyeongki Park**[J]* Explicit Formulas of Area-preserving Deformation of Plane Curves in the Equicentroaffine Geometry (#133, p. 93)	**Cris Hasan*** Mixed-mode oscillations, slow manifolds and twin canards in chemical systems (#65, p. 57)
3:40–4:00	**Hayden Tronnolone** Flighty Dimorphin Yeast Arrangers (#170, p. 111)	**Rebecca Chisholm** The effects of asymptomatic carriers on the transmission of bacterial pathogens (#23, p. 35)	**Michael Greg Watson** A Pore-Scale Investigation of Low-Salinity Waterflooding in Uniformly Wetted Porous Media (#181, p. 117)	**Jaroslav Chovan*** Reconstruction of a time dependent source term from a single boundary measurement in Maxwell's equations with a nonlinear generalized Ohm's law (#25, p. 36)	**Russell Andrew Edson*** Lyapunov exponents measure chaos in the Kuramoto–Sivashinsky dynamics (#41, p. 44)
4:00–4:20	Afternoon tea on The Deck				

Wednesday afternoon continued

*student talk [J]JSIAM/Japan collaboration

	AHCC 1	AHCC 2	Lakeview Room	Business Centre	Hahns Room
	Chair: Deborah Cromer	*Chair:* Michael Meehan	*Chair:* Elliot Joseph Carr	*Chair:* Trent Mattner	*Chair:* Bernd Krauskopf
4:20–4:40	**James McCaw** A dynamic stress model explains the delayed drug effect in artemisinin treatment of *Plasmodium falciparum* malaria (#112, p. 82)	**Robert Cope** Characterizing influenza epidemiology using GP surveillance data (#28, p. 38)	**Yvonne Stokes** Fibre drawing with temperature dependent surface tension (#158, p. 105)	**Winston Sweatman** Mathematics-in-Industry Study Groups in Australia, New Zealand and Japan (#162, p. 107)	**Judith Bunder** Modeling emergent behaviour of a random walker in a multiscale domain (#17, p. 32)
4:40–5:00	**David Samuel Khoury** Modelling host control of malaria by slowing parasite development (#89, p. 70)	**Robert Moss** Bayesian forecasting of seasonal influenza: putting prior knowledge into the prior (#120, p. 86)	**Brendan Harding** Understanding fluid flow in microfluidic sorters (#63, p. 56)	**James Murray Hill** Newton–de Broglie's second law (#71, p. 60)	**Tony Roberts** Modelling emergent macroscale dynamics in long thin domains of microscale heterogeneity (#145, p. 99)
5:00–5:20	**Graeme Wake** Using a Bio-Control Agent on a Crop Pest: A Case Study (#178, p. 115)	**Mick Roberts** Nobody expects a flu epidemic (#143, p. 98)	**Scott McCue** What is the sound of a ship wave? (#113, p. 83)	**Darren Engwirda** Locally-orthogonal unstructured grid-generation for general circulation modelling on the sphere (#44, p. 46)	**Hinke Osinga** Intrinsic excitability and the role of saddle slow manifolds (#131, p. 92)
5:20–5:40	**Mark Nelson** Snacking on sludge (#122, p. 87)	**Dirk Nuyens** Parameter identification using QMC in an insulin-glucose model with uncertain data (#125, p. 89)	**Shaun Hendy** Dynamics of Janus Particles in a Uniform Flow (#68, p. 59)	**Eduardo G. Altmann** Efficient sampling of rare trajectories in dynamical systems (#5, p. 27)	**Holger Dullin** A new twisting somersault — 513XD (#37, p. 42)
6:30–10:30	Conference Banquet at Maximillian's Restaurant				

Thursday morning

*student talk [J]JSIAM/Japan collaboration

8:30–9:30	**Invited: Martine Woolf, (Geoscience Australia)**, ACHH 1–2 **Title:** When Nature Comes Knocking — Disasters, Risk and Resilience (#183, p. 118) *Chair: Roslyn Hickson*				
	AHCC 1	AHCC 2	Lakeview Room	Business Centre	Hahns Room
	Chair: Hans De Sterck	*Chair:* Rebecca Chisholm	*Chair:* Hayden Tronnolone	*Chair:* Mark Joseph McGuinness	*Chair:* Gary Froyland
9:40–10:00	**Robert Scott Anderssen** Assessing Heterosis using Genetic Distance Formulas (#7, p. 28)	**Andrew Rawlinson** Modelling Anxiety and Depression to determine the effect of community stigma around mental health (#141, p. 97)	**Takashi Sakajo[J]** Point Vortex Dynamics on a Toroidal Surface (#149, p. 101)	**Troy Farrell** From bagasse to biofuel — modelling the hydrolysis of hemicellulose (#47, p. 47)	**Andrew Eberhard** Computing high-quality Lagrangian bounds of the stochastic mixed-integer programming problem (#40, p. 44)
10:00–10:20	**Jeremy Sumner** Dimensional reduction for phylogenetic tree models (#160, p. 106)	**Michael Meehan** Coupled, multi-strain epidemic models of drug-resistant pathogens (#115, p. 84)	**Larry Forbes** Turbulence in Pipe Flow (#51, p. 49)	**Tammy Lynch** Modelling fermentation processes in the rumen (#107, p. 80)	**Ryan Loxton** Optimisation Algorithms for Mine Plant Shutdowns (#103, p. 78)
10:20–10:40	**Deborah Cromer** Optimising and understanding new HIV therapies (#31, p. 39)	**Roslyn Hickson** Dengue fever in Taiwan: An IBM Health Corps adventure (#70, p. 60)	**Trent Mattner** Large-eddy simulations using the stretched-vortex subgrid model with artificial damping (#110, p. 81)		**Silvio Tarca** Dispatchability of Wind Power with Battery Energy Storage in South Australia (#165, p. 109)
10:40–11:00	Morning tea on The Deck				

	Thursday morning and afternoon *student talk J JSIAM/Japan collaboration				
	AHCC 1	AHCC 2	Lakeview Room	Business Centre	Hahns Room
	Chair: Mick Roberts	*Chair:* Maryam Alavi	*Chair:* Shaun Hendy	*Chair:* Winston Sweatman	*Chair:*
11:00–11:20	**Matthew Simpson** Quantifying the role of burn temperature, burn duration and skin thickness in an in vivo animal skin model of heat conduction (#153, p. 103)	**Fabricio Oliveira** Efficiently Solving Stochastic Mixed-Integer Problems combining Gauss–Siedel and Penalty-Based methods (#129, p. 91)	**Tony Miller** A probabilistic interpretation of the von Mises yield criterion (#117, p. 85)	**Geoff Vasil** Introducing Dedalus: A new, efficient, accurate, and flexible toolkit for computational fluid dynamics (#175, p. 114)	
11:20–11:40	**Collin Zheng*** Mathematical model for checkpoint blockades in cancer immunotherapy (#195, p. 125)	**Mark Fackrell** Modelling Queueing Networks as Cooperative Games (#45, p. 46)	**Barry Cox** Regular seven-membered loops with arbitrary join angle (#30, p. 39)	**Peter Samuel Straka** Max-sum stable distributions and Extremes of Intermittent Events (#159, p. 106)	
11:50–12:50	**Invited: Frank de Hoog, (CSIRO)**, ACHH 1–2 **Title:** Mathematics for Industry; a Non-Stationary Process (#33, p. 40) *Chair: Philip Broadbridge*				
12:50–1:00	Closing remarks, ACHH 1–2				
1:00–2:00	Lunch on The Deck				

4 Conference Abstracts

1 Microenvironment population estimation using Markov model and land-use information at high spatial resolution

Maryam Alavi
The University of Auckland
Timetable: p. 17

In the context of human exposure to air pollution, a microenvironment (ME) is defined as space where the air pollutant level at some specified time scale is uniform or has constant statistical properties. Population exposure to short-term episodes of high pollutant concentrations has become of interest in environmental epidemiological studies due to its impact on public health. However, at such high temporal and spatial resolution, population estimation over a fine mesh of small-sized MEs is required. Mobile and wireless devices yield information about when and where people are present; however, the number of device sensors is limited due to budget and feasibility constraints. In this talk, we present a stochastic model that estimates the population at a finite number of MEs by simulation according to the information provided by a limited number of device sensors and the MEs land-use information. In this framework, the population at each ME is quantified as the sum of individuals whose movements are modelled by a Markov process. We investigate the sensitivity of the proposed approach to the number of MEs compared to the number of device sensors, the prior estimate of the transition matrices, and the prior estimate of the rate at which individuals enter or exit the total system.

2 Energy-efficient train control: the two-train separation problem on level track

Amie Albrecht
University of South Australia
Co-authors: Phil Howlett, Peter Pudney, Xuan Vu and Peng Zhou
Timetable: p. 16

The classic single-train control problem is find the optimal driving strategy that minimises the energy required to drive a train from one station to the next within a given time. This problem has been solved for practical applications, including general track of hundreds of kilometres with continuously varying gradients and speed limits.

In contrast, there has been almost no work done on the optimal control of a fleet of trains on a corridor. This problem is challenging due to safe separation constraints; one common requirement for two trains travelling in the same direction is that they must be separated by at least one section of track. Thus, for trains travelling sufficiently close together, safety requirements may mean that at least one of the trains is unable to follow a speed profile that minimises energy use.

One way to ensure safe separation between two trains is to specify supplementary section clearance times which define, for each section, the latest allowed exit time for the leading train and the earliest possible entry time for the following train. Our recent work finds driving strategies for a leading train

and a following train so that total energy consumption is minimised and so that both trains finish on time while adhering to the separation constraints imposed by a given feasible set of designated section clearance times. We also show that adjusting the section clearance times can substantially change the total energy required by the trains.

In this talk we demonstrate a procedure to find an optimal set of designated intermediate section clearance times and the corresponding speed profiles for each train that minimise the total energy consumed. We lay the groundwork for ultimately constructing energy-efficient timetables for a fleet of trains travelling in the same direction on a corridor.

3 The dynamics of selfish flocks*

Shannon Dee Algar
The University Of Western Australia
Timetable: p. 12

Many well-known models of collective motion focus on the asymptotic behaviour of groups but it is the transient motion that produces some of the most interesting dynamics such as those seen just prior to a murmuration of starlings roosting for the evening. These models tend to incorporate some form of intrinsic cooperation and mimicking of neighbours eventually concluding that a global order can emerge for appropriate choice of parameters. We highlight several situations where dynamic behaviour is subdued or differs significantly in the absence of predators leading one to consider that self interest, and not cooperation, is the key driver for the pattern formation. We build on the notion of a selfish herd, first proposed by W. D. Hamilton in 1971, using an interaction network defined by the Delaunay triangulation. The dynamics is assured with the inclusion of inertial social forces that aim to minimise the dual Voronoi cell, which is used as a proxy for each individual's positional danger. Numerical simulations of self propelled particles illustrate that purely selfish motives can lead to realistic and seemingly cooperative motion. Behaviours such as aggregation, swarming and flocking are all observed. Transitions between these behaviours are dependent on a delicate interplay between the relative strengths of the inertial and damping components.

4 Network Communities identify Sectors within Financial Markets — A Scale-Free Network Model*

Abdulrahman Nasser Alossaimy
The University Of Western Australia
Timetable: p. 20

A model financial network was constructed using a scale-free network model. The standard preferential attachment algorithm, the conditional sectoral preferential attachment algorithm and a selection probability were merged into an algorithm to construct a model financial market with scale free properties. The conditional sectoral preferential attachment algorithm is that a new node will be connected to node i depends on the degree k_i of node i multiplying the sector of node i. The properties and features of financial scale free network were investigated. The community structure of financial scale free network was detected utilizing three different methods to demonstrate the capacity of financial scale free network to detect the sectors of financial market. We infer that the vertices of sector connected together in one community, especially the largest one, and the number of dominant communities, which were dominated by a sector, was high when the probability biased towards the conditional sectoral preferential attachment. This demonstrates the potential for complex network methodologies to meaningfully detect the sectors of a financial market through their network community structure.

5 Efficient sampling of rare trajectories in dynamical systems

Eduardo G. Altmann
University of Sydney
Timetable: p. 22

Rare trajectories of dynamical systems are crucial in many problems. For instance, extreme events are often responsible for more economical impact than the cumulative impact of all typical events. The complexity of the (high-dimensional non-linear) dynamical systems generating extreme events pose challenges not only to analytical treatment but also to computational methods that struggle to find and sample the (extremely rare) trajectories of interest. In this talk I will show how importance sampling methods can be applied to chaotic dynamical systems. Our main result is that an efficient method is obtained only when properties of the dynamics are carefully incorporated into the sampling algorithm. For instance, we show that information on the positive Lyapunov exponents of the system has to be included in the proposal step of a Metropolis–Hasting Monte Carlo method in order to achieve a polynomial efficiency of the sampling of open systems (otherwise the efficiency scales exponentially with the survival time of the trajectories).

6 Optical dispersive shock waves in defocusing colloidal media*

Xin An
University of Wollongong
Timetable: p. 19

The propagation of an optical dispersive shock wave, generated from a jump discontinuity in light intensity, in a defocussing colloidal medium is analysed. The equations governing nonlinear light propagation in a colloidal medium consist of a nonlinear Schrödinger equation for the beam and an algebraic equation for the medium response. In the limit of low light intensity, these equations reduce to a perturbed higher order nonlinear Schrödinger equation. Solutions for the leading and trailing edges of the colloidal dispersive shock wave are found using modulation theory. This is done for both the perturbed nonlinear Schrödinger equation and the full colloid equations for arbitrary light intensity. These results are compared with numerical solutions of the colloid equations.

7 Assessing Heterosis using Genetic Distance Formulas

Robert Scott Anderssen
CSIRO
Timetable: p. 23

Various genetic distance (GDist) formulas have been proposed for formalizing and quantifying the concept of genetic difference (GDiff), so that heterosis phenotypes, for different choices of parents that are crossed, can be compared quantitatively. Biologically, GDist formulas, such as that of Jaccard, Nei and Nei and Li, are defined in terms of the proportional presences, in the paternal and maternal parents, of trigger point regions (TPRs) assumed to be driving the associated genetics, such as transposable elements in promoters. However, such formulas do not allow the relative importance biologically of the proportional presences to be taken into account. Here, a parametric formula is proposed, analyzed and validated, where the value of the parameter can be chosen to take account of the perceived relative biological performance of the individual proportional presences. The validation is based on the fact that, for particular choices of the parameter, some of the traditional formulas, such as Jaccard and Nei, are recovered which in turn highlight how such formulas are giving different weightings to the proportional presences.

This is joint work with Ming-Bo Wang of CSIRO Agriculture and Food, and Mark Westcott of Data61.

8 Intervention to maximise the probability of epidemic fade-out*

Peter Ballard
The University of Adelaide
Timetable: p. 12

Epidemic fade-out refers to the situation in which an infection dies out after the first wave of an outbreak. We use the Markovian SIR-with-demography model, and assume that we have the ability to implement control measures which reduce the transmission rate. We wish to determine a policy for applying these control measures, in order to maximise the probability of epidemic fade-out. The optimal policy can be found using a Markov Decision Process, but this becomes impractical for large population sizes. We present a simpler technique which specifies an almost optimal policy, which can still substantially increase the probability of epidemic fade-out. We also consider the application of this technique to other models.

9 Can we assemble DNA without oversimplifying our mathematical models?*

Pouya Baniasadi
Flinders University
Timetable: p. 20

The ground-breaking discovery of DNA structure in the 1950s opened up an unparalleled opportunity for multidisciplinary efforts, such as the multi-billion dollar Human Genome Project, to come together in a quest for understanding 'life'.

Mathematics has proved to be vital in many such efforts, especially the DNA Sequencing Problem; aligning and merging fragments of DNA to construct the original sequence. The importance and mathematical beauty in the DNA-Sequencing Problem stem from its close ties to fundamental problems in Combinatorial Optimization and Complexity Theory. In particular, the basic idealized DNA-sequencing Problem can be easily embedded in a Traveling Salesman Problem (TSP) which, arguably, is the most widely studied problem in combinatorial optimization. However due to the computational difficulty of TSP these mathematical links are not exploited. Instead simplified models that compromise solution quality are widely used to assemble DNA.

Recent advances in the quality of TSP heuristic algorithms provide a compelling opportunity for a new approach to DNA assembly. Our project is aimed at exploring this opportunity for developing TSP-based models and algorithms to advance our mathematical understanding of the DNA-Sequencing Problem as well as offering practical solutions to DNA assembly problems.

10 Ice shelf vibrations

Luke Bennetts
University of Adelaide
Co-authors: Michael Meylan, Roger Hosking and Olga Sergienko
Timetable: p. 14

I'll present a hydroelastic model of vibrations of a floating ice shelf, and show how poles/zeros in the analytic continuation of a particular physical quantity into the complex plane explains the relationship between normal modes of a closed system and near resonances of an open system.

11 Stochastic models of multi-level Darwinian populations

Andrew Black
The University of Adelaide
Timetable: p. 21

Many evolutionary systems are multi-level. This means that we can identify a Darwinian population at one level, but also a second at a higher level composed of the lower level entities. An important example of this phenomena is during the evolutionary transition from unicellular to multicellular organisms. In this talk I will discuss some recent work on developing stochastic models of these systems, in particular looking at the ecological conditions needed to create these two interacting populations and how these in turn affect their evolutionary properties.

12 Probabilistic Forecasting of Solar Radiation

John Boland
University of South Australia
Timetable: p. 17

With the growth in use of solar energy utilisation in the electricity grid, not only domestic, but increasingly with solar farms, robust short term forecasting of the resource is needed. Short term means at the time scales of the electricity market — sub-hourly. In Boland and Soubdhan (2015), it was shown that hourly, and also sub hourly, solar radiation data displayed an autoregressive conditional heteroscedastic (ARCH) attribute. This means that the variance of solar radiation time series varies over time but in a stochastic manner. Recent work (Grantham et al 2016) shows that there is also a systematic variation in variance, with higher variance in summer, and also in the middle of the day. Thus both approaches identify one aspect of the change in variance with time, but without dealing with the other. This paper describes methods to merge the two. Preliminary investigations have identified a likely pathway, and preliminary testing looks very promising. It is more complicated than might have

been originally thought but it follows a precise algorithm. It has been tested at two sites and appears to perform well.

13 A numerical look at the inversion of linear matrix pencils*

Elizabeth Bradford
University of South Australia
Timetable: p. 13

Complex phenomena can often be described by systems of equations. If the system consists of a finite number of linear equations then it can be represented as a matrix equation $A(s)x(s) = b(s)$ where s is an unknown small parameter. Because the matrices $A(s)$ and $b(s)$ come from physical data they may not be precise. The aim is to understand how small changes within these matrices affect the solution $x(s)$. I focus on problems where a small perturbation in the data causes a dramatic change in the solution. In particular I consider the case where the system matrix takes the form of a linear matrix pencil $A(s) = A_0 + sA_1$ which is singular in the unperturbed state ($s = 0$), but is invertible when perturbed. In this talk I will describe a Matlab algorithm that can be used to calculate the coefficients of the Laurent expansion in powers of s on some set $0 < |s| < r$ for the inverse matrix $A(s)^1$ and thereby understand the behaviour of $x(s) = A(s)^1 b(s)$.

14 Exact 3D solutions for unsaturated water content through a web of plant roots[J]

Philip Broadbridge
La Trobe University
Timetable: p. 21

The Darcy–Buckingham continuum formulation of soil water content leads to a highly nonlinear diffusion-convection equation. In the continuum model, a web of plant roots leads to a sink term. In horticultural crops, the sink strength is an increasing function of water content, and convex at high water content. For the past 50 years, exact solutions have been produced only after approximating by a linear model, often misrepresented as a nonlinear model. A feasible nonlinear model is given here, for which a class of exact solutions is constructed.

15 Estimating parameters in a discrete model of cell proliferation assays*

Alexander Paul Browning
Queensland University of Technology
Timetable: p. 20

Cell proliferation assays are widely used to quantify the rate at which a population of cells grows over time. This knowledge is important in many applications, including tissue engineering and drug design. In this presentation we describe a novel lattice-free model of a cell proliferation assay that incorporates cell movement, cell proliferation and cell-to-cell crowding. We then explore how this model can be parameterised to a new experimental data set using approximate Bayesian computation.

16 A stiffness detection technique for selecting adaptive step size in the parareal algorithm

Sunyoung Bu
Hongik University
Timetable: p. 20

A technique is introduced to select an adaptive step size in parareal algorithm for solving stiff initial value problems. For this, we propose criterions to detect stiffness of a given system and its solutions so that the time step size can be chosen according to the extent of stiffness. Numerical experiments demonstrate the theoretical results.

17 Modeling emergent behaviour of a random walker in a multiscale domain

Judith Bunder
The University of Adelaide
Timetable: p. 22

Many physical systems are well described on domains which are relatively large in some directions but relatively thin in other directions. In this scenario we are often interested in the emergent behaviour over the large dimensions, and not the fine detail of the thin dimensions. For practical mathematical modelling we require efficient and accurate methodologies for reducing the dimension of the original system and extracting the emergent dynamics. However, common mathematical approximations require the ratio of the large to thin dimensions to be unphysically infinite. I discuss a new mathematical approximation which analyses the dynamics at one arbitrary cross-section of the domain with a rigorous multivariate Taylor series, with the union of all cross-sections describing the dynamics across the large domain. Advantages of this methodology are that the ratio of the large to thin dimensions need not be

infinite and the error of the modelling is quantified. The methodology is presented using the example of a random walker, constrained to walk in one of three directions on a large two dimensional domain.

18 Three dimensional flow over arbitrary bottom topography*

Nicholas Buttle

Queensland University of Technology

Timetable: p. 12

We consider the problem of free surface flow past an arbitrary bottom topography in three dimensions, concentrating on the shape of the wave pattern that forms on the surface of the fluid. The problem is reformulated using a boundary integral method and discretised to produce a linear system of algebraic equations. The Jacobian of this system is dense due to integrals being evaluated over the entire free surface. To overcome the computational difficulty and large memory requirements, a Jacobian-free Newton Krylov method is utilised. Using a block banded approximation of the Jacobian from the linearised system as a preconditioner for the JFNK scheme, we find significant reductions to computational time and memory required for generating numerical solutions. These improvements also allow for a larger number of mesh points over the free surface and the bottom topography. Free surface waves due to several bottom topographies are able to be generated due to the arbitrary definition of the bottom surface in the problem formulation. We present some examples and point out features of the wave patterns that are common to ship waves.

19 Artemisinin-induced parasite growth retardation in blood-stage Plasmodium falciparum infection

Pengxing Cao

The University of Melbourne

Co-authors: Nectarios Klonis, Sophie Zaloumis, David S. Khoury, Deborah Cromer, Miles P. Davenport, Leann Tilley, Julie A. Simpson and James M. McCaw

Timetable: p. 20

Falciparum malaria is a major parasitic disease causing widespread morbidity and mortality across South East Asia and Africa. Artemisinin — one of the most effective and widely-used antimalarials that has been responsible for helping reduce the burden of malaria by 60% over the past decade — has recently been found to induce growth retardation of blood-stage Plasmodium falciparum parasites. Importantly, by prolonging the parasite life-cycle by up to a few hours, such retardation effects may explain one of the ways in which P. falciparum has evolved in the face of drug-induced selective pressure. To date, no model has been designed to quantify the growth retardation effect and assess the influence of this emerging property on in vivo parasite killing. Here we introduce a mechanistic model of parasite growth from the ring to trophozoite stage of the parasite's life-cycle to consider drug-induced growth retardation. By incorporating a sub-model of the accumulation of an RNA-binding dye, we fit the

model to available in vitro data, allowing us to quantify the dependence of the growth retardation on drug concentration. The model provides a platform to propose experimentally-testable mechanisms of growth retardation. We show that a drug-induced delay in growth may significantly influence the outcome of in vivo (i.e. clinical) drug regimens, demonstrating the important role that growth retardation may play in the design of optimal dosing regimens.

