

**ANZIAM 2004**  
**The 40th Applied Mathematics Conference**

**Hobart Tasmania**  
**1–5 February 2004**

**The 2004 ANZIAM Applied Mathematics Conference Abstracts**  
**L. Forbes (Editor)**  
**ISBN Number 7259 0869 6**

**Australian Mathematical Society  
ANZIAM  
(formerly the Division of Applied Mathematics)**

**The 40th Applied Mathematics Conference  
Hobart Tasmania  
1–5 February 2004**

**ANZIAM 2004**

The 2004 ANZIAM Applied Mathematics Conference Abstracts  
L. Forbes (Editor)  
ISBN 7259 0869 6



# Contents

<b>1</b>	<b>Information</b>	<b>1</b>
1.1	Previous AMC/ANZIAM locations . . . . .	1
1.2	The organising committee . . . . .	1
1.3	Invited speakers committee . . . . .	1
1.4	Acknowledgments . . . . .	1
1.5	T.M. Cherry Student Prize . . . . .	2
1.6	Winners of the T.M. Cherry Student Prize . . . . .	2
1.7	Winners of the Cherry Ripe Prize . . . . .	2
1.8	Recipients of the J.H. Michell Medal . . . . .	3
1.9	Recipients of the ANZIAM Medal . . . . .	3
<b>2</b>	<b>Conference timetable</b>	<b>5</b>
2.1	Speaker timetable . . . . .	5
	Posters . . . . .	5
	Sunday Evening . . . . .	5
	Monday Morning . . . . .	6
	Monday Afternoon . . . . .	7
	Tuesday Morning . . . . .	8
	Wednesday Morning . . . . .	9
	Wednesday Afternoon . . . . .	10
	Thursday . . . . .	11
<b>3</b>	<b>Conference delegates</b>	<b>13</b>
<b>4</b>	<b>Abstracts of invited presentations</b>	<b>17</b>
<b>5</b>	<b>Abstracts of contributed presentations</b>	<b>21</b>
<b>6</b>	<b>Abstracts of student presentations</b>	<b>51</b>
<b>7</b>	<b>Abstracts of poster presentations</b>	<b>61</b>
	<b>Speaker index</b>	<b>64</b>



# Information

## 1.1 Previous AMC/ANZIAM locations

1966 Kangaroo Island (Aug)	1978 Broadbeach	1991 Hammer Springs, NZ
1966 Coorong (Dec)	1979 Leura	1992 Bateman's Bay
1967 Adelaide	1980 Cowes	1993 Hahndorf
1968 Hall's Gap	1981 Victor Harbor	1994 Pokolbin
1969 Victor Harbor	1982 Bundanoon	1995 Busselton
1970 Lorne	1983 Perth	1996 Masterton, NZ
1971 Smiggin's Hole	1984 Merimbula	1997 Lorne
1972 Wollongong	1985 Launceston	1998 Coolangatta
1973 Surfers Paradise	1986 Wirrina	1999 Mollymook
1974 Lorne	1987 Wairakei, NZ	2000 Waitangi, NZ
1975 Tanunda	1988 Leura	2001 Barossa Valley
1976 Jindabyne	1989 Ballarat	2002 Canberra
1977 Terrigal	1990 Coolangatta	2003 Sydney (ICIAM)

## 1.2 The organising committee

Professor Larry Forbes	Director	University of Tasmania
Dr Peter Trotter	Treasurer	University of Tasmania
Dr S. Wotherspoon	Secretary	University of Tasmania
Karen Bradford	Secretary	University of Tasmania

## 1.3 Invited speakers committee

Professor Larry Forbes	Convenor	University of Tasmania
Ass Prof Graeme Hocking		Murdoch University
Professor Jim Hill		University of Wollongong
Ass Prof Kerry Landman		University of Melbourne
Professor David Ryan		University of Auckland
Professor Hugh Possingham		University of Queensland

## 1.4 Acknowledgments

The organising committee gratefully acknowledges the support of:

- The Australian and New Zealand Industrial and Applied Mathematics Society
- The School of Mathematics and Physics, University of Tasmania

## 1.5 T.M. Cherry Student Prize

A student prize was introduced in 1969 at Victor Harbor and is awarded annually to the best student talk presented at the Conference. In May 1976, ANZIAM (then the Division of Applied Mathematics) adopted the title “T.M. Cherry Student Prize” in honour of one of Australia’s leading scientists, Professor Sir Thomas MacFarland Cherry, Kt., Sc.D., F.A.A., F.R.S.

For an extensive history on Professor Cherry we recommend the article published in the records of the Australian Academy of Science vol.1 (1966–9).

## 1.6 Winners of the T.M. Cherry Student Prize

1969	Mr. R. Jones	Adelaide	1986	Ms. A. Becker	Monash
1970	Mr. J.A. Rickhard	London		Mr. K. Thalassoudis	Adelaide
1971	Ms. J. Jones	Mt. Stromlo(?)	1987	Mr. M. Rumsewicz	Adelaide
1972	not offered		1988	Ms. W.M. Henry	ANU
1973	not offered		1989	Ms. M.R. Myerscough	Oxford
1974	Mr. R.P. Oertel	Adelaide		Mr. J.A.G. Roberts	Melbourne
1975	Mr. R.E. Robinson	Sydney	1990	Mr. J.P. Best	Wollongong
1976	Mr. J.P. Abbott	ANU	1991	Mr. S.K. Lucas	Sydney
1977	Mr. J. Finnigan	CSIRO		Ms. A. Tordesillas	Wollongong
	Ms. S. Bhaskaran	Adelaide	1992	Mr. S.F. Brown	Sydney
1978	Mr. B.D. Hughes	ANU	1993	Mr. D. Standingford	Adelaide
	Mr. P. Robinson	Queensland	1994	Ms. B. Barnes	Monash
1979	Mr. J.R. Coleby	Adelaide	1995	Mr. A.V. Buryak	ANU
	Mr. B.D. Hughes	ANU	1996	Mr. A. Gore	Newcastle
1980	Mr. M. Lukas	ANU		Mr. D.C. Scullen	Adelaide
1981	Mr. A.W. Plank	UNSW	1997	Ms. S. Cummins	Monash
1982	Mr. G. Fulford	Wollongong	1998	Mr. J. Clark	Sydney
	Mr. J. Gear	Melbourne		Mr. T.P. Gourlay	Adelaide
1983	Mr. P. Kovest	UWA	1999	Ms. E. Ostrovskaya	ANU
1984	Mr. A. Kucera	Wollongong	2000	Mr. C. Reid	Massey
	Mr. S. Wright	Queensland	2001	Mr M. Haese	Adelaide
1985	Mr. G. Fulford	Wollongong	2002	Mr V. Gubernov	ADFA
	Mr. F. Murrell	Melbourne		Mr W.M. Megill	UBC/Woll

## 1.7 Winners of the Cherry Ripe Prize

Since 1995 the students have run an alternative competition for the best non-student talk. The winners are:

1995	Dr N. Boland	Melbourne
1996	Dr A. Pullan	Auckland
1997	Prof. N. deMestre	Bond
1998	Dr D. Stump	Queensland
1999	Dr M.J. McGuinness	Wellington
2000	Prof. J.J. Monaghan	Monash
	Assoc. Prof. A.B. Philpott	Auckland

## 1.8 Recipients of the J.H. Michell Medal

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

1999 Dr Harvinder Singh Sidhu

2000 Dr Antoinette Tordesillas

2001 Dr Nigel