20 Using volume averaging to correct the boundary conditions in macroscale models of multilayer diffusion

Elliot Joseph Carr

Queensland University of Technology

Timetable: p. 21

Numerous important scientific problems involve modelling using PDEs with coefficients that vary spatially over a small length-scale (microscale). To avoid direct numerical simulation, a common approach is to use a macroscale model, where the coefficients are replaced with smooth/constant values. This talk focusses on the form of the boundary conditions (BCs) used in such models. Specifically, I will focus on the one-dimensional multilayer diffusion problem, a simple prototype problem where an analytical solution is available. For given microscale BCs (e.g., Dirichlet, Neumann, Robin, etc.) corrected macroscale BCs are derived using the method of volume averaging. Numerical results demonstrate that the macroscale field computed using the corrected BCs more accurately captures the averaged microscale field and leads to a reconstructed microscale field that is in excellent agreement with the actual microscale field.

21 Strong-field magnetoconvection*

Matthew Cassell

The University of Sydney

Timetable: p. 15

Very strong magnetic fields exist throughout the universe. Sunspots are one such example. These localised regions of reduced temperature on the solar surface were first observed in the 8th century BC. Spots arise due to complex interactions between temperature, convection and magnetism. Whilst the dynamics have been examined since the 1930s, this interplay is still poorly understood. Examining the quantitative behaviour of the governing equations presents a significant challenge. We use a new scaling approach and apply state-of-the-art computational methods to numerically solve the governing equations. We reproduce dynamics consistent with the theory and demonstrate the importance of non-linear corrections to the system.

22 Characterising the performance of rooftop solar panels: A data-driven perspective

Sue Ann Chen
IBM Research Australia
Co-authors: Arun Vishwanath and Saket Sathe
Timetable: p. 16

Rising electricity prices alongside an increasing level of consumer awareness of the detrimental impact of fossil fuels have sparked numerous initiatives in generating and consuming renewable energy resources in various nations around the world. Additionally, consumers conscious about their carbon footprint have begun to take a proactive role in recent years by not only wishing to be in control of how efficiently they generate and consume energy. Several households and organisations around the world have embraced the use of solar panels as a means for generating clean and sustainable energy to meet the building's energy demand. Analysing data gathered from these panels can reveal valuable insights into their operating performance. In this talk, we describe a data-driven framework to shed light on the performance of solar panels and demonstrate its general applicability using four different power generation data sets obtained from panels situated in diverse geographies. We show how results from the framework can be used to infer the operational efficiency of solar panels for home owners and facility managers of commercial organisations alike.

23 The effects of asymptomatic carriers on the transmission of bacterial pathogens

Rebecca Chisholm
The University of Melbourne
Co-authors: Nic Geard
Timetable: p. 21

Asymptomatic carriage is the contraction of an infectious disease without displaying symptoms. Many successful human pathogens cause mostly asymptomatic carriage and infrequent symptomatic infection including *Streptococcus pyogenes* and *Staphylococcus aureus*, which is suggestive of asymptomatic carriers playing an important role in the spread of these infectious diseases. However, if carriers are less contagious than symptomatically-infected hosts, how do these mostly commensal organisms that cause disease infrequently have sustained and sometimes complex patterns of transmission? We addressed this question with a mathematical model describing the transmission dynamics of a general bacterial pathogen that infects hosts asymptomatically before progressing to symptomatic infection. Our analysis of a one and two-strain version of the model provides insights into the conditions which allow such pathogens to persist in host populations, maintain strain diversity and generate different patterns of disease prevalence and transmission.

24 The Caledonian symmetric four-body problem: a Schubart-like family of periodic orbits and its stability*

Valeriia Chopovda
Massey University
Co-authors: Winston Sweatman and Robert McKibbin
Timetable: p. 17

The research includes the investigation of the gravitational four-body problem which arises from interactions involving binary stars. It involves studies of the dynamics of small-body systems and finding periodic orbits, and subsequently analysing their stability. Such systems perform an interplay motion similar to that of the periodic three-body orbit discovered by Schubart in 1956. One of the challenges of the problem is the necessity of using regularisation algorithms in order to avoid the singularities when there is a possibility of close encounters between stars.

We consider the special case of the planar four-body problem where the system is symmetric and consists of four equal masses. The bodies are initially collinear with transverse velocities. We use a Heggie-type regularisation on the interbody distances along with time transformation. Starting from a planar Schubart-like orbit found by Sweatman in 2014, we generate a family of related symmetric periodic orbits using the angular momentum of the system as a parameter. The stability of the family of orbits is studied using linear stability analysis and nonlinear simulation.

25 Reconstruction of a time dependent source term from a single boundary measurement in Maxwell's equations with a nonlinear generalized Ohm's law*

Jaroslav Chovan
University of Ghent
Timetable: p. 21

Hyperbolic Maxwell's equation with an unknown time dependent source term is investigated. We consider a nonlinear generalized Ohm's law in our model. The source term is reconstructed from a single boundary measurement over the part of the boundary. Existence of a solution is proved via Rothe's method. In the case of a regular solution we provide a uniqueness proof as well. To support our theoretical results a numerical experiment is provided.

26 Modelling the interactions between the uterine blood vessels and the placenta in pregnancy

Alys Rachel Clark
The University of Auckland
Co-authors: Rojan Saghian, Sally Collins and Joanna James
Timetable: p. 20

In pregnancy, the mother's blood supplies all the nutrients that the developing fetus needs via the placenta. To do this specialised placental cells invade into, and transform, the uterine blood vessels to allow an increasing flow of uterine blood through pregnancy. Abnormal transformation of uterine blood vessels is associated with several pregnancy complications. However, it is not clear to what extent current ultrasound measurements of the uterine arteries reflect this transformation. Here we present a model of the interaction between uterine blood flow and the placental bed through pregnancy. Our model predicts that 'high resistance metrics' in uterine artery ultrasound only reflect abnormal cell-mediated arterial transformation if there are also structural abnormalities elsewhere in the uterine vasculature, which supports increasing clinical and experimental evidence that the entire uterine vasculature must be considered to determine the impact of abnormal arterial transformation on pregnancy health.

27 Scan rate dependent ion transport through nanopores*

Eamon Conway
Queensland University of Technology
Co-authors: Troy Farrell and Steven Psaltis
Timetable: p. 19

The transport of ionic species through a nanopore is important in determining the underlying behaviour of electrolytes on the nanoscale; the understanding of which has important applications in the development of biomolecular sensors and nanofluidic diodes. Experimentally, the effect of a nanopore on ionic transport is characterised by current-voltage curves, where current is measured whilst scanning the potential at the working electrode in a triangular wave. This is typically done with a slow scan rate. However, recent experimental studies on nanopores have shown that faster scan rates cause pinched hysteresis loops in the ionic current between the forwards and backward scan. Current models of the experimental results can only account for this hysteresis in the ionic transport when the simulated scan rate is increased to an experimentally unrealistic value. To determine the underlying mechanisms of the experimentally observed current-voltage curves, we propose a novel extension to the transient Poisson–Nernst–Planck equations by incorporating Butler–Volmer kinetics at the electrodes. In doing so, we are modelling both the faradaic and nonfaradaic processes that contribute to the measured ionic current. This presentation focuses on the key work done to date.

28 Characterizing influenza epidemiology using GP surveillance data

Robert Cope
The University of Adelaide
Timetable: p. 22

Understanding seasonal circulation of influenza is critical for effective healthcare resource allocation, prediction of future seasons, and early detection of anomalous seasons. However, influenza is difficult to confirm without expensive PCR testing, so data is limited, and many aspects of influenza epidemiology are poorly understood. We use a new dataset of confirmed weekly influenza cases from a subset of GPs (in the ASPREN network) to model seasonal influenza dynamics in Sydney, Australia. We apply state of the art Bayesian model selection and parameter estimation methods, to draw insights into population level dynamics of influenza using stochastic epidemic models. We include a hierarchical observation process, informed by high-quality denominator data. We highlight the impact of assumptions around parameter values such as R_0 and the duration individuals remain immune, and note that the results of many previous studies can be contextualised around their chosen assumptions.

29 Investigating the role of random walks on music networks

Debora Cristina Correa
The University Of Western Australia
Timetable: p. 16

Markov models have been extensively used as computational creativity models for music composition. By applying random walks algorithms on music networks (where the adjacency matrix captures the note transition dynamics of a music score), one can generate new compositions that hopefully will preserve important properties of the original music while including some level of variety in the new compositions. In this work we use recurrence quantification analysis on the top of recurrent plots to investigate the extent to which the random walks models are capable of preserving the dynamics of the repeated patterns present in the original song. We show that some modifications to the traditional algorithms (as, for instance, avoiding preferences to hubs notes) may be necessary in order to better preserve the temporal structure of the song.

30 Regular seven-membered loops with arbitrary join angle

Barry Cox
The University of Adelaide
Timetable: p. 24

The problem of ring molecules come up in a number of contexts in physical chemistry. Perhaps the simplest example of a seven-membered ring is cycloheptane C_7H_{14}, which is a molecule where the carbon-carbon bonds form a regular seven-membered loop. However it is possible to envisage more complicated arrangements of proteins chains comprising straight rigid sections linked in a way that enforces the same angles at all of the joins. This work is also applicable in the field of robotics where such loops are termed Bricard linkages. In this talk we present a coordinate system that reduces the problem to four free variables and three constraints. Previously we have presented numerically derived families of solutions for all join angles θ between $\pi/7$ and $5\pi/7$ with the solutions undergoing a major reorganisation at the join angle $\theta = \pi/3$. The focus of this talk will be the nature of the solutions available at $\theta = \pi/3$ and the relation (via polynomial homotopy continuation) to the families of real solutions available for other angles.

31 Optimising and understanding new HIV therapies

Deborah Cromer
University of New South Wales
Co-authors: Mykola Pinkevych, Thomas Rasmussen, Sharon Lewin, Stephen Kent and Miles Davenport
Timetable: p. 23

A major avenue of current HIV research is focused on providing HIV infected subjects with a prolonged period of treatment-free remission. Although current therapies are able to suppress the virus below the levels of detection in most subjects, if treatment is discontinued HIV commonly rebounds within weeks, with associated increases in morbidity. It is assumed that this rebound virus is most likely derived from long-lived latently infected cells, which persist for many years despite effective therapy. Cure is obviously ideal, but recent work has also focused on reducing the size of this 'latent reservoir' to allow for prolonged remission. But what average duration of remission might is useful?

Using a mathematical model of HIV remission and viral reactivation, we estimate the optimal duration of remission we should target to minimise drug exposure over a prolonged period. We also use a stochastic model to predict the proportion of patients who will experience early viral rebound even after such a reduction in their latent reservoir, and the probability that these patients will be able to transmit HIV before their rebound is detected.

We find that to minimise drug exposure over a 5 year period the latent reservoir would have to be decreased sufficiently to allow an average time between reactivation events of around 20 years. This is equivalent to more than a one thousand fold decrease in the size of the latent reservoir and is significantly longer than the one-year remission that is currently being targeted. Even if this prolonged remission were achieved, 5% of patients would still reactivate in the first two years after treatment

interruption purely due to stochastic events. Additionally, over 15% of patients would have a greater than 1 in 50 chance of transmitting the virus before their rebound is detected.

Our modelling shows that while therapies designed to reduce the size of the latent reservoir present a promising avenue of research, prior to widespread implementation of such strategies, the possibilities and consequences of viral reactivation from latency must be adequately considered.

32 Absolute instabilities of travelling wave solutions in a Keller–Segel model*

Paige Nicole Davis
Queensland University of Technology
Timetable: p. 16

In this talk we investigate the spectral stability of travelling wave solutions in a Keller–Segel model of bacterial chemotaxis with a logarithmic chemosensitivity function and a constant, sublinear, and linear consumption rate. Linearising around the travelling wave solutions, we locate the essential and absolute spectrum of the associated linear operators and find that all travelling wave solutions have essential spectrum in the right half plane. However, we show that in the case of constant or sublinear consumption there exists a range of parameters such that the absolute spectrum is contained in the open left half plane and the essential spectrum can thus be weighted into the open left half plane. For the constant and sublinear consumption rate models we also determine critical parameter values for which the absolute spectrum crosses into the right half plane, indicating the onset of an absolute instability of the travelling wave solution. We observe that this crossing always occurs off of the real axis. This work is joint work with Peter van Heijster (QUT) and Robert Marangell (USyd).

33 Mathematics for Industry; a Non-Stationary Process

Frank de Hoog
CSIRO
Timetable: p. 24

This talk sketches some of the developments of modelling of industrial processes that began in the late 1970's in CSIRO's division of Mathematics and Statistics and, whilst it represents only a tiny fraction of industrial mathematics, its evolution is similar to other comparable groups elsewhere.

Although many industrial processes are quite complex, early work focussed on understanding, controlling and improving industrial processes using very simple models. Despite the apparent contradiction between complex processes and simple models, this approach can be spectacularly successful because many manufacturing processes are very robust. In such cases, the phenomena in question is often only weakly coupled to their environments and only a few key non-dimensional parameters dominate. Such

problems are often amenable to simplifying mathematical analysis and approximation techniques and some case studies will be described that demonstrate this.

As computer hardware improved and algorithms were developed for solving partial differential equations, obtaining quantitative solutions for a far broader range of industrial problems became feasible and led to a number of activities associated with developing software using finite elements, smoothed particle hydrodynamics and discrete element methods. This, in addition to the decline of manufacturing and the availability of commercial specialist software have the potential to substantially change the interaction of mathematics with industry. Some case studies will be given to illustrate this.

34 Nonlinearly Preconditioned Optimisation Methods for Data Analytics

Hans De Sterck
Monash University
Timetable: p. 14

In the era of big data, fast parallel optimisation methods are required to analyse data sets of ever-increasing size. In the context of solving linear systems, the technique of preconditioning has been extremely successful, and fast preconditioned conjugate gradient (CG) or GMRES methods have been applied in many areas of science, engineering and technology. I will discuss how the linear preconditioning approach can be generalised to successful nonlinear preconditioning strategies for nonlinear optimisation problems. Nonlinear preconditioning will be considered for the nonlinear CG and GMRES optimisation methods. The techniques will be illustrated for matrix and tensor decomposition problems with applications in data analysis and distributed music recommendation systems.

35 Recirculating Flow of an Euler Fluid[J]

Robert L. Dewar
Australian National University
Co-authors: Naoki Sato
Timetable: p. 15

A new formulation of magnetohydrodynamics (MHD) appropriate to hot, magnetically confined plasmas, has recently been proposed [1] based on Hamilton's Principle of Stationary Action, using the MHD Lagrangian but replacing the local holonomic constraints of ideal MHD that freeze in magnetic flux and entropy with *global* entropy and magnetic helicity [2] invariance enforced using Lagrange multipliers. The resulting Euler–Lagrange equations are the Beltrami equation for the magnetic field and those of compressible isothermal Euler fluid dynamics (the magnetic field being force-free, it is decoupled from the plasma). This leads us to revisit the problem of the Euler fluid in a toroidal domain [3]. We show the only stationary solution valid for arbitrary non-axisymmetric boundaries also obeys a (nonlinear)

Beltrami equation. We discuss a variational principle for deriving such a state, analogous to that for the Taylor-relaxed magnetic field.

[1] R. L. Dewar, *et al., Variational formulation of relaxed and multi-region relaxed magnetohydrodynamics* J. Plasma Phys. **81**, 515810604 (2015)

[2] H. K. Moffatt, *Magnetic relaxation and the Taylor conjecture*, J. Plasma Phys. **81**, 905810608 (2015)

[3] R. Grimshaw, *On steady recirculating flows*, J. Fluid Mech. **39**, 695 (1969)

36 Studying stripe formation in zebrafish: stochastic modelling and PDE approximation of a run-and-chase system*

Saber Dini

The University of Adelaide

Co-authors: Ben Binder and Edward Green

Timetable: p. 14

Run-and-chase interactions between groups or individuals are ubiquitous in the natural world. A common example is predator-prey systems where predators chase the escaping prey. Interestingly, similar interactions can also occur at the cellular level. For example, recent studies suggest that run-and-chase is the underpinning mechanism for the formation of the stripes on the skin of zebrafish. In this talk, I introduce a stochastic model for this process. In addition, by means of linear stability analysis of a PDE approximation of the stochastic model, I consider whether this mechanism alone is capable of producing the stripes.

37 A new twisting somersault — 513XD

Holger Dullin

University of Sydney

Timetable: p. 22

Modelling an athlete as a system of coupled rigid body we derive a time-dependent reduced Euler equation for the dynamics of shape changing bodies. Reconstruction allows to recover the full dynamics in SO(3), and the number of somersaults is decomposed into a geometric phase and a dynamics phase. A kick model is used to approximate the dynamics, and using the insight gained from this we propose a new 10 meter platform twisting somersault dive (FINA code 513XD) that incorporates 5 full twists.

https://www.technologyreview.com/s/603308/mathematicians-create-entirely-new-dive-with-5-twists-and-15-somersaults/

38 Wrinkle Structures formed during Graphene Growth*

Thomas Dyer
University of Wollongong
Timetable: p. 15

The chemical vapor deposition (CVD) method is currently the preferred method for producing high quality monolayers of graphene by growing sheets of graphene on substrates in a controlled, high temperature environment. During the cooling process, the faster thermal contraction of the substrate cause the graphene sheet to form wrinkles. The form of this wrinkled structure will affect the mechanical and electronic properties of the sheet. We model potentially optimal wrinkled structures using a variational approach.

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

Jonathan Eade
The University of Sydney
Timetable: p. 16

We present a mathematical model for the transmission of the disease *Nosema ceranae* through a honey bee colony. *N.ceranae* is a parasite which attacks the midgut of a honey bee, and has been posited as a contributing factor in the honey bee 'colony collapse disorder' which is affecting agricultural sectors worldwide. We formulate and analyse a system of ordinary differential equations, based on standard SIR disease models, that includes important demographic features of the colony. The total colony population is split into hive bees which work within the hive, and forager bees which leave the hive to forage for nectar and pollen. These two populations have different susceptibilities to the infection pathways of *N.ceranae* and so have different transmission terms. Results show that the disease can remain endemic in honey bee colonies without collapsing them, consistent with empirical evidence, and that colonies already under stress from other factors are in fact more resistant to infection by the disease.

40 Computing high-quality Lagrangian bounds of the stochastic mixed-integer programming problem

Andrew Eberhard
RMIT University
Co-authors: N. Boland, J. Christiansen, B. Dandurand, J. Linderoth, J. Luedtke and F. Oliveira
Timetable: p. 23

A new primal-dual decomposition method is presented, based on an integration of the Progressive Hedging (PH) and the Frank–Wolfe (FW) methods, referred to as FW–PH, for computing high-quality Lagrangian bounds of the stochastic mixed-integer programming problem (SMIP). The deterministic equivalent (DE) form of the SMIP typically lacks convexity due to the assumed integrality restrictions, and since PH is a specialisation of the alternating direction method of multipliers (ADMM), the application of PH to the SMIP is not theoretically supported due to this lack of convexity. Thus, PH applied to the SMIP is understood as a heuristic approach without convergence guarantees, where either cycling or suboptimal convergence is possible. Although Lagrangian bounds may be computed after each PH iteration, these bounds often show limited improvement with increasing number of iterations, and the amount of improvement is highly sensitive to the value of the PH penalty parameter. Motivated by these observations, we modify the PH method so that the generated sequence of Lagrangian bounds is guaranteed to converge to the optimal Lagrangian bound for any positive-valued PH penalty parameter. The new integrated method is shown to be both theoretically supported due to an integration of established theory for ADMM and the FW method, and practically implementable. Numerical experiments demonstrate the improvement of FW–PH over the PH method for computing high-quality Lagrangian bounds.

41 Lyapunov exponents measure chaos in the Kuramoto–Sivashinsky dynamics*

Russell Andrew Edson
The University of Adelaide
Co-authors: Tony Roberts, Judith Bunder and Trent Mattner
Timetable: p. 21

The one-dimensional Kuramoto–Sivashinsky partial differential equation, which models flame front instability and pattern formation on thin fluid films, is an example of a simple nonlinear reaction-diffusion system with spatio-temporally complex dynamics. As the size of the periodic spatial domain for the Kuramoto–Sivashinsky system is made larger, the system exhibits increasingly chaotic behaviour, interspersed with regimes of predictable, periodic behaviour.

The spectrum of Lyapunov exponents for the Kuramoto–Sivashinsky system measures the divergence of nearby trajectories in phase space, and so characterises the chaos. The n most positive Lyapunov exponents are computed by simulating the system with a set of n adjacent initial conditions, and tracking the trajectory separation over time. Viewed across a range of system domain sizes, the computed Lyapunov exponents of the Kuramoto–Sivashinsky system reveal the alternating windows of chaotic and periodic dynamics, and show the general trend of increasing system complexity.

42 Predicting Sydney's Temperatures from Chemicals in our Atmosphere*

Linda Miriam Eitelberg
The University of Newcastle
Co-authors: Lachlan Peter O'Neill
Timetable: p. 13

Research was conducted concerning the correlation between some ozone depleting and greenhouse gases in the Southern Hemisphere and the temperature at Observatory Hill, Sydney Australia, over a 55 year period.

Time Series Analysis was conducted to examine this correlation as well as try to predict the temperature using the chemicals and gases.

Specifically, the research fits ARIMA models to the available data to regress against temperatures. The temperature data is the average daily maximum temperature each year, and the chemical data is either in parts per trillion or parts per billion in dry air. The chemicals of interest were Sulfur Hexauoride, Nitrous Oxide, Carbon Tetrachloride, Trichlorotriuoroethane, Dichlorodiuoromethane and Trichlorouoromethane.

The best ARIMA models were chosen for the temperature data and each of the chemical data based on AIC values, standard deviation of residuals, predictions and other criteria. From here pre-whitening was performed and the cross-correlation function was observed between the temperature data and the chemical data, such that the most significant lags could be observed. This was all used to form a model.

It was found that though an ARIMA model with only temperature was a good predictor, an ARIMA model with lagged chemical information as a regressor produced a better fit. This suggests that chemicals can be successfully used as a predictor for the maximum temperatures in Sydney. It was also found that a model which included lead chemical information provided an even better model. However this would imply that temperature could be used as a predictor for chemicals as well. This is an area that requires further research.

43 Asymptotic behavior of stochastic cellular automata with conserved quantities[J]*

Kazushige Endo
Waseda University
Timetable: p. 20

The goal of this talk is to explain how to analyze asymptotic behavior of stochastic cellular automata with conserved quantities. In particular, we introduce our method to derive 'Fundamental Diagram' (FD) which shows relation between density of conserved quantities and mean flow for asymptotic solution of stochastic cellular automata utilizing max-plus algebra, Cole–Hopf type transformation, reduction relations, and equilibrium equations.

44 Locally-orthogonal unstructured grid-generation for general circulation modelling on the sphere

Darren Engwirda
MIT
Timetable: p. 22

The development of atmospheric and oceanic general circulation models based on unstructured numerical discretisation schemes is an emerging area of research. This trend necessitates the development of accompanying unstructured grid-generation algorithms designed to provide very high-resolution, guaranteed-quality tessellations of spheroidal geometries. In this talk, an algorithm for the generation of non-uniform, locally-orthogonal staggered unstructured spheroidal grids is described. Using a recently developed Frontal-Delaunay refinement technique, a method for the construction of unstructured spheroidal Delaunay triangulations is introduced. A locally-orthogonal polygonal grid, derived from the associated Voronoi diagram, is computed as the staggered dual. The initial staggered Voronoi/Delaunay tessellation is iteratively improved through hill-climbing optimisation techniques — producing grids with very high element quality and smooth grading characteristics, while imposing relatively low computational expense. Results are presented for a selection of uniform and non-uniform spheroidal grids appropriate for high-resolution, multi-scale general circulation modelling on the sphere. Applicability to recent 'mimetic'-type staggered finite-volume numerical discretisation schemes is discussed in detail.

45 Modelling Queueing Networks as Cooperative Games

Mark Fackrell
The University of Melbourne
Co-authors: David Ferguson-Sharp and Victor Choy
Timetable: p. 24

We consider n M/M/c queues working in parallel with different arrival rates and numbers of servers, but with all servers having a common mean service time. The servers are allowed to pool their resources and cooperate. That is, they can form coalitions where the members can serve customers from other members? arrival streams. Each coalition of queues functions as an M/M/c queue where the arrival rate is the sum of the individual members? arrival rates, the number of servers is the sum of the individual numbers of servers, and the mean service time is the common one. We model this cooperative system as a transferable utility game with n players (queues) and characteristic function the mean number in the system (queue plus service). We first consider the case where all individual queues are stable (that is, the mean number in the system is finite), and then the unstable case where some of the queues are unstable but the coalition of all queues is stable. We also consider a similar setup with n M/M/c/c queues where the characteristic function is the mean number of busy servers.

46 Numerical Simulation of Variable-order-in-space fractional diffusion equations*

Megan Elizabeth Farquhar
Queensland University of Technology
Timetable: p. 15

There has been interest in recent years in fractional diffusion equations in models for biological applications, such as transport processes in the heart and brain. The models have traditionally used a single value for the anomalous diffusion index across the whole domain. However, in some applications, certain regions of the domain may exhibit markedly different characteristics from the bulk of the domain, such as in damaged heart tissue following a heart attack. Hence more recently the use of variable-order-in-space diffusion equations has gained popularity for such problems where the anomalous diffusion index can vary spatially. For constant-order fractional Laplacian-based models, the natural numerical implementation deals purely with the sparse matrix representation of the standard (non-fractional) Laplacian by formulating the scheme in terms of matrix-function-vector-products. For variable-order-in-space models, this approach requires modification. We first clarify how to formulate such variable-order models in terms of an appropriate discrete representation. Second, we show how to devise a numerical scheme that retains the desirable sparse matrix characteristics of the constant-order scheme, permitting efficient evaluation using contour integral methods coupled with Krylov subspace iteration. We present numerical results to demonstrate the scheme recovers the expected solutions for previously studied one-dimensional reaction-diffusion problems, before moving on to two-dimensional examples.

47 From bagasse to biofuel — modelling the hydrolysis of hemicellulose

Troy Farrell
Queensland University of Technology
Timetable: p. 23

Acid hydrolysis is a popular pretreatment for removing hemicellulose from lignocelluloses in order to produce a digestible substrate for enzymatic saccharification. Such a process forms the precursor stage for the development of biofuels, for example. In this work, a novel model for the dilute acid hydrolysis of hemicellulose within sugarcane bagasse is presented and calibrated against experimental oligomer profiles. The efficacy of mathematical models as hydrolysis yield predictors and as vehicles for investigating the mechanisms of acid hydrolysis is also examined.

48 Hospital's Instability Wedge

Jerzy Filar
Flinders University
Co-authors: T. Bogomolov and S. Qin
Timetable: p. 17

Like many of Australia's public hospitals Flinders Medical Centre (FMC) frequently operates at, or near, full capacity. Since a hospital's primary mission is to provide an essential public service to the local community a situation where patients in need of admission are either turned away or significantly delayed prior to admission constitutes a system failure. Typically, these failures are a direct consequence of what we refer to as congestion episodes. For the purpose of this contribution a congestion episode is a situation when the number of new patients needing admission is too large and we define the associated "risk" as the probability that the hospital's occupancy exceeds a certain threshold. In this study, based on the analysis of FMC's data, we demonstrate that this measure of risk exhibits a characteristic sensitivity phenomenon that we have named a hospital's instability wedge (IW, for short). In particular, it will be seen that frequently even small changes in the numbers of patients admitted or discharged can dramatically change the risk of exceeding the threshold and thereby of subsequent congestion episodes.

49 Dynamical analysis of a universal, size-scale free predator prey model using Groebner Bases*

Jody Fisher
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Co-authors: Jody C. McKerral, Maria Kleshnina, Jerzy A. Filar, Vladimir Ejov and James G. Mitchell
Timetable: p. 15

We present a universal, size-scale free representation of the Rosenzweig-Macarthur predator-prey model with a Type II functional response. By using the ecological principle of energetic equivalence, we incorporate mass-dependent scaling into model parameters to develop a universal model which is applicable to organisms across 18 orders of magnitude in mass. The model's equilibria, for organisms ranging in size from bacteria to whales, recreate Damuth's classical $-3/4$ size-abundance ecological scaling law. We use Groebner Bases with novel application in ecology to investigate parameter sensitivity and dynamical properties of the model to link baseline ecosystem properties to population stability and potential for species coexistence.

50 Mathematical modelling of phase change in nanowires

Brendan Florio
CSIRO
Co-authors: Tim Myers
Timetable: p. 20

Recent research indicates that in the near future nanowires will be at the forefront of electronics and computing. It has also been shown that they can be utilised in low cost solar cells, high power density batteries, flexible screens, to detect proteins to act as cancer biomarkers and for water filtration. One feature observed in nanoparticles is the depression of the melting point from the bulk value. For example, 1 nm radius gold particles show a decrease of 50% from the bulk melting value. This has implications in nanoelectronics where the load-carrying capacity of nanowires may be limited by the melting point depression.

We use continuum theory to model the melting behaviour of cylindrically symmetric nanowires in a thermal bath. The melting point depression is described by the Gibbs–Thomson equation. This continuum approximation is valid down to approximately 2 nm. The problem is treated semi-analytically by a perturbation expansion in the large Stefan number. The results are compared with similar approaches for spherical nanoparticles. An equivalent solidification problem is also studied.

We found that the melting of a nanowire occurs much slower than the melting of a nanosphere with same radius. This is due to fewer degrees of freedom and the smaller effect of the melting point depression in the cylindrical geometry. The melting and solidification processes are shown to be different due to the release of surface energy from the solid-liquid interface as it decreases in size.

51 Turbulence in Pipe Flow

Larry Forbes
University of Tasmania
Timetable: p. 23

Everyone knows what turbulent fluid flow looks like, and we've all seen examples of it in fast-moving fluids. The flow becomes wild and unstable, and there are three obvious characteristics; it is inherently three-dimensional, time-dependent, and involves strong swirling motion (vorticity). Although turbulence research has been on-going for about 140 years, it remains unclear why fluid flow becomes turbulent at high speeds (Reynolds numbers). It is generally stated that the Navier–Stokes equations of viscous fluid flow are sufficient to describe turbulence, and so investigations start from these equations. Nevertheless, Navier–Stokes theory assumes linear material behaviour, valid for small strain rates in the flow. However, turbulence is characterized precisely by large local strain rates, so that there is a possible epistemological contradiction here. For this reason, we look at a model for fluid flow that allows large strain rates, so that a more general equation than Navier–Stokes theory is obtained. We find that, for flow in a circular pipe, there are indeed critical Reynolds numbers at which the flow becomes unstable due to the formation of very high-dimensional quasi-periodic behaviour. Non-linearity would then

trigger a collapse onto a high-dimensional chaotic attractor. This follows on from some earlier work (in the ANZIAM Journal) and we argue that this possible mechanism for the transition to turbulent flow deserves further careful investigation.

52 PDE Models of Cytotoxin Biomagnification in Inflammation: Applications to Atherosclerosis and Infection*

Hugh Ford

University of Sydney

Co-authors: Mary R. Myerscough

Timetable: p. 19

Infection control comes at a price: inflammation. Inflammation causes tissue damage which, if chronic, unresolved and/or maladapted, underpins inflammatory diseases such as atherosclerosis. Immune cells called professional phagocytes are central to both inflammation resolution and pathogenesis. Whether an inflammatory response is chronic or resolves depends on the balance between apoptotic (anti-inflammatory) or necrotic (pro-inflammatory) phagocyte death. We argue that cytotoxin biomagnification within phagocytes lie at this crux.

Biomagnification is the process whereby substances increase within organisms along successively higher orders of a food chain. Phagocytes enter the inflamed tissue, ingest noxious substances, ingest dead phagocytes and die at the site. Apoptotic phagocytes loaded with accumulated substances are recycled back into the phagocyte population and causes said substances to biomagnify throughout successive generations of phagocytes. Necrosis is induced when indigestible compounds (asthma), pathogen toxins (infection) or biomolecules such as cholesterol (atherosclerosis) bioaccumulate to cytotoxic levels. Once the very phagocytes required to resolve inflammation become necrotic inflammation remains sustained.

We explore this theory using PDE's similar to age-structured models but where the independent variable is the accumulated substance. These equations are non-local in nature yet, under certain assumptions, are analytically tractable. We will outline conditions for inflammation resolution, pathogenesis (persistent necrosis) or 'necrotic catastrophe' (all cells are necrotic). Interestingly, this catastrophe is significantly prevented through proliferation which divides the material in a parent cell between two daughter cells—studied by Hall & Wake (1989). Throughout this study we focus on atherosclerosis (inflamed arteries) and show how macrophages (phagocyte) are distributed by cholesterol (cytotoxic substance).

53 Optimal mixing enhancement

Gary Froyland
University of New South Wales
Timetable: p. 15

I will introduce a general-purpose method for optimising the mixing rate of advective or advective-diffusive fluid flows. An existing velocity field is perturbed in a small neighbourhood to maximize the mixing rate for flows generated by velocity fields in this neighbourhood. The perturbations can easily be constrained to satisfy physical constraints such as volume preservation and the numerical optimization problem is solved by standard linear programming methods. If time permits I will also discuss how to similarly optimize the diffusive terms in advection–diffusion equations to maximally enhance mixing. This is joint work with N. Santitissadeekorn, C. Gonzalez-Tokman, and T. Watson.

54 Optimal scheduling of trains through junctions using connected driver advice systems*

Ajini Galapitage
University of South Australia
Timetable: p. 16

Railways around the world are using driver advice systems to provide drivers with driving advice to help them stay on time and reduce energy use. The use of driver advice systems to keep trains on time has become a key strategy in the UK and elsewhere. By using driving advice systems connected to centralised scheduling systems, train delays can be detected as they happen, and new schedules can be calculated and issued to trains so that additional delays are avoided.

On large congested rail networks with many trains, such as passenger networks in the UK or Sydney or the coal network in the Hunter Valley, it is impossible to schedule the whole rail network at once—the problem is too large. An alternative, more practical approach is to independently optimise key congested sections of the network, such as individual lines or junctions.

The talk will describe a practical junction scheduling system that regulates the progress of trains heading towards a busy junction to ensure smooth traffic flow through the junction. Calculations done on each train predict the earliest possible arrival time at the junction, and the optimal arrival time if there are no conflicts. The central junction scheduling system uses a mathematical program to find a feasible target arrival time for each train so that spacing between trains at the junction meets minimum requirements. Revised target times are transmitted to each train so that the driver advice system on the train can calculate an optimal driving strategy that meets the target arrival time at the junction.

55 Correcting Abnormally Developed Retinotopic Maps using Transcranial Magnetic Stimulation*

Nicholas Gale
The University Of Western Australia
Timetable: p. 15

Topographic maps are sets of point to point connections between brain regions: neighbouring cells in a source region connect to neighbouring cells in a target region. These maps are ubiquitous across the brain and are critical for sensory processing. Their highly structured pattern and development, ubiquity and specialised function make them an important area of study.

One of the most investigated systems for understanding and modelling topographic maps is the mouse visual system. Ganglion cells in the retina project to the superior colliculus. The systems development has two major stages: chemical gradients establish a coarse map then neural activity refines the projection into a precise topographic map.

The ephrin A2A5 mutant mouse strain lacks several genes associated with chemical signalling. It develops abnormally resulting in multiple projections from the ganglion cells. Recent biological studies on this mutant strain have examined the effects of repetitive transcranial magnetic stimulation (rTMS). The studies showed that rTMS can drive re-organisation of the abnormal visual circuitry suggesting that rTMS induces a system level plasticity.

We use a plasticity based neural field theory within a simple model of excitatory neuronal populations to reproduce the biological data and provide a mechanistic explanation for the underlying processes. We aim to contribute to the discussion around whether the rTMS technique may be generalised to correcting abnormally developed neural circuitry in topographic maps.

56 Applying quasi-Monte Carlo integration to a parametrised elliptic eigenproblem*

Alexander Gilbert
University of New South Wales
Timetable: p. 12

In this talk we study an elliptic eigenproblem, with a random coefficient which can be parametrised by infinitely many stochastic parameters. The randomness in the coefficient also results in randomness in the eigenvalues and corresponding eigenfunctions. As such, our quantity of interest will be the expected value, with respect to the stochastic parameters, of the smallest eigenvalue which we formulate as an integral over the infinite-dimensional parameter domain. Our approximation involves three steps: truncating the stochastic dimension, discretising the spatial domain using finite elements and approximating the now finite but still high-dimensional integral.

To approximate the high-dimensional integral we use quasi-Monte Carlo (QMC) methods. These are deterministic or quasi-random quadrature rules that can be proven to be very efficient for the numerical integration of certain classes of high-dimensional functions. QMC methods have previously

been applied to similar elliptic source problems, however the existing framework for a rigorous analysis of the integration error does not cover the eigenvalue problem. We show that the minimal eigenvalue belongs to the spaces required for QMC theory, outline the approximation algorithm and provide numerical results.

57 A methodology for predictive topic modelling*

Vanessa Glenny
The University of Adelaide
Timetable: p. 19

Topic modelling is an area of natural language processing in which text corpora are assumed to have some underlying structure of themes, or 'topics'. In using these topics as a form of dimension reduction, we are able to easily extract information from large amounts of text. While topic modelling and natural language processing as a whole are a common occurrence in fields such as computer science, the predictive capabilities of textual data have not been thoroughly explored. This talk will present a methodology for predictive topic modelling based on text corpora, and compare the effectiveness of different topic modelling approaches for dimension reduction. The method will be applied to problems such as predicting genres of films and plays based on textual features of the scripts, and discovering relinquished pets based on the language used in online advertisements.

58 Getting Ready to Jump: Being in the right place at the right time*

Catheryn Gray
University of New South Wales
Co-authors: Adelle C. F. Coster
Timetable: p. 17

Biological signals are largely carried by biochemical effectors. These are activated by chemical reactions, often phosphorylation. The dynamics of the reactions are affected by the chemical specificity and also the spatial distribution of the key components.

In mammalian cells, one key effector is Akt. This has a major role in signalling networks controlling metabolism, apoptosis and cell development, amongst other things. In this study we develop deterministic compartmental ODE-based models for the translocation of Akt within adipocytes in response to the application of insulin. The presence of Akt at the cell membrane can be measured, and using least-squares optimisation, we have refined our model of Akt dynamics with data obtained from collaborators.

We explore the possible modalities in which the Akt translocation can respond to increasing insulin stimulus and determine the probable location of Akt under different conditions. We find that a "ready

to release" pool of Akt is essential in describing the observations. This is an integral part of the further development of the hybrid mathematical description of Akt action combining both location and phosphorylation.

59 The effect of surface tension on steadily translating bubbles in an unbounded Hele-Shaw cell

Christopher Green

Queensland University of Technology

Co-authors: Christopher J. Lustri and Scott W. McCue

Timetable: p. 16

The Hele-Shaw cell is an experimental apparatus which sandwiches a thin layer of viscous fluid between two close-to-touching parallel planes. In this talk, we will consider the theoretical case of an unbounded Hele-Shaw cell featuring either one or two steadily translating bubbles. Our model shall include the effect of surface tension on the bubble boundaries. The mathematical problem of determining the shape of the bubble boundaries turns out to be a highly non-linear free boundary problem which is amenable to solutions by appealing to a combination of potential theory and conformal mapping techniques.

This addition of surface tension to the bubble boundaries is particularly interesting and plays an important role when finding solutions. With zero surface tension, there is a continuum of bubble speeds for which there are solutions. However, for non-zero surface tension, there is no longer a continuum but instead a discrete, countably infinite family of solutions which exist for each fixed value of the surface tension, with the bubble shapes becoming more exotic as the solution branch number increases. Such problems are dubbed selection problems.

We will present several new numerical solutions to the selection problem for one bubble, and discuss several qualitative results pertaining to this selection mechanism. We will then present some preliminary results to the selection problem involving two bubbles where the separation or interaction of the bubbles in addition to the surface tension now plays an important role in the selection. This is the first time a selection problem has been considered to include more than one bubble.

60 Modelling Steaming Surtseyan Ejecta I*

Emma Greenbank
Victoria University of Wellington
Co-authors: Mark McGuinness and Ian Schipper
Timetable: p. 20

Eruptions through crater lakes or shallow sea water, known as Subaqueous 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 is washed 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 build-up in pressure that is released either by vapour escaping through the pores of the lava or the bomb exploding.

This talk will focus on a highly simplified model of partial differential equations that describe the transient changes in temperature and pressure in Surtseyan ejecta. The model was solved numerically and asymptotically to derive a parametric condition for rupture of the ejecta. I will cover how consistent this criterion for rupture is with both the numerical results and existing field estimates of the permeability of surviving intact ejecta.

In a follow-up talk, my supervisor will describe the improvements that allow us to couple the pressure and temperature in the model. This results in a set of coupled non-linear partial differential equations used to model the ejecta's behaviour.

61 Calcium waves on the surface of amphibian eggs

Bronwyn Hajek
University of South Australia
Co-authors: Philip Broadbridge and Nick Zacker
Timetable: p. 17

When an amphibious egg is fertilised, a wave of calcium ions travels around the egg to help prevent the entry of multiple sperm. This process can be described with a reaction diffusion equation. Using the nonclassical symmetry method, we can construct a solution when the nonlinear source and nonlinear diffusion terms satisfy a particular relationship.

62 Phase out of the plane*

James Hannam
The University of Auckland
Co-authors: Bernd Krauskopf and Hinke Osinga
Timetable: p. 13

Many physical systems feature stable oscillations. Such systems are often modelled by ordinary differential equations, such that the stable oscillation is represented by an attracting periodic orbit. Each point in the basin of attraction of this periodic orbit will converge to it with a particular phase; all points that synchronise with the same phase are said to lie on an isochron. Isochrons are smooth manifolds that have one dimension less than that of the basin of attraction, and the family of isochrons associated with all of the phase points which constitute the periodic orbit make up that entire basin. Isochrons are used in applications to study the effects of a perturbation, in terms of the relative phase at which the perturbed point returns to the periodic orbit.

There are very few systems for which isochrons can be computed analytically; as soon as the dynamics become interesting one has to make use of numerical methods. Previously, methods to compute these isochrons have focused on planar systems. I will present an extension of this method to compute isochrons for both orientable and non-orientable saddle-type periodic orbits in three-dimensions which will lie on that periodic orbit's two-dimensional invariant manifolds. This constitutes a first step towards computing isochrons in higher dimensions, and showcases the intricacies of their geometry.

63 Understanding fluid flow in microfluidic sorters

Brendan Harding
The University of Adelaide
Timetable: p. 22

Microfluidic sorters are able to focus cells to specific parts of a channel whose dimensions are typically around the 100 micrometre scale. Geometry of the channel has a significant impact on where and how well a particle is focused. I will discuss some ongoing work on trying to understand the fluid flow in planar spiral channels and how this affects the focusing of particles.

64 Applying Generalised Polynomial Chaos to Epidemic Models with Individualised Parameter Distributions*

David Harman
Griffith University
Timetable: p. 14

Epidemic models constructed using compartment models consisting of systems of ordinary differential equations are widely used and studied. However, the parameters within these models, as well as their initial conditions, are rarely known with complete accuracy.

Generalised Polynomial Chaos (gPC) is a new method that incorporates the uncertainty in these parameters and initial conditions directly into the model by writing them as functions of random variables with known probability distributions. gPC assumes the solution can be written as the sum of the product of deterministic functions and orthogonal polynomials from the Askey scheme. From the gPC expansion, the mean solutions as well as its variance can easily be determined.

During my talk, I will extend the gPC method to work with random variables with different types of probability distributions as well as using orthogonal polynomials that are not part of the Askey scheme. Rather than trying to find the 'best' values for the parameters of the SIR model based upon a given error formula, a range of 'plausible values' for the parameters is considered. From these plausible values, probability distributions for the parameters can be found and which allows gPC to be used to find the mean solution and its variance. These ideas will be tested by looking at a flu epidemic that went through a small boarding school.

65 Mixed-mode oscillations, slow manifolds and twin canards in chemical systems*

Cris Hasan
The University of Auckland
Co-authors: Bernd Krauskopf and Hinke Osinga
Timetable: p. 21

A mixed-mode oscillation (MMO) is a complex waveform with a pattern of alternating small- and large-amplitude oscillations. MMOs have been observed experimentally in many physical and biological applications, and most notably in chemical reactions. We are mainly interested in MMOs that appear in dynamical systems with different time scales. In particular, we consider an autocatalytic chemical system with an explicit time-scale separation parameter. The mathematical analysis of MMOs is very geometric in nature and based on singular limits of the time-scale ratios. Near the singular limit one finds so-called slow manifolds that guide the dynamics on the slow time scale. In the considered chemical system, slow manifolds are surfaces that can be either attracting or repelling. Transversal intersections between attracting and repelling slow manifolds are called canard orbits. Our aim is to study a parameter regime where the time-scale ratio is relatively large. We use continuation methods based on two-point boundary value problems to investigate the underlying complex dynamics of the chemical system in such a parameter regime. By employing these methods, we observe unexpected phenomena such as twin canard orbits and ribbons of the attracting slow manifold.

66 A BEM formulation for doubly-periodic two-dimensional Stokes flow with pressure boundary conditions*

Patrick Hassard
Queensland University of Technology
Co-authors: Ian Turner, Troy Farrell and Daniel Lester
Timetable: p. 16

We present a formulation of the Boundary Element Method (BEM) for calculation of a two-dimensional pressure-driven Stokes flow in a doubly-periodic domain. In contrast to similar methods which require *a priori* knowledge of the average fluid velocity, this formulation is based on knowledge of the hydrostatic pressure gradient only. The gauge freedom associated with the Green's function is used to introduce the pressure gradient, and asymptotic analysis is used to eliminate the dependence on average velocity. We present a method of calculating the permeability tensor without the need to specify either average velocity or pressure gradient. We discuss the optimality of the splitting parameter in the doubly-periodic Green's function, with regard to the numerical overhead required for BEM, and find a significant improvement over the splitting parameter used in the BEMLIB software library.

67 The impact on the taxi industry of improved access to Melbourne airport

John Hearne
Royal Melbourne Institute of Technology
Co-authors: Solmaz Jahed
Timetable: p. 12

Melbourne is one of many cities in the world experiencing congested road access to airports. Adding extra lanes to access roads or building a new rail link between the central city and the airport are strategies used to alleviate this problem. But will be the impact on the taxi industry? A system dynamics model to understand the impact of such a strategy on the taxi industry will be presented. The focus of this analysis is on the transient effects on taxi drivers and investment in vehicles. It will be shown that the staging of improvements to airport access has important ramifications.

68 Dynamics of Janus Particles in a Uniform Flow

Shaun Hendy
The University of Auckland
Timetable: p. 22

We study the dynamics of Janus particles, micro- or nanoparticles that are not spherically symmetric, in the uniform flow of a simple liquid. In particular, we consider spheres with an asymmetry in the solid-liquid interaction over their surfaces and calculate the forces and torques experienced by the particles as a function of their orientation with respect to the flow. We also examine particles that are deformed slightly from a spherical shape. For particles with variable slip lengths or aspherical deformations that are much smaller than the particle radius we compute the forces and torques to first order. We find good agreement between the approximate expressions and molecular dynamics simulations when the slip condition is applied to the first layer of liquid molecules adjacent to the surface. The results suggest that Janus particle clusters, which can form due to solvophobic interactions between the particles, may be unstable in uniform flows.

69 New insights on dead water*

Eric William Hester
The University of Sydney
Timetable: p. 12

Dead water refers to a mysterious increase in resistance experienced by boats in density-stratified waters. The problem has been documented since ancient times, and studied scientifically for over a century. However, past investigations have been limited in several important ways. For the first time, we study the phenomenon using state-of-the-art numerical simulations. We reproduce the effect and demonstrate that it is most pronounced in strongly nonlinear regimes poorly modelled by current theory. The most exciting development found a new trailing vortex behind the boat experiencing the effect. This robust structure is consistent with sailors accounts, but has been missed in previous scientific studies. We expect these results to lead to actionable ways to mitigate dead water in the real world.

70 Dengue fever in Taiwan: An IBM Health Corps adventure

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Timetable: p. 23

Dengue fever is a mosquito-borne disease, with *Aedes aegypti* the primary vector. There was an unexpectedly large number of human dengue cases in Taiwan in 2015, increasing from the typical low numbers of around five hundred to over forty thousand cases. IBM Health Corps worked with the Taiwan Centers for Disease Control (CDC) to develop a decision support tool based on mathematical models to evaluate potential new interventions. We focussed on the example intervention of mosquito population reduction by releasing *Wolbachia*-carrying male mosquitoes. This presentation will discuss the mathematical models and demonstrate how the outputs were visualised in the decision support tool.

71 Newton–de Broglie's second law

James Murray Hill
University of South Australia
Timetable: p. 22

Louis de Broglie first predicted light to display the dual characteristics as both a collection of particles, called photons, or in some respects as a wave. If the particle speed is subluminal then the associated wave speed through the de Broglie relation is necessarily superluminal. If Einstein's special relativity is extended beyond the speed of light then the velocity addition formula still applies and in the limit the de Broglie's formula again emerges. If with respect to some fixed frame, all subluminal frames are grouped together and all superluminal frames are grouped together, then there is no objective way to decide in which set of frames we belong. We propose that the sub and super worlds might be equally important, and that each might exert an influence on the other, such that any mechanical equations must not only be Lorentz invariant but they must also be invariant under the transformation connecting the sub and super worlds. This modification gives rise to an extension of Newton's second law that might well account for the extra mass that is known to exist in the universe, referred to as dark matter. An explicit solution for photons is given with a non-zero photon rest mass.

72 Withdrawal from a stratified fluid in a porous medium.

Graeme Charles Hocking
Murdoch University
Timetable: p. 19

Understanding of the withdrawal of stratified fluid from a confined aquifer is essential to maintain water quality for human consumption and irrigation. I will discuss some interesting exact solutions for withdrawal through a point sink using some neat old-fashioned mathematics in cases of continuous but nonlinear stratification right through to two distinct layers, and discuss the relationship between the two. The pertinent question is whether it is possible to withdraw one layer (of fresh water, say) without sucking up the salt.

73 Firing Up El Niño (El Niño and its relationship with the South East Asian Aerosol Plume)

Roger J. Hosking
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Co-authors: M. Kamruzzaman, A. Metcalfe, S. Beecham, D. Green and K. Potts
Timetable: p. 15

The intentional burning of vegetation in the Indonesian archipelago is the major contributor to the recurring phenomenon known as the South East Asian Aerosol Plume (SEAAP). We have investigated a recent hypothesis by Potts that "local cooling" of the sea surface temperature (SST) due to screening of the solar radiation by the SEAAP triggers El Niño events. Elementary theory shows that aerosol penetration into the Atmospheric Boundary Layer from fire activity is so rapid that the SEAPP can significantly lower the SST within a few days at most, reducing the local atmospheric convection and so weakening (or even reversing) the Walker Circulation as observed during El Niño events. In addition, statistical analysis shows that aerosols are Granger causal for the Southern Oscillation Index, which is commonly used to define the onset of El Niño events.

74 The Kadison–Singer Problem; tight frames for Euclidean vector spaces; and Walsh matrices

Phil Howlett
University of South Australia
Timetable: p. 13

In 1959 Richard Kadison and Isadore Singer asked whether each pure state (an extreme unital nonnegative linear functional on the space of bounded diagonal operators) has a unique extension to a regular state (a unital nonnegative linear functional on the space of all bounded linear operators) on the space of square summable sequences. The so-called Kadison–Singer Problem (KSP) arose as a fundamental question in quantum mechanics and remained unsolved and obscure for the next twenty years. The first great leap forward came in 1979 when Joel Anderson proved that KSP had a positive solution if and only if every zero-diagonal Hermitian matrix could be decomposed by a complete set of diagonal projections into a finite number of small parts where the number of parts depends only on the measure of smallness. The revised formulation was called the Anderson Paving Conjecture (APC) and KSP now assumed the status of an iconic twentieth century mathematical problem. Despite intensive study for the next twenty five years progress was limited. The second great leap forward emerged from the swamp in 2004 when Nik Weaver showed that APC has a positive solution if every quadratic form expressible as a sum of small rank-one quadratic forms can be split into two almost equal parts. I will call this the Weaver Discrepancy Statement (WDS). The third and final great leap forward was in 2013 when Adam Marcus, Daniel Spielman and Nikhil Srivastava thrust themselves into the mathematical limelight by solving WDS using random polynomials with interlacing zeros. Thus, at long last, KSP had a positive answer. In this talk I will discuss mathematical statements of KSP, APC and WDS and show how WDS relates to the existence of tight frames for Euclidean vector spaces. I will illustrate my remarks using frames extracted from Walsh matrices.

75 Spatial modelling of calcium signals in heart cells*

Hilary Hunt
The University of Melbourne
Co-authors: Vijay Rajagopal and Edmund Crampin
Timetable: p. 17

Cardiovascular disease is the leading cause of death in Australia; responsible for 30% of deaths. Diseases that affect the heart are commonly accompanied by a condition known as hypertrophy — heart enlargement through cell growth. This condition causes uneven heart beats and, eventually, heart failure.

Hypertrophy is regulated by calcium dynamics. Calcium is known as a universal carrier of biological signals. In cells, it is involved in everything from generation of fuels to hormone regulation to cell mobility. The resulting overlap of signals within cells is a complicated, self-regulating system that biologists and mathematicians alike are still working to fully describe.

We focus specifically on distinguishing the signal for heart cell growth in the nucleus where gene expression takes place over the background signal for the heartbeat. Using a finite element model, we describe the spatiotemporal properties of these background calcium oscillations as they propagate into the nucleus. We verify this model with existing data to produce a clearer picture of the calcium dynamics involved in initiating hypertrophy.

76 Evolution of copulas and its application to the dependence relation between exchange rates[J]

Naoyuki Ishimura

Chuo University

Timetable: p. 13

Copulas are well employed tool for analyzing the possible nonlinear dependence structure among random events. However, it is recognized that the copula method is not suitable to time-dependent relations. We have introduced, on the other hand, the concept of evolution of copulas both in continuous and discrete senses, which assumes that the copula itself evolves according to the time-variable. Here we apply our evolution of copulas to the analysis of dependence relation model between euro (EUR) – Japanese yen (JPY) exchange rates and Swiss franc (CHF) – JPY exchange rates. We focus ourselves on rapidly changing events such that their directions of change are almost stable. We consider foreign exchange rates on January 15, 2015, when CHF endured a shock breakout after the announcement that the Swiss central bank had stopped monetary policy efforts to maintain CHF against EUR at more than 1.20. We then calculate the Kendall's tau and apply a smoothing technique to its transitions. We then evolve an empirical copula to construct discrete evolution, and compare Kendall's tau of this discrete evolution to the moving averages of the empirical copulas. The results are that the discrete evolution copulas approximate fairy well the smoothed transition of empirical copulas from the viewpoint of Kendall's tau.

77 Insights from a novel PDE model of early atherosclerosis*

Md Hamidul Islam
Griffith University
Co-authors: Peter Johnston
Timetable: p. 19

Atherosclerosis refers to hardening and narrowing of the arteries, resulting from the deposition of fatty materials in the walls of arteries, leading to a thickening of the wall. The mechanical injury or dysfunction from atherosclerotic risk factors alters the normal function of the endothelium, which plays a pivotal role in initiating atherosclerosis. The compensatory response of the immune system initiates a series of complex biochemical and cellular processes in response to an injury, which may result in the development of an atherosclerotic lesion if the immune system becomes compromised and fails to replace the injured endothelium successfully. This failure occurs due to an imbalance between the pro-and anti-inflammatory actions taken by some cells and cellular species that are relevant to the repair mechanism and lesion development.

In this talk, we will present a reaction-diffusion PDE model comprising equations for the six different species that are believed to play a key role in the early stages of atherosclerosis. These include the mutual interactions between the inflammatory mediators, monocytes, macrophages, low density lipoprotein, modified low-density lipoprotein, foam cells and high density lipoprotein. Another novel aspect of the model is that it is based on the response-to-injury hypothesis of atherosclerosis. We examine the steady states of the model and their stability, and then investigate how these changes as the significant parameters of the model change.

78 Can maths help viruses treat cancer? Exploring model parameter space to optimise therapies*

Adrianne Jenner
University of Sydney
Timetable: p. 13

Ever considered how effective viruses could be as a cancer killing agent? Currently there are many clinical and experimental results showing how successful genetically engineered viruses are at treating cancer, but there is still a long way to go. To help identify and quantify the key processes underlying the effectiveness of viral therapies on breast and cervical cancers we created mathematical models for both *in vitro* and *in vivo* experiments. Compartmental ODEs were employed and the parameter space of the model was explored. We used both a parameter sensitivity analysis and Quasi Monte Carlo parameter space sampling to determine the regions of applicability of the system, and determine any specific heterogeneity in the behavior of the virus on the differing tumour types. The optimised model is now being used to further understand the complex dynamics of the virus-tumour interaction and investigate the optimal application of these therapies.

79 Logistic proliferation of cells in scratch assays is delayed*

Wang Jin
Queensland University of Technology
Timetable: p. 15

Scratch assays are used to study how a population of cells re-colonises a vacant region on a two-dimensional substrate after a cell monolayer is scratched. To provide insights into the mechanisms that drive scratch assays, solutions of continuum reaction-diffusion models have been calibrated to data from scratch assays. These models typically include a logistic source term to model carrying capacity-limited proliferation, however the choice of using a logistic source term is often made without examining whether it is valid. Here we study the proliferation of PC-3 prostate cancer cells in a scratch assay, and we focus on the proliferation of these cells far away from the scratch. All experimental results for the scratch assay are compared with equivalent results from a proliferation assay where the cell monolayer is not scratched. Guided by experimental data, we find that there are two phases of proliferation in a scratch assay. At short time we have a disturbance phase where proliferation is not logistic, and this is followed by a growth phase where proliferation appears to be logistic. Accounting for the differences in the growth and disturbance phase, we obtain biologically realistic estimates of the proliferation rate and carrying capacity density. In contrast, simply calibrating the solution of the logistic growth equation to all data from the scratch assays, we obtain an excellent match between the data and the model, but the parameter estimates vary wildly and are not biologically realistic. Overall our study shows that simply calibrating the solution of a continuum model to a scratch assay might produce misleading parameter estimates, and this issue can be resolved by making a distinction between the disturbance and growth phases. Repeating our procedure for other scratch assays will provide insight into the roles of the disturbance and growth phases for different cell lines and scratch assays performed on different substrates.

80 Quantifying the effect of input uncertainty in a cardiac tissue model

Barbara Johnston
Griffith University
Co-authors: Sam Coveney, Eugene T. Y. Chang, Peter R. Johnston and Richard H. Clayton
Timetable: p. 21

This study uses a number of uncertainty quantification techniques (polynomial chaos, Gaussian Process emulators, partial least squares regression) to study the effects of uncertainty in the input parameters of a cardiac tissue model on the outputs of the model. We model ST-segment epicardial potentials in a slab of cardiac ventricular tissue, which contains a region of partial thickness ischaemia, in an effort to increase our understanding of elevation and depression in the ST-segment of the electrocardiogram caused by myocardial ischaemia. We use emulators (surrogate models) to quantify the sensitivity of outputs, which characterise the epicardial potential distributions, to uncertainty in the model inputs.

We find that three possible types of epicardial potential distributions can be identified and these exist for a much wider range of input conductivity values than previously identified. We also found that the

bidomain conductivities in the longitudinal and normal (but not the transverse) directions affect the magnitude of ST depression, but its position is affected only by the fibre rotation angle through the tissue and the depth of ischaemia.

81 A Study of the Method of Fundamental Solutions Applied to the Inverse Problem of Electrocardiology

Peter Johnston
Griffith University
Timetable: p. 15

The inverse problem of electrocardiology (IPE) is the determination of heart surface electrical potentials from electrical measurements recorded on the body surface and is an ill-posed problem. Typically, this is solved by obtaining a matrix that maps the heart surface potentials to the body surface potentials and inverting this matrix using some form of regularisation. The matrix itself is obtained by solving Laplace's equation in the volume conductor of the human body with insulation conditions on the body surface and a given heart surface potential distribution. Laplace's equation can be solved using the finite difference, finite element, finite volume or boundary element methods.

In the 1970s the Method of Fundamental Solutions (MFS) was proposed as an alternative approach for solving Laplace's equation. The main advantage of MFS is that it is a meshless method and, hence, is straightforward to implement. More recently, MFS has been employed as a method to solve the IPE. However, the IPE is still ill-posed and some form of regularisation is still required.

Here, the MFS approach to solving the IPE will be compared to a more conventional boundary element solution method. Various schemes for choosing the regularisation parameter will also be discussed.

82 A new and accurate continuum description of moving fronts*

Stuart Johnston
Queensland University of Technology
Co-authors: Ruth Baker and Matthew Simpson
Timetable: p. 20

Processes that involve moving fronts of populations are prevalent in ecology and cell biology. A common approach to describe these processes is a lattice-based random walk model, which can include mechanisms such as crowding, birth, death, movement and agent-agent adhesion. However, these models are generally analytically intractable and it is computationally expensive to perform sufficiently many realisations of the model to obtain an estimate of average behaviour that is not dominated by random fluctuations. To avoid these issues, both mean-field and corrected mean-field continuum descriptions of random walk models have been proposed. However, both continuum descriptions

are inaccurate outside of limited parameter regimes, and corrected mean-field descriptions cannot be employed to describe moving fronts. Here we present an alternative description in terms of the dynamics of groups of contiguous occupied lattice sites and contiguous vacant lattice sites. Our description provides an accurate prediction of the average random walk behaviour in all parameter regimes. Critically, our description accurately predicts the persistence or extinction of the population in situations where previous continuum descriptions predict the opposite outcome. Furthermore, unlike traditional mean-field models, our approach provides information about the spatial clustering within the population and, subsequently, the moving front.

83 Consistency in dynamical systems subject to complex driving signals

Thomas Jungling
The University Of Western Australia
Timetable: p. 12

Nonlinear dynamical systems have been considered recently for their potential in unconventional forms of information processing. A powerful neuro-inspired method of this kind is reservoir computing, where a recurrent network of dynamical units is driven by an information-carrying signal, and its response is post-processed via a training procedure to realize the desired computational task. A typical feature of nonlinear systems, however, is their capacity to develop instabilities that lead to chaotic behaviour. A chaotic response will deteriorate the reliability of the network and hence also the performance of the computation. In this talk, we first review the reservoir computing technique by the example of a photonic delay system, where a single dynamical node with time-delayed feedback replaces the network. For such a delay system, we then show how a complex external drive affects the quality of the response. The concept of consistency is introduced in order to quantify the reliability of the nonlinear transformation provided by the dynamical node. We finally relate consistency to conditional Lyapunov stability, and we give an outlook to its role for the design of improved reservoir computers.

84 Construction and Simulation of Discrete Integrable Model for Soil Infiltration Problem[J]

Kenji Kajiwara
Kyushu University
Co-authors: Philip Broadbridge, Ken-ichi Maruno and Dimetre Triadis
Timetable: p. 21

We propose an integrable full-discrete (discrete in both space and time) model describing the soil water infiltration problem. The continuous model is formulated as the nonlinear boundary value problem for a one-dimensional nonlinear diffusion-convection equation which is obtained by applying a certain hodograph (reciprocal) transformation to the Burgers equation. By using the technique of integrable discretization, we first construct the discrete model as the nonlinear boundary value problem for a certain difference-difference equation with adaptive moving mesh, preserving the underlying integrable nature. If we require the numerical stability and high precision coincidence with the special case where the exact solution is known, we need further investigation from various viewpoints different from the theory of discrete integrable systems. We will discuss this point and present numerical results.

85 Optimal vaccination scheme for influenza like disease with heterogeneity in infectivity and susceptibility

Reena Kapoor
IBM Research Australia
Timetable: p. 14

One of the fundamental questions for vaccination strategies to control infectious diseases is who in the population should be prioritized? We outline a linear programming based branch and bound optimization method to identify the optimal sub-population to target for an influenza-like-illness in order to reduce both final size and number of deaths due to the pathogen, whilst taking into account population heterogeneity in susceptibility and infectivity. We analyse the problem by conducting an extensive experimental analysis by varying various parameters such as the weights given to conflicting objective, the transmission rate, the scale of heterogeneity, and the available amount of vaccines. We find that the core target population remains static with increasing numbers of vaccine available with the optimal target population expanding as more resources become available.

86 Modelling rainfall induced landslides with a combined analytical and computational approach*

Laura Karantgis
La Trobe University
Timetable: p. 19

Landslide events have a devastating impact on communities and industries. Modelling these complex systems is valuable for predictive and preventative measures to reduce the impact of these events. Landslides are often caused by heavy rainfall so soil water content is important to consider when considering slope stability as it alters the soil strength.

We have constructed analytic series solutions for the phreatic free surface problem of two dimensional steady downslope saturated-unsaturated flow, with water exiting at a seepage face. This model will be used to predict the water table and flow of water through soil for varying parameters such as slope angle, length, rainfall rate, and soil type.

We will also consider problems such as those including surface evaporation (which will be used in a comparative analysis with Finite Element Methods) and those including pure fluid flow interaction with porous media flow (where the Stokes and Brinkman equations will be used in each of the phases respectively).

We use a computational method Smoothed Particle Hydrodynamics to model the slope failure. The results for the water table will be used to define a saturated region that considers pore water pressure and a change of the soil strength parameters of cohesion and friction angle. The results of this investigation will be compared with experimental data to validate results.

87 The importance of being chaotic: Bifurcations in an El Niño model

Andrew Keane
University of Auckland
Co-authors: Bernd Krauskopf and Claire Postlethwaite
Timetable: p. 21

We consider a conceptual model for the El Niño Southern Oscillation system, where the delayed effects of energy transport across the Pacific Ocean are incorporated explicitly into the model, which gives a description by a delay differential equation. We conduct a bifurcation analysis of the model by means of dedicated continuation software, which allows us to find regions of different types of solutions in the parameter space. In this way, we determine how the observed dynamics is influenced by changing certain parameters of the model. Our bifurcation analysis demonstrates that the irregular nature of El Niño events can be reproduced by chaotic behaviour resulting from the interplay between delayed feedback and seasonal forcing. It also uncovers the phenomenon of folding invariant tori, which may be interpreted as a form of climate tipping.

88 A Tale of Two Topographies: Exponential Asymptotics of the forced KdV equation*

Jack Samuel Keeler
The University of Adelaide
Timetable: p. 12

The forced Korteweg De–Vries equation (fKdV) is used as a model to analyse the wave behaviour on the free surface in response to a prescribed topographic forcing. In this talk we examine the consistency of asymptotic solutions of this equation when the non-dimensional Froude number is 1. For the first topography; a Gaussian type, a naive asymptotic expansion fails to satisfy the boundary conditions yet a consistent expansion can still be found by introducing internal boundary layers and examining the far-field behaviour in these layers.

For the second topography; the so-called 'Witch of Agnesi', a naive asymptotic expansion can be shown to satisfy the boundary conditions at each order. However, if the solution is extended into the complex plane then the existence of singularities in the leading order term of the expansion lead to the introduction of Stokes' lines crossing the real axis. Across these Stokes' lines exponentially small quantities are 'switched on' and it can be shown that the naive asymptotic expansion is not consistent with the boundary conditions despite each term satisfying them.

89 Modelling host control of malaria by slowing parasite development

David Samuel Khoury
University of New South Wales
Co-authors: Deborah Cromer, Jasmin Akter and Ismail Sebi
Timetable: p. 22

Children under the age of five account for 71% of malaria deaths globally. This is because immunity to malaria takes years of exposure to develop. When these non-immune individuals are infected their first line of defence against the parasite are a group of general immune responses called, innate immune mechanisms, and these are important for controlling infection. It is thought that the host spleen and macrophages are primarily responsible for the early control of malaria infection in non-immune individuals. However, little work quantifying the amount of host removal of infected red blood cells (iRBCs) in early-infection has been performed. We used a combination of experimental work in mice and modelling to explore this question. Over the first 5-days of an infection the rodent malaria parasite (Plasmodium berghei ANKA) proliferates in the host circulation, but the rate of proliferation slows. We used a unique experimental approach to transfer label iRBCs into naive and mice that have been infected for 5-days. By regularly measuring the concentration of these labelled iRBCs in the host circulation over a 24 hour period we sought to measure the rate of removal of these iRBCs. Using age-structured differential equations models, we sought to quantify how much of the slowing in total parasite growth could be explained by any observed increase in removal of iRBCs in 5-day infected mice compared with naive mice. Surprisingly, our models reveals a completely new mechanism of host control of parasites. Rather than removal of iRBCs, we observed the developmental time of parasites

was increased in 5-day infected mice, compared with naive mice. This novel mechanism broadens our understanding of host control, and highlights other potential strategies in the treatment of malaria.

90 Evolution of human longevity, menopause, and sex conflict with grandmothering

Peter Kim

University of Sydney

Co-authors: Matthew Chan and Kristen Hawkes

Timetable: p. 15

Human post-menopausal longevity makes us unique among primates, but how did it evolve? The Grandmother Hypothesis proposes that as ancient Africa become more arid, it became harder for juveniles to acquire food without adult help. As a result, older females improved survival and number of descendants by assisting grandchildren. This new evolutionary opportunity favoured increased longevity while maintaining the ancestral end of female fertility.

We develop a partial differential equation model that allows mutation of longevity and age of menopause and accounts for mating and grandmother help. Using this model, we show how the grandmother effect could have driven the evolution of human longevity while keeping a lower, great-ape-like end of female fertility. Then, to investigate the effect of male fitness tradeoffs, we also investigate the evolutionary fitness landscape that results from sex conflict, which occurs when males and females have different evolutionary optima. These models open multiple paths for fascinating new directions in modelling primate evolution.

91 Evolutionary Games Under Incompetence: A New Approach to Adaptation Dynamics*

Maria Kleshnina

Flinders University

Timetable: p. 19

The idea of incompetence was first proposed by Beck et al. in the context of stationary normal form games. They assumed that N players might make mistakes with some probabilities which make up the stochastic matrices $Q_j,\ j = 1, .., N$. Then, for example, for a two-person game the reward matrix R is becoming a new incompetent reward matrix R_Q given by

$$R_Q = Q_1 \times R \times Q_2^T.$$

They showed that such assumption may change the outcome of the game. In this talk we introduce the incompetence into evolutionary games, in particular in classical replicator dynamics, and analyse its influence on the equilibria and stability of the system.

This research is funded by the ARC Discovery Grant DP160101236.

92 Error analysis of Lagrange interpolation on tetrahedrons[J]*

Kenta Kobayashi
Hitotsubashi University
Timetable: p. 14

The error analysis of Lagrange interpolation plays an important role in the error analysis of the Finite Element Method. In this talk, we will describe the analysis of Lagrange interpolation errors on tetrahedrons. In many textbooks of the Finite Element Method, the error analysis of Lagrange interpolation is conducted under geometric assumptions such as shape regularity or the (generalized) maximum angle condition. In our talk, we present a new estimation in which the error is bounded in terms of the diameter and projected circumradius of the tetrahedron. It should be emphasized that we do not impose any geometric restrictions on the tetrahedron itself.

93 Verified quadrature for integrand with power-type singularity using partial integral[J]*

Ryo Kobayashi
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Co-authors: Kouta Sekine, Masahide Kashiwagi and Shin'ichi Oishi
Timetable: p. 12

We consider the integral $I_f = \int_0^\alpha x^{r-1} f(x)dx$ with α and r being positive real numbers and $f \in C^\infty([0,\alpha])$. Obviously, whenever r is not an integer, the integrand has a singularity at the end point $(x = 0)$.

Our concern is the application of a verified quadrature to this integral. A verified quadrature is a method that exploits an approximate solution obtained via a quadrature formula and the corresponding error term to compute an interval that includes an exact value of integral. In many cases, the error term of the quadrature formula includes higher derivatives of the integrand. However, due to the presence of a singularity, we cannot directly apply those verified quadratures to the above integral.

Here we propose a verified quadrature method that circumvents this issue. We apply the strategy of integration by parts. By doing so n times to the above integral, we obtain $I_f = C_n + a_n \int_0^\alpha x^{r+n-1} f^{(n)}(x)dx$ where C_n as well as a_n are constants, and $f^{(n)}(x)$ is the nth derivative of $f(x)$. The integrand $x^{r+n-1} f^{(n)}(x)$ in the second term is at least $n-1$ times differentiable.

For the verified quadrature of the so transformed integral we propose a method that is based on Euler–Maclaurin's formula. This enables us to compute an interval rigorously enclosing the actual value of the above integral.

Some numerical examples will be presented demonstrating that our method is practically applicable for integrand with power-type singularity.

94 Statistical gene analysis to develop techniques of artificial heterosis in plants[J]*

Satoru Koda
Kyushu University
Timetable: p. 20

Plants in a state of heterosis are known to hold some desirable advantages in plant size, environmental tolerance, growth speed, and so on. Moreover, they are paid attention as an efficient source of environmentally friendly biofuels and also hugely expected to contribute to deal with environmental problems.

However, molecular systems of heterosis have not been clarified yet. To tackle the challenge and develop an artificial technique to induce heterosis into arbitrary plants without hybridization, we analyzed time series gene expression data mathematically. Specifically, we used the statistical sparse modeling tool (Group SCAD) to infer gene networks and frequency analysis tools based on Wavelet Transform to detect gene periodicity.

Using these approaches, we were able to find characteristic genes which might be the key of heterosis. Our presentation shows interesting results of the experiments done on the basis of our analysis.

95 Why be afraid of state-dependent delays?

Bernd Krauskopf
University of Auckland
Co-authors: Renato Calleja and Tony Humphries
Timetable: p. 20

Delay differential equations (DDEs) are the mathematical models of choice in applications where delays arise naturally, for example, due to the time it takes different subsystems to communicate, process information and finally react. The delays that are encountered are usually modelled as constant. This may be a good approximation, but communication/processing times may well depend on the state of the system in a significant way, meaning that the delays change dynamically and the governing DDE is state dependent.

We present here a case study of a scalar DDE with two delayed feedback terms that depend linearly on the state. The associated constant-delay DDE, obtained by freezing the state dependence, is linear and without recurrent dynamics. With state dependent delay terms, on the other hand, the DDE shows very complicated dynamics. A bifurcation analysis reveals interacting Hopf bifurcations, two-frequency

dynamics on invariant tori and associated resonance tongues. Our results may serve as a 'health warning': state dependence alone is actually capable of generating a wealth of dynamical phenomena. Hence, it must be taken seriously in applications. On the other hand, as this talk will also demonstrate, tools from bifurcation theory and associated numerical methods are now available to deal effectively with state-dependent delays. This means that there is no need to avoid/disregard state dependence in DDE models.

96 Optimising Patient Flow and Throughput in a Surgical Suite*

Ashwani Kumar
The University of Melbourne
Timetable: p. 16

Demand for healthcare services is growing rapidly in Australia, and rising healthcare expenditure is increasing pressure on the sustainability of the government-funded healthcare system. To keep up with the rising demand, we need to be more efficient in delivering healthcare services. To make a system efficient, we need to identify the source of inefficiency and eliminate it.

In this research project, we will apply statistical and operations research tools to improve the healthcare delivery process in the surgical suite of a major metropolitan hospital. Randomness in patients? length of stay (LoS) at healthcare facilities is the major cause of inefficiency in the system. We will develop a scientific method to minimise inefficiency in the system because of the randomness in patient's LoS.

We will develop some strategies to understand the distribution of healthcare LoS data. Understanding the healthcare data is important in order to characterise the load each patient brings to the system. Next, we will develop a patient classification scheme to classify the elective surgery patients into lower variability LoS groups. Doing so will help us in decreasing the variability caused by stochastic LoS.

We will develop a mixed integer linear programming (MIP) based elective surgery scheduling scheme to maximise the throughput in a surgical suite. We will test our scheduling scheme by using a simulation model, and will analyse patient flow after implementing the new scheduling scheme. We will also develop an assessment tool to predict the availability of resources depending on the current resource users.

97 Modelling the effectiveness of therapeutic cancer vaccines: an agent-based approach*

Adarsh Kumbhari
University of Sydney
Timetable: p. 14

Therapeutic cancer vaccines treat cancers that have already developed by stimulating special cancer killing cells known as cytotoxic T cells. Despite showing promise, positive clinical outcomes have yet to be realised and a possible reason is due to the functional avidity of the T cell response. Vaccines elicit a low-avidity (i.e., weakly tumour-killing) T cell response, and the mere presence of low-avidity T cells can inhibit cancer killing by high-avidity T cells (Chung et al., 2014). By considering this "high-low interference" explicitly we use a probabilistic agent-based model to explore what the optimal vaccination strategy is.

98 Chimeras in networks with purely local coupling

Carlo Laing
Massey University
Timetable: p. 17

Chimera states in spatially extended networks of oscillators have some oscillators synchronised while the remainder are asynchronous. These states have primarily been studied in networks with nonlocal coupling, and more recently in networks with global coupling. Here we present a network with only local coupling (diffusive, to nearest neighbours) which is numerically found to support chimera states. The network is analysed using a self-consistency argument in the continuum limit, and this is used to find the boundaries of existence of a chimera state in parameter space.

99 Well-posedness for the Keller–Segel system coupled with the Navier–Stokes fluid in the critical Besov spaces[J]*

Minsup Lee
Kyushu University
Co-authors: Masanari Miura and Yoshie Sugiyama
Timetable: p. 20

We will deal with the chemotaxis model under the effect of the Navier–Stokes fluid, that is, the incompressible viscous fluid. We shall show the existence of a local mild solution for large initial data and a global mild solution for small initial data in the scale invariant class. Our method is based on the perturbation of linearization together with the estimates of the heat semigroup in the Besov spaces. We shall emphasize that our results are developed in the critical Besov spaces which include the delta-function in the 2D case. This is based on a joint work with Mr. Masanari Miura (Kyushu University) and Professor Yoshie Sugiyama (Kyushu University).

100 Out-of-phase epidemics in a model of infectious disease transmission with immune boosting and cross-immunity*

Tiffany Ngo Nam Leung
The University of Melbourne
Co-authors: Barry D Hughes, Federico Frascoli and James M McCaw
Timetable: p. 16

Many countries have reported an increase in case notifications of pertussis, a contagious respiratory disease caused by two closely related pathogens, Bordetella pertussis and Bordetella parapertussis. The two pathogens have been observed to exhibit out-of-phase epidemics — behaviour that may plausibly be generated by cross-immunity.

Motivated by these observations, we consider how immunological interactions between two pathogens may contribute to the epidemiology of a disease. We build upon an existing susceptible-infectious-recovered-waning-susceptible (SIRWS) model with immune boosting, where those whose immunity has waned sufficiently (W) can experience a 'boost' to their immunity level upon re-exposure. We extend this model by including a second pathogen that confers cross-immunity, and show that the presence of cross-immunity can cause the model to produce dynamics that are qualitatively similar to those observed for pertussis and parapertussis. In particular, different initial conditions can lead the two pathogens to each produce recurring epidemics that are out-of-phase, where the peak heights of the epidemics produced by one pathogen are higher than the peak heights produced by the other.

A better understanding of the immunological interactions between pathogens may aid the development of models that are more grounded in biology. In application to a specific disease, such understanding may provide guidance in explaining its epidemiology.

101 Modelling electricity prices with regime switching models*

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

Low cost generators of electricity cannot easily vary their supply, and demand for electricity is inelastic. Hence, during times of system stress, such as heatwaves and infrastructure failures, large price spikes occur and market participants face significant market risk. To hedge this risk, derivative contracts are used, and to price derivatives a model of the price process is required. Regime switching models are popular as they can capture the spikes and mean reverting autoregressive behaviour observed in electricity prices. This talk will introduce popular regime switching models found in the electricity price modelling literature, and will describe an application of MCMC methods for parameter estimation.

102 Evolution of male reproductive strategy as payoffs are driven by male-biased sex ratios.*

Sara Li-Yen Loo
The University of Sydney
Co-authors: Kristen Hawkes and Peter S Kim
Timetable: p. 15

In human hunter–gatherer populations, male reproductive success is determined by an individual's chosen mating strategy. Common strategies include multiple mating, paternal care, and mate guarding. These have been studied to varying degrees, by observing immediate reproductive payoffs, as well as the existence of evolutionary stable states [e.g. Hawkes et al., 1995; Fromhage et al., 2007; Kokko, 1999; Kokko and Jennions, 2003; Kokko and Jennions, 2008]. The potential benefit of male care to offspring survival is insufficient for selecting for paternally caring males, as they must compete with promiscuous males who are attempting to steal the paternities assigned to them. As documented in the literature, males must face a form of "the social dilemma", wherein increased production increases the pay-off for theft. Males must overcome the pressures of mating competition from other searching males, as they compete for a continually diminishing number of available females. The pay-offs for their investment strategy is strongly frequency-dependent. The dynamic and evolutionary response of male reproductive strategic choice to changing female availability must necessarily be an outflow of the male-biased adult sex ratio (ASR) observed in humans. We present a difference equation model of this behaviour, modelling the evolutionary response to three competing male strategies; paternal care, multiple mating, and mate guarding. Where previous models have artificially imposed a changing adult sex ratio by removing guarded females completely from eligibility (assuming fully efficient guarding), we model the total available female population with an additional inefficiency of mate guarding, allowing for a proportion of female stealing by multiple maters. For female-biased adult sex ratios, multiple mating is observed to overtake the population. As the population moves towards a male-biased ASR and females grow increasingly scarce, the pay-off to guarding increases and the mate guarding strategy is more favourable.

103 Optimisation Algorithms for Mine Plant Shutdowns

Ryan Loxton
Curtin University of Technology
Timetable: p. 23

Processing plants at mine sites require regular shutdown maintenance to ensure optimal plant efficiency and reduce the risk of catastrophic plant failures. Real maintenance shutdowns involve hundreds of personnel and hundreds of inter-related maintenance activities; and budget and time overruns are common. This talk will describe the outcomes of a joint research project between Curtin University and Linkforce Engineering, one of WA's largest engineering services companies, on mine shutdown optimisation. The project has resulted in new mathematical algorithms for scheduling shutdown maintenance activities to minimise time, resource use, and personnel travel distance, subject to operational constraints. These algorithms can reduce shutdown duration by 10% on average—in addition to many other benefits—and are the foundation of a professional scheduling software that Linkforce are now developing.

104 Nonlinear Time Series Analysis using an Ordinal Partition Metric*

Ben Luo
The University Of Western Australia
Timetable: p. 20

In the study of complex systems we are often presented with time series for which we know little of the underlying dynamics. A first step in analysing a deterministic system is to detect changes in the dynamic regime, e.g. identification of time intervals for which the system shows periodic or chaotic behaviour. Possible methods addressing this problem must be robust against measurement noise, possibly irregular sampling and other typical challenges of experimental data.

Previous work in this field has looked at the usage of symbolic dynamics, namely ordinal partitions to gauge the characteristics of a dataset. This research has primarily focused on the existence of forbidden patterns that occur in deterministic systems.

We explore the use of metrics on symmetric groups to perform recurrence quantification analysis (RQA) on time series that have been encoded using ordinal partitions. Each ordinal partition in a dataset can be viewed as an element of a symmetric group. These elements can then be compared using the aforementioned metrics. RQA then provides us with several indicators of the system's underlying dynamics such as determinism and laminarity. RQA methods have previously been shown to be robust but any new method devised will need to be tested on a variety of datasets. I will present the general outline of this ordinal partition method and some of the preliminary findings.

105 Bubble Selection in a Hele-Shaw Cell using Stokes' Phenomenon

Christopher Lustri
Macquarie University
Timetable: p. 16

This study of translating air bubbles in a Hele-Shaw cell containing viscous fluid reveals the critical role played by surface tension in these systems. The standard zero-surface-tension model of Hele-Shaw flow predicts that a continuum of bubble solutions exists for arbitrary flow translation velocity. The inclusion of small surface tension, however, eliminates this continuum of solutions, instead producing a discrete, countably infinite family of solutions, each with distinct translation speeds. We are interested in determining this discrete family of solutions, and understanding why only these solutions are permitted. This is an example of a selection problem.

Studying this problem in the asymptotic limit of small surface tension does not seem to give any particular reason why only these solutions should be selected. It is only by using exponential asymptotic methods to study the Stokes' structure hidden in the problem that we are able to obtain a complete picture of the bubble behaviour, and hence understand the selection mechanism that only permits certain solutions to exist. In this talk, I will describe how exponential asymptotics can be used to resolve selection problems, and illustrate this methodology on the translating Hele-Shaw bubble in the small surface tension limit.

106 Developing a model for the transmission of Group A Streptococcus*

Michael Lydeamore
The University of Melbourne
Co-authors: Patricia Campbell, Jodie McVernon and James McCaw
Timetable: p. 16

Infections with Group A Streptococcus are highly prevalent in remote communities in northern Australia. Manifesting most commonly in skin sores, Group A Streptococcus is a precursor for rheumatic heart disease and acute post-streptococcal glomerulonephritis. Despite this, little mathematical attention has been devoted to modelling this disease. As such we start by assuming the infection dynamics follow the simple SIS model. This model has only two parameters: the infectiousness parameter and the mean duration of infection. The infectiousness parameter can be calculated directly by using the age of first infection. We demonstrate a technique from cancer cure models that allow the age of first infection (and thus the infectiousness parameter) to be calculated by utilising time to event data from a review of clinical presentations of young children. We show that given a fixed prevalence, a mean duration of infection can be determined utilising an SIS model. We then assess the plausibility of this estimate for the duration of infection, and consider the possibility of a Group A Streptococcus Infection being followed by a period of immunity. We apply similar techniques to the resulting SIRS model, and attempt to ascertain an estimate on the period of immunity, and the duration of infectiousness, and undertake a model selection exercise in an attempt to ascertain the existence of an immune period.

107 Modelling fermentation processes in the rumen

Tammy Lynch
Massey University
Timetable: p. 23

Methane production from fermentation processes that occur in the rumen of animals such as cattle and sheep is one of the major sources of anthropogenic greenhouse gas emissions. Existing mathematical models that estimate this production are based largely on the calculation of hydrogen balances without considering the presence of methanogens, the microbes responsible for this production of methane. In this talk, we present a mathematical model that depicts the interaction between the microbial populations in the rumen (glucose fermenters and methanogens), their feed substrates (glucose and hydrogen), and the end products of their fermentation processes (such as volatile fatty acids). Thermodynamic control of substrate concentration on the rates of substrate metabolism and hydrogen and volatile fatty acid generation is included. This thermodynamic control allows for co-existence of microbes that use the same substrate but different fermentation pathways.

108 Absolute Instabilities in a Chemotaxis Model

Robert Marangell
University of Sydney
Timetable: p. 19

In the 1970's Keller and Segel introduced a class of models for bacterial chemotactic motion through a consumable substrate. In general these models exhibit travelling wave solutions. In this talk I will talk about the spectral stability of these types of travelling waves. In particular, I will discuss how the absolute spectrum plays a role in the stability analysis. This is joint work with P v Heijster and P Davis at QUT.

109 The changes induced in the far-field pattern upon rounding the corners of a structure*

Audrey Markowskei
Macquarie University
Co-authors: Paul Smith
Timetable: p. 14

An integral equation formulation is a satisfactory basis of numerical studies of the scattering of plane waves by a smooth obstacle. This approach can be adapted to accommodate obstacles with sharp corners: efficient methods may be devised using a graded mesh. In this talk, we quantify the changes in the far-field pattern of such sharp-cornered objects when the corners are rounded. We examine the dependence of the far-field pattern upon the parameter $k\rho$, where k is the wavenumber and ρ is the radius of curvature of the rounded corner. A number of structures with corners are examined with a variety of boundary conditions: Dirichlet, Neumann and impedance loaded.

110 Large-eddy simulations using the stretched-vortex subgrid model with artificial damping

Trent Mattner
The University of Adelaide
Timetable: p. 23

Turbulent flows are characterised by irregular three-dimensional motion over a wide range of spatial and temporal scales. In a direct numerical simulation of turbulent flow, the entire range of relevant physical scales is resolved on a computational grid. In many applications, including aerodynamic, atmospheric and oceanic flows, for example, the range of scales is so enormous that a direct numerical simulation is not computationally feasible. In a large-eddy simulation, only the large-scale features are resolved, which reduces computational cost, and a subgrid model is used to account for the effect of the unresolved subgrid scales on the resolved-scale flow.

One problem that is encountered in some large-eddy simulations are artificial undershoots and overshoots, which are especially problematic in the case of active scalars, such as temperature or density. A simple way to reduce these undershoots and overshoots is with artificial damping, but this must be applied with care so as not to interfere with the subgrid model. I will present results from large-eddy simulations of decaying homogeneous isotropic turbulence using the stretched-vortex subgrid model with artificial damping. The most promising results are obtained when there is some overlap between the subgrid model cutoff length-scale and the computational grid spacing.

111 Optimal observation times and the Fisher Information*

Thomas Alexander McCallum
The University of Newcastle
Timetable: p. 12

Consider a growing population governed by a simple birth process. This process has a parameter, namely the birth rate which is unknown in reality. In order to estimate this unknown parameter, we have to take some observations from the population at some observation times. An intriguing question is that at what times those observations should be made? Presumably, a good choice for those observation times is finding them such that the total volume of information gained from the sample to estimate the unknown birth rate is maximised. A good tool to measure that information is the Fisher Information. In this talk, we present our findings to calculate the Fisher Information to find the optimal observation times, numerically.

112 A dynamic stress model explains the delayed drug effect in artemisinin treatment of *Plasmodium falciparum* malaria

James McCaw
The University of Melbourne
Co-authors: Pengxing Cao, Sophie Zaloumis and Julie A Simpson
Timetable: p. 22

Artemisinin derivatives (ART) provide the first-line treatment for *falciparum malaria*, a major parasitic disease affecting millions of people every year. Their extensive use over the past decade has dramatically reduced the burden of malaria on human populations. However, over recent years clinical signs of drug-resistance have become established in South East Asia and ART therapy is now at risk of failure.

Here, we introduce a pharmacokinetic–pharmacodynamic (PK–PD) model that allows us to capture cumulative drug exposure effects that have recently been identified and implicated in the development of drug resistance. Our model introduces the concept of a drug-induced "stress" which parasites eventually succumb to (leading to a loss of viability). We suggest that artemisinin resistance is a result of changes in how parasites accumulate stress.

Using the model, we find that the previously reported hypersensitivity of early ring stage parasites of the 3D7 strain to dihydroartemisinin (DHA) is primarily due to the rapid development of stress, rather than a substantial increase in the maximum achievable killing rate. Of direct clinical relevance, we further demonstrate using our generalised PK–PD model that the complex temporal features of artemisinin action observed *in vitro* have a significant impact on predictions of *in vivo* parasite killing.

113 What is the sound of a ship wave?

Scott McCue
Queensland University of Technology
Timetable: p. 22

A sound wave can be visualised by constructing a time-frequency heat map called a spectrogram. As such, the spectrogram of a wave pattern can be associated with a sound, regardless of where the wave comes from. I will discuss spectrograms of ship waves. I hope to convince you that computing spectrograms provides an interesting and useful tool for analysing ship wakes. And just for fun, I will play you the sound of a ship wave.

114 Modelling Steaming Surtseyan Ejecta II

Mark Joseph McGuinness
Victoria University of Wellington
Co-authors: Emma Greenbank, Ian Schipper and Andrew Fowler
Timetable: p. 20

The context for this mathematical modelling is that of a particular kind of volcanic eruption which involves the bulk interaction of water and hot magma. I will talk about an extension of the modelling described by Emma Greenbank on the flashing of water to steam inside a hot erupted lava ball called a Surtseyan bomb. The overall motivation is to understand what determines whether such a bomb will fragment or just quietly fizzle out...

Previously, Emma presented partial differential equations that model transient changes in temperature and pressure in Surtseyan ejecta. We used a highly simplified approach to the temperature behaviour, to separate temperature from pressure. The resulting pressure diffusion equation was solved numerically and asymptotically to derive a single parametric condition for rupture of ejecta. We found that provided the permeability of the magma ball is relatively large, steam escapes rapidly enough to relieve the high pressure developed at the flashing front, so that rupture does not occur. This rupture criterion is consistent with existing field estimates of the permeability of intact Surtseyan bombs, fizzlers that have survived.

I describe a planned improvement of this model that allows for the fact that pressure and temperature are in fact coupled, and that the process is probably not adiabatic. A more systematic reduction of the resulting coupled nonlinear partial differential equations that arise from mass, momentum and energy conservation is described. We adapt an energy equation presented in G.K. Batchelor's book *An Introduction to Fluid Dynamics* that allows for pressure-work. This is work in progress.

115 Coupled, multi-strain epidemic models of drug-resistant pathogens

Michael Meehan
James Cook University of North Queensland
Timetable: p. 23

The growing threat of antimicrobial drug-resistance presents a significant challenge not only to the medical community, but the wider general population. Drug-resistant micro-organisms are already endemic in many communities — particularly in developing countries and lower socio-economic settings — with new strains, that enjoy even more extensive resistance, continually emerging. The misuse and overuse of existing antibiotics severely exacerbates the problem by rendering previously successful treatments ineffective. Indeed, we are already faced with a rapidly diminishing arsenal of effective therapies, with poor practice only accelerating us along this path. As such, concern mounts that "superbugs" will emerge that are resistant to all available treatments, with many fearing that we are approaching the end of the antibiotic era. To examine this growing public health concern, we introduce a general mathematical model designed to simulate the emergence and dissemination of drug-resistant strains of infectious diseases. The coupled multi-strain SIS/SIR/SIRS epidemic model we analyse is intended to replicate the phenotypic phenomenon of amplification, whereby individuals infected with a particular pathogen strain develop a new strain resistant to some combination of existing antibiotics. This introductory work, which should be considered as the first step in a wider investigation, focuses on the mathematical and biological aspects of the proposed coupled epidemic models.

116 How thick is your skin? The effect of cell behaviour on epidermal tissue structure*

Claire Miller
The University of Melbourne
Co-authors: James Osborne, Edmund Crampin
Timetable: p. 15

Although our largest and seemingly most accessible organ, surprisingly little is understood about how our skin's outermost layer, the epidermis, forms and maintains itself in a healthy state. Biological research has given us insights into epidermal tissue structure. For example, two characteristics we know are: the cells form sheets before they are shed from the skin's surface, and the epidermis can be sub-divided into layers with specific properties. In addition there is data showing the range of thicknesses of these epidermal layers within and between individuals. However we lack a definitive understanding on how these structures form, and we can't yet specify how different cell-level behaviours determine the known structural properties of the tissue.

In this talk we will focus on how the proliferative cells at the base of the epidermis divide, and how different scenarios for this process would influence the tissue structure. In order to investigate this we have developed a three-dimensional multi-cellular model using overlapping spheres to represent the epidermal cells. Cell fate decisions are stochastic and different hypotheses for potential cell division scenarios are considered. We compare the resulting effects on the epidermal tissue structure from these different hypotheses in relation to the known structural properties of the epidermis.

117 A probabilistic interpretation of the von Mises yield criterion

Tony Miller
Flinders University
Timetable: p. 24

A probabilistic interpretation of the classical von Mises yield criterion is presented in terms of the distribution of the shear stresses acting on all possible planes through a point in a material. The von Mises criterion is shown to be equivalent to a criterion expressed in terms of the root mean square (rms) of this distribution, assuming a uniform distribution of shear plane orientations. This rms value proves to be close to the simple mean of the shear stress distribution and also to the 87.5th percentile. This percentile result can be interpreted as saying that yielding takes place when the shear stresses at a point exceed some critical value for 12.5% of the plane orientations, which is an extension of the usual Tresca maximum shear stress criterion. Predictions based on other percentiles of the shear stress distribution are also given and compared to some classical experimental data from the literature. A yield criterion based on percentiles has a very straightforward and physically intuitive interpretation, and possible extensions of this kind of interpretation to anisotropic materials and fatigue are sketched.

118 Your friends are more popular than you. But your best friends are not so bad.

Lewis Mitchell
The University of Adelaide
Timetable: p. 13

The friendship paradox states that ‘your friends have more friends than you do’, or, in network terms, a node’s neighbours tend to have higher outdegree than the node itself. Much research on this important paradox has focussed on static properties of networks. By looking at two real, large social network datasets, we find that there is an additional subtlety to the friendship paradox: the strength of social ties between individuals as measured by contact volume relates to the strength of the paradox. We observe that it is in fact your most distant friends who most strongly have more friends than you do. Motivated by this observation, we use a conceptual stochastic model of information dynamics to investigate the effect of our finding on phenomena such as rumour spreading. We conclude with a discussion of the significance of our results for problems such as vaccination strategies, the formation of online ‘echo chambers’ or ‘filter bubbles’, and more broadly, the dynamics of social information flow.

119 Melting crystals in space*

Liam Morrow
Queensland University of Technology
Timetable: p. 20

In this talk, we consider a Stefan problem which describes experiments performed on the space shuttle Columbia. In these experiments, dendritic crystals were melted and their aspect ratios were recorded as a function of time. It was observed that as the crystals melted, the aspect ratio would increase before decreasing to unity. While previous models of these experiments provide reasonably accurate predictions of the melting rate of these crystals, they are unable to accurately describe the evolution of the aspect ratio. To extend these models we include two additional terms, namely surface tension and kinetic undercooling. Using a combination linear stability analysis and computation techniques, we assess the importance of these terms in replicating the behaviour of dendritic crystals as they melt to extinction.

120 Bayesian forecasting of seasonal influenza: putting prior knowledge into the prior

Robert Moss
The University of Melbourne
Co-authors: Alexander E Zarebski, Peter Dawson and James M McCaw
Timetable: p. 22

Bayes filters are a general probabilistic approach for estimating the state of a dynamic system ("nowcasting"), given a mathematical model of the system and a series of observations (each of which is typically noisy and/or incomplete). Long used in fields such as robotics and geophysics, this approach has more recently been applied to forecasting infectious disease epidemics, raising a number of new methodological challenges.

For the past 2 years, we have used Bayes filters to provide near-real-time forecasts of seasonal influenza epidemics in several Australian cities to both state and Commonwealth Departments of Health. We have been able to predict the size and timing of the epidemic peaks 4–6 weeks in advance, but forecasts in the very early stage of an epidemic are typically inaccurate and systematically biased. This is due, at least in part, to our use of broad (non-informative) uniform priors for key model parameters.

In this talk, I will detail how we are using key summary statistics — such as the epidemic timing, size, and duration — from the past 7 years to help construct more informative model priors, with the aim of reducing these biases and substantially improving forecast skill in the early stages of an epidemic. Because seasonal influenza is also influenced by external factors (such as climate), these priors must necessarily allocate some probability mass to model simulations that do not match past influenza epidemics. Using these informative priors in our forecasts will substantially improve their decision-support utility for public health epidemiologists.

121 A simple geometric flow model for fire propagation*

Gene Nakauchi
Queensland University of Technology
Timetable: p. 17

This talk is concerned with a two-dimensional geometric flow model that can be used as a simple model for the propagation of wildfires. The model is a generalisation of the well-studied curve shortening flow. We show how merging of two fire fronts produces oscillatory speeds at the intersection point that are much larger than the speeds of each front. The so-called jump velocity is calculated by computing exact travelling wave solutions. We also consider the so-called hole-closing problem, for which a simple closed curve shrinks in time according to the geometric flow rule. The problem for convex curves is interesting in the singular limit that the curvature term vanishes. The problem for non-convex curves can lead to self-intersection as demonstrated by numerical results computed using the level set method.

122 Snacking on sludge

Mark Nelson
University of Wollongong
Timetable: p. 22

The most widely used biological wastewater treatment method for both domestic and industrial wastewaters is the activated sludge process.

A significant drawback of the activated sludge process is the production of 'sludge'. The expense for treating excess sludge can account for 50–60% of the total operating costs in a wastewater treatment plant. Traditional methods for disposing of excess sludge, such as incineration, the use of landfill sites, and dumping at sea, are becoming increasingly restricted. Thus there is a pressing need, and growing interest, in methods that reduce the volume and mass of excess sludge produced as part of biological wastewater treatment processes.

A promising method to reduce sludge formation is to introduce a higher order organism, such as protozoa or metazoa, into the system which predate upon the bacteria. Experimental investigations have shown that the introduction of such predators can lead to substantial reductions in sludge formation.

We extend a standard activated sludge model by adding an equation for the predators. We provide a qualitative understanding of the model by finding analytically the steady-state solutions of the model and determining their stability as a function of the residence time.

In practice a target value of the mixed liquor suspended solids content within the reactor is specified. We investigate how effective predators are at maintaining the sludge content below the target value.

123 How geometric constraints affect the 3D morphology of di-block copolymer[J]

Yasumasa Nishiura
Tohoku University
Co-authors: Edgar Avalos, Takashi Teramoto and Hiroshi Yabu
Timetable: p. 19

It is known that di-block copolymer shows a variety of morphologies in bulk including lamellars, cylinders and double-gyroid. Suppose that a geometric constraint such as two parallel planes or spherical confinement is imposed, then the system starts to search for a more energetically comfortable state subject to the constraint. Notice that affinity to the environments (solvent) is also an important factor for this problem. We present a coupled Cahn–Hilliard equations as a means to find morphologies of diblock copolymers in three-dimensional spherical confinement. This approach allows us to find a variety of energy minimizers including rings, tennis balls, Janus balls and multipods among several others depending on the size and affinity. We modify the size of the interface between microphases to control the number of holes in multipod morphologies. Moreover morphological changes such as from lamellar shape to onion can be reproduced in a robust way as an appropriate parameter is changed. All these results are consistent with the experimental observation by transmission electron microtomography of multipods in polystyrene-polyisoprene diblock copolymers. This is a joint work with Edgar Avalos, Takashi Teramoto and Hiroshi Yabu.

124 Forecasting Monthly Turnover in Cafes, Restaurants and Takeaways in Australia*

Katelyn Grace Nolan
The University of Newcastle
Timetable: p. 13

The total turnover for cafes, restaurants and takeaway food services in Australia has been recorded by the Australian Bureau of Statistics (ABS) on a monthly basis from April 1982 to August 2016 (ABS, 2016). This data was used to construct a time series and a model that has been fitted to help forecast the future values of Australian turnover for cafes, restaurants and takeaway food services. The forecasted values from the model for June, July and August gave a relative error of 0.974%, 0.031% and 1.695%, respectively. Thus, an average relative error of 0.9%.

125 Parameter identification using QMC in an insulin-glucose model with uncertain data

Dirk Nuyens
KU Leuven
Co-authors: Pieter Gillard and Adrian Ebert
Timetable: p. 22

We apply Bayesian inversion to fit model parameters to an insulin-glucose model given noisy sensor data and extremely uncertain (guessed by patient) input data. Bayesian inversion techniques to identify parameters of a mathematical model have started to make use of high-dimensional integration methods in recent years, (see Stewart (2010), Schillings & Schwab (2013)). This in contrast with the traditional use of Markov chain Monte Carlo algorithms which are limited to Monte Carlo rates of convergence.

Our application quickly delivers us hundreds of dimensions without even considering Banach space valued parameters. Our method of choice for the high dimensional integrals which appear are quasi-Monte Carlo methods.

This is joint work with Pieter Gillard (UZ Leuven) and Adrian Ebert (KU Leuven).

126 Satellite orbit prediction using structure preserving geometric numerical integrators*

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

The use of Space based satellite technology, whether it be for industry, commerce or navigation, has now become part of everyday civilian life. Furthermore, Global Navigation Satellite Systems (GNSS), like those operated by the U.S military and the Russian republic are both fully operational and available to civilians at the click of a button. With the development of similar systems by both the European Space Agency (ESA) and the People's Republic of China, reliable, cost effective and highly accurate orbiting models are sought after.

The current theory of gravity, as proposed by Albert Einstein in his general theory of relativity defines gravity as a consequence of space-time curvature, where, among others things, can be caused by massive objects. Despite experimental evidence in favour of Einstein's theory of gravity, orbital models, such as the one used by the Global Positioning System (GPS) are still designed using a Newtonian framework where the *effects* of Einstein's theory are compensated for by daily corrections and the incorporation of a relativistic term into a Newtonian force model. It is proposed to design a relativistic, long term orbit prediction model where the governing equations of motion will be numerically integrated using sophisticated, structure preserving geometric numerical integrators. Comparisons can then be made with extensive GPS ephemeris data that is readily available so that the validity of the different models can be examined. The relativistic model will be designed in line with Australia's satellite

utilisation policy and is intended to encourage the Australian government to pursue space based satellite technology.

127 Industrial Mathematics and Wave Propagation

John Ockendon
University of Oxford
Timetable: p. 17

This talk will begin with a brief review of the evolution of industrial mathematics around the world and the ways in which it has stimulated various areas of mathematical research. One such area is that of partial differential equations, especially parabolic and elliptic ones. However, new ideas for hyperbolic equations have recently emerged in connection with i) violent elasto-plastic wave propagation, relevant to the defence industry, ii) wave propagation in layered media, relevant to the oil industry. A brief overview will be given of both these developments.

128 Verified numerical computation for stationary problem of Allen–Cahn equation[J]

Shin'ich Oishi
Waseda University
Co-authors: Kazuaki Tanaka
Timetable: p. 15

We are concerned with verified numerical computation methods for the stationary problem of the Allen–Cahn equation:

$$\begin{cases} -\Delta u = \varepsilon^{-2}(u - u^3) & \text{in } \Omega, \\ u = 0 & \text{on } \partial\Omega, \end{cases}$$

where Ω is a bounded polygonal domain (i.e., an open connected bounded set with polygonal shape) in $\mathbb{R}^2$, Δ is the usual Laplace operator, and $\varepsilon > 0$ is a small parameter related with the so called singular perturbation phenomenon. In addition, our objective includes the problem of finding positive solutions to this equation. Therefore, we also discuss the positivity of verified solutions if necessary. We present some numerical examples where solutions to this equation are verified with their rigorous inclusions.

129 Efficiently Solving Stochastic Mixed-Integer Problems combining Gauss–Siedel and Penalty-Based methods

Fabricio Oliveira
RMIT University
Co-authors: J. Christiansen, B. Dandurand and A. Eberhard
Timetable: p. 24

In this talk, we will present the development of a novel decomposition approach for mixed-integer stochastic programming (SMIP) problems that is inspired by the combination of penalty-based Lagrangian and block Gauss–Seidel methods (the PBGS method). In this sense, we will present the technical aspects associated with the development of PBGS, which in turn focus on exploiting in a computationally efficient manner the inherent decomposable structure that SMIPs present. The performance of the proposed method is compared with the classical Progressive Hedging method (PH), which also can be viewed as a Lagrangian relaxation-based method for obtaining solutions for SMIP. We will also present extensive numerical results performed using several instances from the literature that illustrate the efficiency of the proposed method in terms of computational performance and solution quality.

130 Generalized master equations and fractional Fokker–Planck equations from continuous time random walks with arbitrary initial conditions*

Ignacio Ortega Piwonka
University of New South Wales
Timetable: p. 13

In the standard continuous time random walk the initial state is taken as a non-equilibrium state, in which the random walking particle has just arrived at a given site. Here we consider generalizations of the continuous time random walk to accommodate arbitrary initial states. One such generalization provides information about the initial state through the introduction of a first waiting time density that is taken to be different from subsequent waiting time densities. Another generalization provides information about the initial state through the prior history of the arrival flux density. The master equations have been derived for each of these generalisations. They are different in general but they are shown to limit to the same master equation in the case of an equilibrium initial state. Under appropriate conditions they also reduce to the master equation for the standard continuous time random walk with the non-equilibrium initial state.

The diffusion limit of the generalized master equations is also considered, with Mittag-Leffler waiting time densities, resulting in the same fractional Fokker–Planck equation for different initial conditions.

131 Intrinsic excitability and the role of saddle slow manifolds

Hinke Osinga
The University of Auckland
Timetable: p. 22

Excitable cells, such as neurons, exhibit complex oscillations in response to external input, e.g., from other neurons in a network. We consider the effect of a brief stimulation from the rest state of a minimal neuronal model with multiple time scales. The transient dynamics arising from such short current injections brings out the intrinsic bursting capabilities of the system. We focus on transient bursts, that is, the transient generation of one or more spikes, and use a simple polynomial model to illustrate our analysis. We take a geometric approach to explain how spikes arise and how their number changes as parameters are varied. We discuss how the onset of new spikes is controlled by stable manifolds of a slow manifold of saddle type. We give a precise definition of such a stable manifold and use numerical continuation of suitable two-point boundary value problems to approximate them.

132 Pulsing Dynamics In An All-Fibre Laser With Saturable Absorber*

Robert Nawiekang Otupiri
The University of Auckland
Timetable: p. 14

Recent experimental work has revealed promising applications of laser systems with saturable absorbers for developing novel telecommunication and optical logic schemes. In this project, we characterize the behaviour of such a laser system by using a dynamical systems approach and associated numerical methods. Our primary focus is a model, developed by Yamada, that describes self-pulsing dynamics in lasers with saturable absorbers accurately and in good agreement with experimental findings.

We conduct a bifurcation analysis of an all-fibre laser system with emphasis on the relaxation times of both the gain medium and the absorber medium and their influence on the general behaviour of this laser system. In this way, an in-depth guide or map is obtained of how to generate desired output pulse characteristics.

Our results show a plethora of complex dynamics exhibited by the laser. Additionally, depending on the ratio of relaxation times of gain and absorber media, we obtain qualitatively different bifurcation diagrams. By carefully tuning the ratio of these relaxation times we can obtain a desired characteristic of the pulsed laser system.

133 Explicit Formulas of Area-preserving Deformation of Plane Curves in the Equicentroaffine Geometry[J]*

Hyeongki Park
Kyushu University
Timetable: p. 21

We present a formulation of discrete dynamics of discrete plane curves in the equicentroaffine geometry which is characterized as an area-preserving deformation. The deformation is governed by the discrete Korteweg–de Vries(KdV) equation. We also construct explicit formulas for the discrete deformation of discrete curves as well as the continuous deformation of smooth curves, in terms of the τ function. In the construction, we use the correspondence to the isoperimetric (arclength-preserving) deformation of plane curves in the Minkowski plane.

134 Modelling the effect of treatments for Coarctation of the Aorta on blood flow*

Dilan Pathirana
Griffith University
Co-authors: Barbara Johnston and Peter Johnston
Timetable: p. 20

Coarctation of the Aorta (CoA) is a serious congenital heart disease that is characterised by a narrowing of the aorta. Treatments are available for the disease but they all result in decreased life expectancy compared to healthy humans, as well as increased incidence of diseases such as hypertension and aneurysms. Two commonly used treatments are resection and end-to-end anastomosis, which is a surgical intervention, and stents, which is a catheter-based intervention. Since some treatments for CoA, such as stents, have only recently become commonly used, long-term clinical data are not available. We simulate blood flow through models of treated aortas to determine the effect that these treatments have on blood flow properties.

In this talk, one-dimensional models of treatments for CoA will be presented. Since treatments expand the narrowed region of the aorta, artery wall properties, such as stiffness, are also altered in this region. For example, sutures used for anastomosis and metal mesh stents would increase the stiffness of the artery wall. We model this increased stiffness by altering the Young's modulus of the artery wall. We will present results that show the effect of the treatments on blood pressure, change in aorta wall radius, blood flow velocity and wall shear stress.

135 Quantifying rates of cell migration and cell proliferation in coculture barrier assays reveals how skin and melanoma cells interact during melanoma spreading and invasion

Catherine Penington

Queensland University of Technology

Co-authors: Parvathi Haridas, Jacqui McGovern, Sean McElwain and Matthew Simpson

Timetable: p. 21

Melanoma is the third most common cancer in Australia, and associated with high rates of mortality. Melanoma spreading involves the migration of cancer cells amongst other native skin cells. We explore the interactions between melanoma cells and fibroblast cells by performing a suite of cell barrier assays with one or two types of cells at different ratios, and compare the experimental results to mathematical models. This allows us to investigate the interactions between the two types of cell, and reveals no evidence of interactions other than cell-to-cell contact.

136 The Diffusion of an Oncolytic Virus within a Solid Tumour*

Pantea Pooladvand

The University of Sydney

Timetable: p. 13

One of the biggest barriers in treating solid tumours is the inability of the therapeutic vectors to propagate throughout the tumour mass due to the high density of the tumour and tumour stroma. In this project, we explore this problem by introducing a system of reaction–diffusion equations, including tumour cells and anti-tumour viruses. We find that this system yields interesting oscillatory dynamics induced by diffusion. We also investigate an extension of our initial system by including inhomogeneous diffusion and two new populations to better model the treatment with anti-tumour viruses.

137 Noisy attractors: modelling using heteroclinic and excitable networks

Claire Maria Postlethwaite
The University of Auckland
Timetable: p. 12

Physical processes that evolve continuously with time can often be described by differential equations, and solutions of these can display a variety of behaviours, for instance, they may be at equilibrium, or be periodic in time. A heteroclinic network is type of solution consisting of a finite set of dynamical states connected by trajectories in phase space. Heteroclinic networks appear robustly in a range of applications and have been used as a way to model a number of types of biological and cognitive processes. Excitable networks are a close relation of heteroclinic networks for which finite amplitude perturbations are required to transition from one state to another.

In this talk I will present methods for realizing an arbitrary directed graph as a heteroclinic or excitable network in phase space. These networks attractors display a high sensitivity to low amplitude noise both in terms of the regions of phase space visited and in terms of the sequence of the transitions around the network. In some circumstances, the noise may even cause long-time correlations, or memory, in the sequence of transitions between states. I will give several examples of using heteroclinic or excitable networks as mathematical models for physical processes and discuss how these modelling approaches have the potential to be applied in a wide variety of fields, from population dynamics to cognitive processing and computational systems.

138 Faraday instability and nonlinear patterns in a two-layer liquid films with a free upper surface

Andrey Pototsky
Swinburne University of Technology
Co-authors: Michael Bestehorn
Timetable: p. 13

We study the linear stability of a laterally extended flat two-layer liquid film under the influence of external vertical vibration. The first liquid layer rests on a vibrating solid plate and is overlaid by a second layer of immiscible fluid with deformable upper surface.

Standing surface waves, excited as the result of the Faraday instability, can be characterized by a time-dependent relative amplitude of the displacements of the liquid-liquid and the liquid-gas interfaces. The in-phase displacements are associated with a zig-zag (barotropic) mode and the anti-phase displacement correspond to the varicose thinning mode. For the liquid parameters from the recent experiments with floating droplets we numerically determine the stability threshold in the vibrated two-layer film and compute the dispersion relation together with the decay rates of the surface waves in the absence of vibration. Nonlinear pattern formation in the unstable system is studied by means of an integrated boundary layer model.

139 A Monte Carlo evaluation of the sensitivity of bivariate Kolmogorov–Smirnov style tests*

Rachael Quill
University of New South Wales
Timetable: p. 12

The Kolmogorov–Smirnov (K–S) test can be used to determine whether two samples are drawn from the same parent distribution by considering the maximum difference between the two empirical distribution functions. To handle circular data, such as wind directions, Kuiper's test is an adaptation of the K–S test based on the same principle but accounts for circularity by combining the maximum and minimum differences between empirical distribution functions. Through simulation studies, it is shown that these univariate tests are powerful to changes in distribution structures, and the behaviour of their sensitivities are identified.

When considering bivariate samples, the empirical distribution functions can be defined in four different directions. A bivariate extension of the K–S test simply considers the maximum of the maximum difference between the empirical distribution functions defined in each of these four directions. In the astronomy literature, this extended K–S test is commonly used, but the consistency of the extension in relation to the univariate test has not been well studied. This research considers a Monte Carlo evaluation of the power of the bivariate K–S test in order to investigate its sensitivity in relation to that of the univariate version. By identifying parallel sensitivity behaviours to that of the univariate case, it is evident that the extension of the K–S test is consistent and powerful.

A bivariate extension of Kuiper's test to handle bivariate circular samples has not yet been suggested in the literature. This study therefore proposes an extension of Kuiper's test that is analogous to that of the extended K–S test. By analysing the sensitivity of this proposed extension through a Monte Carlo simulation study, it is possible to determine whether this extension is reasonable in relation to both the univariate Kuiper's test and the bivariate K–S test, and whether it is powerful against changes in distribution structures.

140 Hard-core interactions in one-dimensional velocity jump models*

Tertius Ralph
The University of Auckland
Co-authors: Steve Taylor
Timetable: p. 20

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

141 Modelling Anxiety and Depression to determine the effect of community stigma around mental health

Andrew Rawlinson
IBM Research Australia
Co-authors: Noel Faux, Roslyn Hickson and Melanie Roberts
Timetable: p. 23

We apply infectious disease compartment modelling techniques to anxiety / depression in a community to gain an understanding of the dynamics. The population is divided into compartments for those unaffected (U), affected by anxiety / depression (A), undergoing treatment (T), and with well managed anxiety / depression (M). The premise is that those people suffering from anxiety/depression can increase the risk of unaffected people developing anxiety/depression through 'epidemiological' contact. We investigate how stigma around mental health issues in a community affects the anxiety / depression dynamics. We also conduct a sensitivity analysis to gain insights on how different treatment policies might affect the overall mental health of a population with regards to anxiety / depression.

142 Bushfire characteristics and the ember risk of a property.

Melanie Roberts
IBM Research Australia
Co-authors: Andrew Rawlinson
Timetable: p. 17

Embers are the cause of the majority of house loss and damage from bushfires in Australia. Despite this, bushfire risk reduction activities, such as vegetation management and planning requirements, continue to focus on radiant heat and direct flame contact risks. Building on a previously presented model, we incorporate characteristics of the bushfire to improve the property-level measure of ember risk. By including bushfire impacts on ember generation, in addition to background wind conditions and the distribution of fuel load in the region, this work improves the previous understanding of ember risk to more accurately reflect the level of resilience required at the property.

143 Nobody expects a flu epidemic

Mick Roberts
Massey University
Timetable: p. 22

Every winter we experience flu epidemics, involving the strains influenza A H1N1 and H3N2, and strains of influenza B. There may or may not be cross-protection between the strains, and between seasons antigenic drift and population turnover reduce the community immunity. A simple model for a single strain, in which infection in year n provides immunity in year $n+1$ and partial immunity in year $n+2$ is presented. The within season dynamics are represented by a set of ordinary differential equations, and a final size equation deduced. The between season dynamics are captured by a discrete map. The model exhibits complicated dynamics in some regions of parameter space. Models for two interacting strains show more complicated behaviour, and the within season dynamics are critically dependent on the initial conditions.

144 Resistance is futile: Predictive modelling of a novel anti-adhesion bacterial therapy

Paul Allen Roberts
University of Birmingham
Timetable: p. 17

As the development of new classes of antibiotics slows, bacterial resistance to existing antibiotics is becoming an increasing problem. A potential solution is to develop treatment strategies with an alternative mode of action. In this talk, we consider one such strategy: anti-adhesion therapy. Whereas antibiotics act directly upon bacteria, either killing them or inhibiting their growth, anti-adhesion therapy works by competitively inhibiting the binding of bacteria to host cells. This prevents the bacteria from deploying their arsenal of virulence mechanisms, whilst simultaneously rendering them more susceptible to natural clearance. We develop a mathematical model to describe the anti-adhesion treatment of a Pseudomonas aeruginosa burn wound infection in the rat. Benchmarking our model against in vivo data from an accompanying experimental programme, we use the model to predict optimum treatment strategies.

145 Modelling emergent macroscale dynamics in long thin domains of microscale heterogeneity

Tony Roberts
The University of Adelaide
Timetable: p. 22

The slowly varying or thin layer assumption empowers understanding of many physical processes from dispersion in pipes and rivers, including beams, shells, and the modulation of nonlinear waves, to homogenisation of micro-structures. Extant mathematical approximation methodologies are typically self-consistency or limit arguments as the aspect ratio becomes unphysically infinite. The developing new approach is to rigorously analyse the dynamics based at each cross-section in a Taylor polynomial: here I discuss the case when the microscale is highly heterogeneous. Centre manifold theory supports the local modelling of the system's dynamics with coupling to neighbouring locales treated as a non-autonomous forcing. The union over all cross-sections then provides powerful new support for the existence and emergence of a centre manifold model global in the long domain, albeit finite sized. The approach may be used to quantify the accuracy of known approximations, to extend such approximations to mixed order modelling, and to open previously intractable modelling issues to new tools and insights.

146 A general reaction–diffusion model for acid-mediated tumour growth

Marianito Rodrigo
University of Wollongong
Timetable: p. 13

I will revisit the modelling of tumour invasion based on the acid-mediation hypothesis, i.e. the assumption that tumour progression is facilitated by acidification of the region around the tumour-host interface. The resulting destruction of the normal tissue environment promotes tumour growth. Gatenby and Gawlinski (1996) proposed a simplified reaction–diffusion system to model this hypothesis. Fasano, Herrero and Rodrigo (2009) used a nonstandard asymptotic analysis to study the properties of travelling waves that can be supported by the Gatenby–Gawlinksi model. Subsequently, Holder, Rodrigo and Herrero (2014) proposed an extension that incorporated a nonlinear acid production term. Another direction was given by McGillen, Gaffney, Martin and Maini (2014), where terms representing mutual competition between healthy and tumour cells, as well as acid-mediated tumour cell death, were added to the original Gatenby–Gawlinski model. In this talk I will consider a general reaction–diffusion model that includes the aforementioned models as special cases, with the aim of trying to determine under a quite broad framework the possibility of tumour progression that takes into account the acid-mediation hypothesis.

147 A more realistic agent based model for the Grandmother Hypothesis*

Danya Rose
University of Sydney
Timetable: p. 14

The Grandmother Hypothesis is a possible explanation for the evolution of human post-menopausal longevity, a rare trait among mammals and unique to humans among the primates. As grasslands spread and food sources changed, becoming less accessible to weaned youngsters without adult help and know-how, it became beneficial for older, less fertile females to take on caregiving roles for their grandchildren, allowing younger, more fertile females to have more children sooner. As more robust elders could provide more help, this spurred the evolution of greater longevity without a corresponding increase in age of menopause.

We discuss a probabilistic agent-based model that incorporates two sexes, mating, fertility-longevity tradeoffs, and the possibility of grandmother help, previously developed by Peter Kim, John McQueen, James Coxworth and Kristen Hawkes. The model is extended to include realistic mortality rates for wild chimpanzees and hunter–gatherers based on a Siler model for mortality and for age-dependent fertility in both cases, based on empirical data, with interpolation depending on a parameter representing longevity.

148 Mathematical problems in pandemic response

Joshua Ross
The University of Adelaide
Timetable: p. 16

The emergence of a novel strain of a virus poses an ever-present threat to our health and well-being. While vaccines provide us protection against a variety of viruses, the development and production of a vaccine for a novel strain will typically take at least five months. Furthermore, the characteristics of the virus, pertinent to its threat and control, are obviously largely unknown. Mathematics and statistics are key to determining the best response to such a threat. I will present some of the contributions I have made to this topic and some insights they have provided.

149 Point Vortex Dynamics on a Toroidal Surface[J]

Takashi Sakajo
Kyoto University
Timetable: p. 23

Interactions of vortex structures play an important role in the understanding of complex evolutions of fluid flows. Incompressible and inviscid flows with point-wise vorticity distributions in two-dimensional space, called point vortices, have been used as a theoretical model to describe such vortex interactions. The motion of point vortices has been investigated well in unbounded planes with boundaries as well as on a sphere owing to their physical relevance. On the other hand, it is of a theoretical interest to investigate how geometric nature of curved surfaces and the number of holes gives rise to different vortex interactions that are not observed in vortex dynamics in the plane and on the sphere. In the preceding studies, point-vortex interactions on surfaces of revolution have been investigated. In this presentation, we consider the dynamics of point vortices on a toroidal surface, which is a compact, orientable 2D Riemannian manifold with a non-constant curvature with one handle. Deriving the equation of motion of point vortices, we obtain some stationary point-vortex configurations and describe the interactions of two point vortices in order to cultivate an insight into vortex interactions on this manifold. This work is a joint work with Yuuki Shimizu at Kyoto University.

150 Topology of Ordinal Partition Symbolic Networks: Characterising System Dynamics*

Konstantinos Sakellariou
The University Of Western Australia
Timetable: p. 14

Complex network-based techniques in nonlinear time series analysis have recently attracted the interest of practitioners across several disciplines, e.g. paleoclimate research. We combine ideas which stem from symbolic dynamics, Markov chains and network theory to produce a transformation that maps a time series onto a graph. Quantisation of state space into a finite number of regions determined by symbolic orderings along with transition probabilities (obtained by means of frequency counts on the data) lead to a weighted network construction. Our findings show a connection between specific dynamical behaviours and network topologies. Stochastic dynamics leads to the random graph paradigm, whereas deterministic dynamics produces networks with a regular structure. Low-dimensional dissipative dynamics, such as chaos or hyperchaos, manifests in the form of a power-law strength distribution in the network representation.

151 Intelligent Decisions

Meinolf Sellmann
General Electric
Timetable: p. 21

At its best intelligence creates aesthetic and beauty, yet from a utilitarian perspective intelligence primarily serves the purpose of making better decisions. Recent technological advances have revived the vision of cooperative decision support systems that can automatically create and manage self-learning adaptive decision support models. In this talk I will highlight some of these technologies and their applications.

152 Phase Change Material: The future of firefighting suits?

Harvinder Sidhu
University of New South Wales
Timetable: p. 17

Fire fighting is a hazardous occupation and the use of good quality thermal protective clothing is vital in the prevention of heat-related injuries. Protective fire fighting clothing is generally chosen for its thermal and fire resistant properties, with consideration also given to the weight, bulk and ease of movement of the suit. This research proposes incorporating a phase change material (PCM) into the fabric of the fire fighting suit in conjunction with air gaps to increase the thermal protection. A mathematical model of heat transport through the suit containing PCMs and air gaps, and the skin is presented. We investigate the distribution of heat through the layers of the fire fighting suit and skin to determine whether the inclusion of a PCM layer and air gaps will provide increased thermal protection when exposed to a range of fire scenarios.

153 Quantifying the role of burn temperature, burn duration and skin thickness in an in vivo animal skin model of heat conduction

Matthew Simpson
Queensland University of Technology
Timetable: p. 24

To determine the extent to which heat conduction through skin is affected by skin thickness, burn temperature, and burn duration, we consider a suite of experiments using an in vivo porcine (pig) model. Fourteen different burn conditions are considered, and each burn condition is replicated at least four times, giving a total of sixty four individual experimental burns. The subdermal temperature within the skin is recorded as a function of time during each experiment. To quantitatively interpret the experimental data, we develop an exact solution of a simplified, depth-averaged, heat equation. Calibrating this solution to the experimental data provide estimates of the effective thermal diffusivity of the skin, α, and the effective thermal loss rate, k. Estimates of α and k are obtained for the fourteen different, clinically relevant, burn conditions. Overall, we find $\alpha = 0.03 \pm 0.02$ mm^2/s, and is approximately independent of the burn duration, burn temperature, and skin thickness (H). We find that $k = 0.002 \pm 0.002$ $/s$. In summary, our results provide contemporary estimates for the thermal properties of *in vivo* porcine skin, which has broad application to heat transfer modelling investigations of thermal injury prevention and thermal therapy studies.

This is joint work with Christine Andrews (University of Queensland) and Leila Cuttle (Queensland University of Technology).

154 Wave Reflection from an Overwashed Step*

David Matthew Skene
The University of Adelaide
Timetable: p. 14

Overwash is the process where water waves force a thin water flow over the surface of an otherwise unsubmerged body. The process itself involves a sharp transition in flow types wherein the flow characteristics change from deep water wave motion to shallow water bore motion. Overwash is believed to be a significant part of wave–sea ice interactions because the occurrence of overwash has a appreciable non-linear impact on how wave propagate through ice coverage.

In this presentation I will compare a computational fluid dynamics (CFD) and mathematical model of water overwashing a solid vertical wall. I will show how a significantly simplified mathematical model can reproduce the CFD's overwash and wave reflection results and explain how this reveals the underlying mechanics of the overwash phenomena.

155 A Stochastic Environment for Metapopulation Models

Andrew Smith
The University of Adelaide
Timetable: p. 21

A metapopulation is a population that is separated into geographically distinct locations, commonly referred to as patches. Typically, a metapopulation is modelled by first classifying each patch as either colonised or extinct and then allowing extinct patches to be colonised via migration. Both deterministic and stochastic approaches for such models exist, both with their benefits. Extending this idea, the model I will present will track the number of individuals on each patch. The model is spatially structured and accounts for the within patch dynamics of births, deaths and migrations via a Markov process. Modelling a metapopulation this way allows a more intuitive explanation of the persistence/extinction criteria by relating the criteria to the birth, death and migration rates of the species. However, one shortcoming of such a model is the exclusion of a changing environment. Various external influences such as fires, unexpected predation and unseasonal temperatures can drastically affect the environment and in turn, these events will impact the birth, death and migration rates of the species. To account for this type of dynamic environment, a new Markov process is introduced which models the current environment. It is coupled with the original metapopulation model by allowing the parameters in the transition rates to depend on the current environment. A functional law of large numbers is applied to the joint process as the population ceiling, N, goes to infinity, which shows that a piecewise deterministic Markov process (PDMP) can approximate the stochastic trajectory of the metapopulation, with a higher accuracy for larger N. The behaviour of the new PDMP is analysed to provide results regarding the extinction of the metapopulation.

156 New Computational Methods for Compression and Recovery of Random Signals*

Pablo Soto-Quiros
University of South Australia
Timetable: p. 20

Techniques associated with data compression are used in a number of areas of signal processing such as, to name a few, wireless communications and its applications in satellite communications, robotics, eye blinking, telephone networks, design for communication channels and synthetic aperture radar (SAR) images. In a general case of stochastic data, data compression is realized via transforms of random signals.

In this talk, we propose and justify new transforms of random vectors which provide, under the certain condition, the better associated accuracy than those optimal transforms: the generic Karhunen–Loeve transform (GKLT) and the transform considered by Brillinger (BT). It is achieved by special structures of the proposed transforms which contain more parameters to optimize compared to the known transforms.

157 Effect of partial slip on boundary-layer instability

Sharon Stephen
University of Sydney
Timetable: p. 13

The linear stability of the flow due to a rotating disc with surface roughness is considered. The aim is to determine whether surface roughness can lead to drag reduction in three-dimensional boundary layers, and thus have an effect on the transition process from a laminar flow to a turbulent flow. The surface roughness is taken into account by considering partial-slip boundary conditions. The basic steady flow is obtained as an exact solution of the Navier–Stokes equations. The linear stability of this flow for perturbations corresponding to stationary crossflow vortices is considered for the inviscid Type I instabilities. An asymptotic study is presented for large Reynolds number, with significant differences from the no-slip case. The solutions for the disturbed flow are determined in the appropriate asymptotic regimes. Predictions for the neutral wavenumbers and orientations of the crossflow vortices are obtained. Solutions are presented for anisotropic roughness and for isotropic roughness. Conclusions are drawn as to the significance of the results in relation to drag reduction.

158 Fibre drawing with temperature dependent surface tension

Yvonne Stokes
The University of Adelaide
Timetable: p. 22

In the drawing of optical fibres viscosity is strongly temperature dependent. However, surface tension is usually assumed to be independent of temperature. Under this assumption, and with temperature assumed to vary with axial position only and fibre tension used as an important control parameter, fibre drawing may be modelled solely as a fluid mechanics problem, and forward or inverse problems solved without knowledge of the temperature profile. If desired, the solution of the fluid mechanics problem may used in a thermal model to determine the temperature profile. This solution method fails for a temperature dependent surface tension.

In this talk we will assume surface tension to be temperature dependent. The model is remarkably similar to the constant surface tension case but coupled fluid mechanics and thermal models must be solved simultaneously. Notwithstanding this, we will see that our approach in the constant surface tension case provides very useful guidance for solving the inverse problem with non-constant surface tension.

159 Max-sum stable distributions and Extremes of Intermittent Events

Peter Samuel Straka
University of New South Wales
Timetable: p. 24

Motivated by empirically observed sequences exhibiting infinite mean inter-arrival times, we model sequences of events via a renewal process with heavy-tailed holding times. Events are marked by magnitudes, and we are interested in the distribution of the largest magnitude. In the regime of large numbers of events, limit theorems apply: Generalized Extreme Value (GEV) distributions govern maximum magnitudes, and stable distributions govern event occurrence times. In the uncoupled case (i.e. holding times and magnitudes are independent), Exceedances and Exceedance Times are Generalized Pareto and Mittag-Leffler distributed, respectively. We discuss parametric estimators. The coupled case has been looked at in the literature, but only since the very recent inception of max-stable distributions the joint limit laws can be characterized in full generality. Financial data suggests that this coupling is relevant, and developing inference methods to capture the coupling leads to many open questions.

160 Dimensional reduction for phylogenetic tree models

Jeremy Sumner
University of Tasmania
Timetable: p. 23

I will present a general method of dimensional reduction for Markov models on phylogenetic trees. The method reduces the dimension of the model space on a phylogenetic tree from exponential in the number of extant taxa, to quadratic in the number of taxa. A key feature is the identification of an invariant subspace which depends only bilinearly on the model parameters, in contrast to the usual multi-linear dependence in the full model space. I will concentrate on the algebraic foundations of the dimensional reduction, particularly discussing the identification of a novel representation of the Markov-type group embedded within the usual array of tensor products. Application to the computation of split (edge) weights on phylogenetic trees from observed sequence data will also be presented.

161 Flow surprises in a swirling electrolyte

Sergey Suslov
Swinburne University of Technology
Timetable: p. 13

We will discuss a deceptively simple problem of a flow in a thin cylindrical electrolyte layer, the setup used in physical modelling of hurricanes. A fluid motion is caused by an azimuthally acting Lorentz force appearing when a radial current flows in the electrolyte layer placed on top of a magnet with a vertical polarisation. A small layer thickness and the circumferential direction of the driving force suggest that the flow in such a system should be essentially uni-directional and could be described by approximate quasi-two-dimensional equations. To our surprise we found that not only the flow is fully three-dimensional, but also multiple axisymmetric flow solutions can exist for the same set of governing parameters. However, a linear stability analysis indicates that only one of such solutions can potentially lead to azimuthally periodic vortex patterns observed in our experiments. The analysis also forecasts a surprisingly rich and complex for such a simple geometry flow behaviour: it is likely to be dictated by multiple interacting instability modes that may lead to subcritical transitions between various observed flow patterns.

162 Mathematics-in-Industry Study Groups in Australia, New Zealand and Japan

Winston Sweatman
Massey University
Timetable: p. 22

Last year I had the privilege of participating in Mathematics-in-Industry Study Groups in Australia, New Zealand and Japan. In this talk I will describe some of the experiences.

163 Equivalence of upwind-element choice method and Lagrange–Galerkin method[J]

Masahisa Tabata
Waseda University
Timetable: p. 12

In devising stable and convergent numerical schemes for flow problems the key issue is how to approximate the material term, $\frac{D}{Dt} \equiv \frac{\partial}{\partial t} + u \cdot \nabla$, where u is the velocity. Main successful schemes are classified into two groups. One is based on the upwind approximation, and the other is based on the method of characteristics. Upwind-element choice method [1], which belongs to the first group, is one of the earliest developed upwind finite element methods. Here we show that this method is equivalent to Lagrange–Galerkin method in the second group. In the case of convection–diffusion equation this equivalence is rather simple in the P1-finite element and the mass-lumping approximation. In the case of the Navier–Stokes equations we show the equivalence in the P1 iso P2/P1 element and the mass-lumping approximation. In both cases we prove the convergence of the finite element solution to the exact solution in the best possible order under the condition $\Delta t \leq ch$. The analysis is performed in the framework of L^2 theory. For the convergence in L^∞ norm in the convection–diffusion equation we refer to [2].

References.

[1] M. Tabata, A finite element approximation corresponding to the upwind finite differencing, Memoirs of Numerical Mathematics, 4(1977), 47–63.
[2] O. Pironneau and M. Tabata, Stability and convergence of a Galerkin-characteristics finite element scheme of lumped mass type, International Journal for Numerical Methods in Fluids, 64(2010), 1240–1253.

164 Nonlinear diffusion as a model mechanism for pattern formation in yeast biofilms*

Alexander Tam
The University of Adelaide
Timetable: p. 16

Yeasts are an important model organism in cell biology research. They have extensive effects on human life — and not just in the production of alcohol! They also cause many pathogenic infections by contaminating medical devices, and are highly resistant to anti-microbial therapies. This resistance is due to yeast's ability to form colonies, for example biofilms. Pattern formation in bacterial biofilms has been extensively studied, but much less is known about yeast colonies. Recent research hypothesises that a reaction–diffusion system with nonlinear cell diffusion can capture much of the yeast biofilm pattern formation. In this talk, we explain how constructing sharp-fronted travelling wave solutions allow us to estimate the speed of colony expansion. We will then show that a two-dimensional travelling wave front is unstable to non-planar perturbations under some conditions. This mathematical framework provides a basis for comparison with yeast growth experiments.

165 Dispatchability of Wind Power with Battery Energy Storage in South Australia

Silvio Tarca
The University of Adelaide
Co-authors: Matthew Roughan, Nesimi Ertugrul and Nigel Bean
Timetable: p. 23

In fiscal year 2016, 42% of electricity generated in South Australia came from intermittent renewable energy sources — a level of penetration that presents challenges to the economic supply of baseload power of acceptable quality. This study measures the improvement in the dispatchability of intermittent renewable energy from an SA wind farm coupled with a utility-scale battery using model predictive control and real-world data published by the Australian Energy Market Operator. The process of wind power dispatch with battery energy storage is represented as an incremental state-space model. The state-space model properly accounts for battery charge/discharge efficiency, and its incremental formulation allows the controller to penalise control effort.

166 How much does dynamic scheduling improve queueing performance?

Peter Gerrard Taylor
The University of Melbourne
Co-authors: John Gilbertson
Timetable: p. 19

Many queueing systems are controlled using an appointments process. However, even with scheduled arrivals, the random nature of service duration can cause undesirable outcomes such as customer waiting or server-idleness.

In this talk, we shall use Markov decision process techniques to study how much better we can do in terms of these performance measures if we allow ourselves to schedule the arrival of one customer only at the arrival time of the previous customer, rather than pre-scheduling the arrival times of all customers at once.

We make some surprising observations about the optimal schedule.

167 Deformation of a large insect screen

Steve Taylor
The University of Auckland
Timetable: p. 15

We model the displacement of a large insect screen which is a component of a sliding French door system. Because of its size and light weight, the screen is susceptible to transverse movement due to wind. The top and bottom edges of the screen sit in slots, allowing the screen to be easily slid across the doorway. A horizontal tension is imposed to maintain the screen's shape. The manufacturer finds that strong winds can blow the screen out of its slots and wishes to understand this.

The problem is from the 2015 Mathematics in Industry Study Group at QUT, Brisbane and this talk is an update on one of the approaches used at the meeting; modelling the screen as a membrane. We derive partial differential equations for the deformation from an associated variational formulation. We look at approaches to solving the system.

168 Effect of delayed feedback on the dynamics of a self-pulsing laser

Soizic Terrien
The University of Auckland
Co-authors: Bernd Krauskopf and Neil G. R. Broderick
Timetable: p. 14

Semiconductor lasers are well known to produce a wealth of different dynamics. Pulsing regimes, where the laser releases periodically a short, high-amplitude pulse of light, are particularly interesting for many applications, such as telecommunications. We investigate here the effect of a delayed optical feedback on the dynamics of a self-pulsing semiconductor laser with saturable absorber. A bifurcation analysis of the Yamada model with feedback — a system of three delay differential equations for the slow gain G and absorption Q and the fast intensity I — is performed, considering both the feedback strength and delay as bifurcation parameters. The resulting bifurcation diagram highlights a rapidly increasing complexity of the system dynamics when the feedback delay is increased from zero. Feedback-induced dynamics includes a high level of multistability, with up to five coexisting stable pulsing periodic solutions with different amplitudes and periods. An attractor map of the multistable laser is computed in the plane of perturbations on gain G and intensity I, and reveals a Cantor set-like intermingled structure of the associated basins of attraction. This structure emerges as an explanation for the experimentally-observed sensitivity of the laser to small perturbations.

169 Modelling the Surge Beds in the Emergency Department of a Hospital by Markov Decision Process and Queueing Theory

Ali Tirdad
The University of Melbourne
Timetable: p. 16

We apply Markov decision theory to the problem involving $M(t)/M/c/c$ queue to conduct a case study at Kelowna General Hospital (KGH) in British Columbia, Canada. Health-care systems have been challenged in recent years to deliver high quality care with limited resources. Emergency departments (ED) are perhaps the most sensitive components of the health-care system due to their nature. KGH has extra beds in its ED in a unit called the surge section. They use this section in case the ED is overcrowded. There is no systematic approach to when this section should be in use, and managerial decisions are made based on the what seems necessary at the time. Therefore, they want to have a policy to know when to use the surge section.

We provide the Markov decision process (MDP) model for solving the problem. In this model, the arrival rate is time-dependent, and there are two levels for the number of servers. We prove that decisions for an MDP with periodic and time-dependent Poisson arrivals are periodic as well. Consequently, the contour control policies which are obtained based on the optimal decision show periodic behaviour as well. Numerical results presented support this claim.

170 Flighty Dimorphin Yeast Arrangers

Hayden Tronnolone
The University of Adelaide
Co-authors: Benjamin Binder
Timetable: p. 21

Yeast cells typically reproduce through the growth of a protrusion called a bud, which breaks away to form a new cell. In response to nutrient deprivation, dimorphic yeasts are able to alter the location of bud sites, change the shape of daughter cells and prevent buds from detaching, which produces chains of elongated cells known as pseudohyphae. It is known, however, that similar spatial patterns may be produced by bacteria due to diffusion-limited growth (DLG) and without a transition to the pseudohyphal growth mode. We develop a lattice-based model of yeast cell growth to determine the relationship between the dominant growth mode and the conditions within the growth medium. The relative importance of each growth mode is quantified using indices that describe the spatial distribution of the cells.

171 Modelling Animal Navigation*

Rebecca Turner
The University of Auckland
Timetable: p. 12

Animals, such as homing pigeons and turtles, are capable of navigating very long distances towards targets, without the use of technology that humans rely on. The mechanisms that they use to navigate, even in the absence of familiar landmarks, are still unknown. Nevertheless, several hypotheses exist based on the idea of the animals using a grid map (Turner et el. 2016). These models take as inputs two predictably varying environmental fields, e.g. the geomagnetic field and an atmospheric chemical gradient, as well as a corresponding cognitive map. The output of the models is the predicted direction that the animal thinks is towards the target. Directions are computed for a range of release site locations in order to compare with observed animal movements. However, the problem with comparing these models to experimental data is that most of the time we have measurements from only one hypothesized coordinate field as well as the observed homing directions. In this talk I will discuss how to invert the models to make predictions about possible second coordinate fields. Results will be shown from applying these methods to a dataset of pigeon bearings from New York State, where one hypothesized coordinate field is the geomagnetic field.

172 Multiphase modelling of atherosclerotic plaque growth*

Ishraq Uddin
University of Sydney
Timetable: p. 19

Atherosclerosis is among the leading causes of death worldwide due to its implication in heart attacks and strokes. The disease is characterised by the localised thickening of artery walls due to the buildup of fatty cholesterol-filled streaks. Specifically, atherosclerotic plaques form as an inflammatory response to the presence of cholesterol-carrying low density lipoproteins inside artery walls. The presence of LDL stimulates the recruitment of macrophages from the bloodstream to consume the LDL, which become engorged with lipid and eventually break down to release free lipids and apoptotic cell material into the surrounding plaque. Plaque dynamics consist of many nonlinear processes between various cellular and biochemical species besides the recruitment and consumption of LDL by macrophages.

In this talk, we present a partial differential equation model for an early stage atherosclerotic plaque. The model accounts for interactions between macrophages, apoptotic cells, and lipids, modelling the plaque space as a 1D domain with a moving boundary. Our model is based on a multiphase framework with mass conservation, and incorporates the effects of cell crowding by having the domain expand to accommodate new material. We discuss how this model gives insight into how early plaque development depends on the levels of LDL in the bloodstream.

173 Coupled Orbital and Thermal Evolution of Major Uranian Satellites*

Attique Ur Rehman
The University of Auckland
Timetable: p. 17

We have developed a model of the orbital and thermal evolution of the five major Uranian satellites over millions of years. The model consists of detailed ordinary differential equations for the orbital evolution coupled to the one-dimensional heat equation for the thermal evolution. We present results obtained from numerical testing that show how the variation in initial physical parameters of satellites effect the orbital semi-major axis, eccentricity, and inclination of the satellites. We also present results of the 3:1 mean motion commensurability of the satellite Miranda with the satellite Umbriel.

174 Localized patterns in a three-component FitzHugh–Nagumo model via an action functional

Petrus van Heijster
Queensland University of Technology
Timetable: p. 19

In this talk, I will combine geometrical singular perturbation techniques and an action functional to study the existence and stability of stationary localized structures in a singularly perturbed three-component FitzHugh–Nagumo model. The action functional replaces the Melnikov-type integral approach used in previously to explicitly derive existence conditions for the stationary localized structures. In addition, the action functional can also be easily used to determine critical information with regards to the stability of the stationary localized structures — circumventing a tedious Evans function computation. This highlights the strength of the action functional approach.

This is joint work with C.-N. Chen, Y. Nishiura and T. Teramoto.

175 Introducing Dedalus: A new, efficient, accurate, and flexible toolkit for computational fluid dynamics

Geoff Vasil
University of Sydney
Timetable: p. 24

In spite of outward appearances, many of the partial differential equations used in contemporary fluid dynamics, and the methods used to solve them, contain enough similarities that one may consider their implementation under a very general framework. In this talk, I describe an equation-agnostic toolkit that incorporates a wide range of possible solving schemes, accurate pseudo-spectral spatial representations, and the expressive python language. Flexibility is a requirement. User specify their own equations in text form. The code runs efficiently on computing platforms ranging from laptops to large-scale supercomputers. Thus far, Dedalus has primarily been used to study problems arising in astrophysical and geophysical fluid dynamics (see e.g., vimeo.com/dedalus), but there exist many more potential applications.

176 A recursive algorithm for inversion of linear operator pencils on Hilbert space

Geetika Verma
University of South Australia
Timetable: p. 13

Systems of linear equations are ubiquitous and widely applied across the sciences. In many cases the system coefficient is an operator that depends on an unknown parameter. We wish to understand how changes in the parameter will alter the solution. If the coefficient is a linear operator pencil which depends on a single complex parameter and the resolvent is analytic on a deleted neighborhood of the origin we will show that the resolvent can be calculated by a recursive reduction procedure. For finite dimensional problems the resolvent has a finite order pole and the procedure will terminate after a finite number of steps. For infinite dimensional problems the resolvent may have an isolated essential singularity. We will illustrate the proposed inversion procedure with an elementary matrix example.

177 Error bounds and approximations for heavy-tailed stochastic systems

Maria Vlasiou
Eindhoven University of Technology
Timetable: p. 19

Many random phenomena are driven by data characterised by asymmetry and thick tails. A typical example is insurance loss data, which are known to be heavy-tailed and oftentimes non-negative, right-skewed and leptokurtic. In this case, accurately fitting the tail is an important modelling task, as the losses in the tail, though rare in frequency, are the ones that have the most impact on the operations of an insurer, possibly leading to bankruptcy. Similar concerns dominate other stochastic systems with heavy-tailed input variables.

At the same time, exact analysis of systems with heavy-tailed input is typically challenging. The usual route is to develop suitable approximations. One way to do so is to approximate the heavy-tailed data with a distribution more suitable for computations. The typical class of distributions chosen is the phase-type distributions, as this class has two main advantages. First, it can be used to approximate any distribution on a positive support arbitrarily closely and second, it introduces a structure in the model that allows for the usage of powerful computational (iterative) techniques known as matrix-analytic methods. Known disadvantages of various approximation schemes for heavy-tailed data are the quality of the approximation for small or large values of the support or technical requirements, such as finite higher moments, which may impose unnecessary restrictions.

In this talk, we present error bounds and accurate approximations for stochastic systems with heavy-tailed input. Using ideas from spectral theory and perturbation analysis, we combine desirable characteristics of the main approximation directions while avoiding their most glaring disadvantages. The approximations we discuss maintain the computational tractability of phase-type approximations, capture the correct tail behaviour, do not require finite higher-order moments, and provide small absolute and relative errors, independent of the initial conditions.

178 Using a Bio-Control Agent on a Crop Pest: A Case Study

Graeme Wake
Massey University
Co-authors: Jairaj Promrak
Timetable: p. 22

The Sharpe–Lotka–McKendrick partial differential equation is extended and combined with an integro-differential equation to study interacting populations of mealybugs and released green lacewings, where an age dependent formula is employed for the prey (mealybug). The solutions and their stability of this system will be considered. The steady age distributions and their bifurcation diagrams are also obtained.

179 Data augmented MCMC for early characterisation of novel pathogens*

James Nicholas Walker
The University of Adelaide
Timetable: p. 14

Outbreaks of novel pathogens occur on a regular basis; most notably strains of influenza. In the early stages of such an outbreak, governments attempt to implement mitigation strategies that are proportionate to the level of risk posed by the disease. Hence this risk must be accurately assessed, typically in terms of clinical severity and transmissibility of the pathogen. Data obtained during these early stages of an epidemic typically only reveal the number of symptomatic cases at a daily resolution, so the underlying epidemic process is largely unobserved. This talk discusses estimating underlying parameters of a range of continuous-time Markov chain epidemic models using a powerful Bayesian method known as data augmented Markov chain Monte Carlo (MCMC).

180 Multilevel Monte Carlo for likelihood-free Bayesian inference of rate parameters for stochastic models of biochemical reactions*

David James Warne
Queensland University of Technology
Co-authors: Ruth E. Baker and Matthew J. Simpson
Timetable: p. 17

Stochastic models of biochemical reaction networks are often more realistic descriptions of cellular processes compared to their deterministic counterparts when small populations of certain chemical species are considered. The statistical inference of reaction rate parameters of these models, however, is a computationally intensive task that often relies upon likelihood-free methods, also called approximate Bayesian computation (ABC). We present a modified ABC approach that is based on multilevel Monte Carlo; a stochastic variant of multigrid methods. Our method constructs an approximation of the posterior distribution function through a telescoping summation of biased estimators. We demonstrate the effectiveness of our method using several stochastic models of biochemical reaction networks and compare performance with Markov chain Monte Carlo and sequential Monte Carlo.

181 A Pore-Scale Investigation of Low-Salinity Waterflooding in Uniformly Wetted Porous Media

Michael Greg Watson
University of Sydney
Co-authors: Steven McDougall
Timetable: p. 21

Within the global petroleum industry, much recent debate has surrounded the use of low salinity (LS) water injection as a method of oil recovery. Both laboratory and field-level studies have indicated significant benefits compared to conventional high salinity (HS) waterflooding, but the presence of many conflicting results indicates that the mechanisms underlying this phenomenon remain poorly understood. In this presentation, we discuss the development of a novel, steady-state pore network model that aims to address this uncertainty by simulating the displacement of oil from a HS-bearing network following LS brine injection. The model permits systematic investigation of parameters, with the aim of identifying features of the crude oil/brine/rock system that may be critical to incremental oil production following LS brine injection. By employing a tracer algorithm to track the evolution of brine salinity within the network, and assuming that a reduction in salinity leads to localised wettability alteration, substantial perturbations to standard pore filling sequences are observed. Our study indicates that LS effects may be strongly scenario-dependent, where factors such as the initial wettability state of the system and the pore size distribution of the underlying network can play crucial roles.

182 Neural Excitability and Singular Bifurcations

Martin Wechselberger
University of Sydney
Timetable: p. 19

We discuss the notion of excitability in slow/fast neural models from a geometric singular perturbation theory point of view. We focus on the inherent singular nature of slow/fast neural models and define excitability via singular bifurcations. In particular, we show that type I excitability is associated with a singular Bogdanov–Takens/SNIC bifurcation while type II excitability is associated with a singular Andronov–Hopf bifurcation. In both cases, canards play an important role in the understanding of the unfolding of these singular bifurcation structures. We also explain the transition between the two excitability types and highlight all bifurcations involved, thus providing a complete analysis of excitability based on geometric singular perturbation theory. (This is joined work with Peter de Maesschalck, Hasselt University, Belgium)

183 When Nature Comes Knocking — Disasters, Risk and Resilience

Martine Woolf
Geoscience Australia
Timetable: p. 23

Figures reported in the press indicate the global financial costs from disasters in 2016 were in the order of a staggering $175bn AUD, which still ranks as a 'mid-range' year. The impacts of disasters can be significant and long-lasting, and for many developing countries the consequences are catastrophic. Moreover, costs from natural disasters continue to show a steeply rising trend over the past 40 years, both nationally and globally. Many studies have investigated what causes and contributes to this trend, with the aim to understand how to halt and reverse it.

There is growing recognition of the potential value of investment in mitigation and resilience actions to minimise or prevent impacts of future disasters. The 2015–2030 UN 'Sendai Framework for Disaster Risk Reduction' emphasises the need for countries to understand their risk as an evidence base to build and direct future resilience actions.

Understanding disaster impacts and risks should not rely on analysis of historical data alone. Disasters are by nature extreme and therefore rare events. Historical records tend to be too short to reflect the full range of potential events, and detailed observations for past events are even more limited or non-existent. Over the past 30 years, computational disaster risk modelling techniques and approaches have matured as an approach to overcome the limitations in historical disaster observations. Risk, defined as the probabilistic impacts of natural disasters, is quantified as a function of the hazard, the elements exposed to the hazard, and their vulnerability. Each of those components of risk is modelled in detail using mathematical, statistical and engineering approaches, often combined through stochastic approaches.

This approach is used to model potential disaster impacts and risk for a range of risk management applications. This includes insurance and financial management applications, as well as preparation and recovery planning for disaster management. However, disaster impact modellings is not yet achieving its potential; adoption is limited because multi-disciplinary models are expensive to construct, data hungry, computationally expensive to run, and difficult to validate and interpret for disaster management practitioners. A particular issue is the challenge of quantifying uncertainty on model outputs across its components, the limited understanding of the meaning of this uncertainty. Accounting for these uncertainties should direct appropriate interpretation and use of model outputs and results.

This talk will illustrate the principles, potential and limitations of disaster impact modelling using examples for the tsunami. Tsunamis are powerful examples of nature's knocks, as communities lose lives and livelihoods, buildings, and critical infrastructure. Recent work has improved geophysical hazard modelling of these events, both at a global, national and local scale. These model outputs are used to strengthen resilience of coastal areas by providing information on potential events beyond the range of historical experience. The talk will further discuss potential methods to model uncertainty in these estimates. Results demonstrate biases and sensitivities associated with assumptions, model choice and available data, despite the use of probabilistic methods used to make models more robust. Irrespective of their limitations, computational disaster models remain an important source of information to build our understanding of severity and frequency of future tsunamis. They are therefore a key component of understanding and potentially reversing the long-term increasing trend in disaster losses.

184 Fast numerical approximation of intermittent maps*

John Wormell
University of Sydney
Timetable: p. 14

One-dimensional discrete-time chaotic systems are classic toy models for chaotic dynamics. However, their statistical properties are often quite difficult to reliably study numerically. Many systems of interest exhibit regularity that existing methods do not take advantage of.

Modern function approximation techniques, based on Chebyshev series, provide very fast and extremely accurate ways to represent differentiable and analytic functions on compact intervals. We illustrate how transfer operators of sufficiently differentiable Markov uniformly-expanding maps can be represented as lazily-evaluated almost-upper triangular infinite matrices acting on Chebyshev series coefficients. This structure can be harnessed to numerically approximate a statistical properties that can be obtained from the transfer operator formalism. This technique is spectrally accurate: for example, the associated errors for smooth maps are super-polynomially small with respect to computational complexity.

A notoriously difficult numerical problem is the simulation of statistical properties of intermittent systems. This is because current methods require very long integrations near a neutral fixed point. However, by calculating an asymptotic approximation to the Abel function of the underlying map near the fixed point, it is possible to approximate the transfer operator of the induced map quickly and with exponentially small error. We then apply Chebyshev methods to the induced maps, from which statistical properties of the full intermittent system may be recovered. Using this algorithm, one may calculate statistical properties of the Pomeau–Manneville map to 13 decimal places in under 20 seconds.

185 Multivariate Approximation for Analytic Functions with Gaussian Kernels*

Henryk Wozniakowski
Columbia University
Timetable: p. 14

We approximate d-variate analytic functions defined on $\mathbb{R}^d$ which belong to a tensor product reproducing kernel Hilbert space. The kernel of this space is Gaussian with non-increasing positive shape parameters. The error of approximation is defined in the L_2 sense with the standard Gaussian weight. We study the worst case error of algorithms that use at most n arbitrary linear functionals on d-variate functions. We prove that for arbitrary shape parameters there are algorithms enjoying exponential convergence, but the exponent of exponential convergence depends on d and goes to zero as d approaches infinity. We also study various notions of tractability and find necessary and sufficient conditions to get these notions in terms of shape parameters.

Joint work with I. H. Sloan.

186 Stretching of Viscous Threads

Jonathan Wylie
City University of Hong Kong
Timetable: p. 13

We investigate the motion of a slender axisymmetric highly viscous threads that are extended either by gravity or by an applied stretching force. Using matched asymptotic expansions, we obtain solutions for the full initial-boundary-value problem and show how inertia ultimately must become important. The solution allows us to understand the complicated mechanisms that underlie highly persistent filaments. This is joint work with B. Hajek, H. Huang, R.M. Miura and Y.M. Stokes.

187 Mathematical Model on Change in Oxygen Concentration in Blood Vessels[J]*

Satoshi Yamada
Kyushu University
Timetable: p. 20

We study the mathematical model of angiogenesis based on the network model of true slime mold. The previous model depends on the blood flow rate in the blood vessels. As a result of simulation using this model, we could obtain useful results as reproduction of retinal vascular network. Currently, we try to improve the model. In particular, we are trying to construct a mathematical model that also depends on oxygen concentration in blood vessels. Ultimately, we would like to create a more reproducible model.

In this presentation, I will propose a mathematical model on changes in oxygen concentration in blood vessels. In addition, I would like to announce how the oxygen concentration changes depending on the thickness and flow rate of the blood vessels, and the results of the simulation.

Collaborators: Atsushi Tero (Kyushu University), Akiyoshi Uemura (Nagoya City University), Hiroshi Kori (Ochanomizu University) and Miura Takashi (Kyushu University)

188 Biologically inspired dynamical frequency separation technique[J]*

Tatsuya Yamaguchi
Kyushu University
Co-authors: Atsushi Tero
Timetable: p. 17

Animals receive a lot of external information with sense organs, and their brain treats the input signals. Functional specialization is a famous structure of brain. It says that the areas of brain can be separated into different areas specialized for different functions, such as auditory cortex, visual cortex, etc. When we focus on the auditory cortex, each area in auditory cortex is specialized for different range of frequencies, which is presented as tonotopy map. Tonotopy suggests that the brain can detect frequency and classify the input signals. From the mathematical view point, Fourier transformation is a good way for wave analysis. From the biological view point, on the other hand, integration in Fourier transformation might be unreasonable because the brain has to keep signal data for some period of time. In this talk, I will propose a mathematical model for classifying frequency of wave data by using phase oscillators. Our model utilizes the collective motion of oscillators, and treats the input wave dynamically.

189 Verified Algorithm for the Gamma Function using Double Exponential Formula[J]

Naoya Yamanaka
Meisei University
Co-authors: Tomoaki Okayama and Shin'ichi Oishi
Timetable: p. 20

An algorithm is presented for computing verified result for the value of the real gamma function. It has been shown that the double exponential formula is one of the most efficient methods for calculating integrals of the form. Recently, a useful evaluation based on the double exponential formula over the semi-infinite interval has been proposed. However, the evaluation would overflow when applied to the real gamma function directly. In this talk, we present a theorem so as to overcome the problem in such a case. Numerical results are presented for illustrating effectiveness of the proposed theorem in terms of the accuracy of the calculation.

190 Fast verification method for solving matrix equations by QR factorization[J]

Yuuka Yanagisawa
Waseda University
Co-authors: Shin'ichi Oishi
Timetable: p. 20

We are concerned with the matrix equation $Ax = b$ where A is an $ntimesn$ real matrix and x and b be n-vectors. If $A = QR$ is a QR factorization, then we can write $QRx = b$ where Q is $n \times n$ with orthonormal columns and R is $n \times n$ and upper triangular. This equation is easy solve because R is triangular. The principal method for computing QR factorization is Householder triangularization, which is excellent numerical stability. Nevertheless, QR factorization is not the standard method for computing the approximate solution to $Ax = b$ in practice, since it requires two times computational cost of LU factorization with partial pivoting, which is unstable for matrices with large growth factors. (In practice, such matrices are very rare in applications.).

Assume that an approximate solution $\tilde{x}$ is given with an approximate QR factorization. In this talk, we will present an accurate and fast method using QR factorization for proving nonsingularity of A and for calculating rigorous error bounds for $\|A^{-1}b - \tilde{x}\|_\infty$. We also present detailed analysis of our method and some numerical results.

191 Control of a robot acting autonomously using a mathematical model of the action of a unicellular organism[J]*

Takahiro Yano
Kyushu University
Co-authors: Tatsuya Yamaguchi, Atsushi Tero and Toshiyuki Nakagaki
Timetable: p. 19

Generally, it is thought that the movements of unicellular organisms are simple. However, it has been found in experiments by Nakagaki et al that Tetrahymena (a water-dwelling unicellular organism) can memorise the shape of the surrounding space. We study the mechanism of spatial memory capacity of Tetrahymena and propose a mathematical model to reproduce this movement. Furthermore, Tetrahymena is thought to be able to memorize space with less storage capacity. By applying the memory action of Tetrahymena to the control of a robot that operates autonomously, we think that it will become possible to memorise space with a simple algorithm. We propose a mathematical model to control a robot using this spatial memory ability.

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192 Mathematical Model of True Slime Mould Tube Network and Its Simulation[J]*

Ryusei Yoshimine

Kyushu University

Timetable: p. 16

When true slime mould contacts food, they crowd around it and absorb nutrients. When two or more foods are given at the same time, they transform their bodies into a tubular shape and form a path connecting the foods. By using this property, true slime mould can solve a maze with the shortest path. At this time, they disappear the pipe which is a dead end and a bypass and leave only the pipe which corresponds to the shortest path. This mechanism is represented by a mathematical model using ordinary differential equations, and the simulation is performed on a simple route. In addition, we simulated the model with the function related to the increase and decrease of the pipe thickness changed, or with a more complicated route.

Ultimately, we aim to propose the optimum network connecting the cities of Kyushu by using this system.

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193 Shadowing Filters for Positioning and Tracking Moving Targets with Application to Flocking Birds

Ayham Zaitouny
CSIRO
Co-authors: Thomas Stemler, Michael Small and Kevin Judd
Timetable: p. 12

Tracking a moving object like a ship, vehicle, aircraft or even an animal or human is challenging especially when given only noisy observations of the target's position. In this research we introduce a new tracking methodology based on shadowing filters, which are especially suited for nonlinear systems. The specific type of shadowing filter that we formulate for tracking purposes is based on the simple assumption that the target's dynamics is Newtonian. This approach is highly versatile. First of all, it may be easily adapted to different settings. For instance, it can be implemented to track a single moving particle, a system of multiple objects or be extended to consider rigid bodies. Secondly, it can be applied to irregularly sampled real-world data without additional effort. Thirdly, it is computationally cheap and outperforms the established and widely used Kalman and particle filters in situations where nonlinearities are present. Furthermore, this tracking algorithm allows for a reconstruction of the full dynamical state space from limited position-only data. Finally, a practical application to track a flying pigeon is employed as a challenging test case for our proposed algorithm.

194 Branching out from exponential models: an inhomogeneous model for early epidemic dynamics*

Alexander Zarebski
The University of Melbourne
Co-authors: Peter Dawson, Robert Moss and James M McCaw
Timetable: p. 12

Exponential growth provides a mathematically convenient model for the early stages of an epidemic. It arises naturally as an approximation of the initial dynamics of many epidemiological models, for example in the branching process approximation to the susceptible-infectious-recovered model. However, for some infectious diseases (such as Ebola), even during the initial stages of sustained transmission, once stochastic effects have diminished but prior to susceptible depletion, the observed growth is slower than exponential. This observation has prompted the investigation of models exhibiting sub-exponential growth. A simple inhomogeneous branching process, capable of sub-exponential growth, will be presented and shown to provide a superior fit to outbreak data relative to the standard branching process model. With the utility of the model established, results from a simulation study will be presented demonstrating the feasibility of using this model with data collected for the purposes of rapid assessment of transmissibility, i.e., data collected through so-called "First Few Hundred" (FF100) studies.

Rapid characterisation of emerging pathogens is crucial for informing a proportionate response to public health emergencies, such as Ebola, pandemic influenza and Zika. The data collected in FF100 studies

is seen as a way of obtaining this characterisation and it is vital to have models capable of making use of such data. This work contributes a simple model which is nonetheless capable of describing pathogen transmission at both an individual and population level.

195 Mathematical model for checkpoint blockades in cancer immunotherapy*

Collin Zheng

The University of Sydney

Co-authors: Peter Kim and Peter Lee

Timetable: p. 24

The human immune system has checkpoint proteins, such as CTLA-4 and PD-1, that keep it from attacking healthy cells. Unfortunately, cancer cells have the ability to take advantage of these checkpoints to avoid being attacked by the immune system, thereby evading some of the most potent anti-tumor weapons in the immune arsenal. One such weapon is the cytotoxic T-lymphocyte, or killer T-cell. As a result, the development of drugs targeting these checkpoints is becoming an important part of some anti-cancer treatments. Despite promising results, an unexplained phenomenon has been the unexpected delay—roughly three to six months—before the drugs appear to take tangible effect. Such a delay may reflect the notion that inhibiting checkpoints plays only a partial role in unleashing a T-cell response. Two other factors upon which T-cell activation is dependent is antigen simulation via the T-cell receptor (TCR) and co-stimulation via the ligation of the T-cell's CD28 molecule by molecules on the cancer's surface, such as B7. Understanding the relationship between the levels of checkpoint inhibition, TCR stimulation and CD28 co-stimulation is crucial to explaining the delay in the efficacy of current checkpoint inhibition drug treatments. We present an ordinary differential equation model that integrates these relationships to predict the mysterious delay in anti-cancer response in the presence of the CTLA-4 checkpoint blockade treatment and analyse the findings. The predictions made by the model sheds light on the power and limitations of immunotherapic blockade treatments and offers new biological insights.

196 On the pricing of European options with discrete dividend payments

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

In this talk, two relevant problems related to pricing European options with discrete dividend under the classic Black–Scholes framework are discussed. For the case when a discrete dividend payment is proportional to the underlying asset value, we discuss an interesting phenomenon observed; the option price is independent of the dividend payment date. This appears to be at odds with one's intuition that dividend amount, as well as the dividend date, should both affect the price of a European call or put option. The fundamental reasons why this occurs are discussed first from both mathematical and financial viewpoints. Then, for the case that the discrete dividend payment is a fixed amount, we provide an approximation formula for European option prices, with only one-dimensional integrals involved. It should be noted that our formula is applicable not only when there is a single dividend payment, but also for the case of multiple dividend payments.

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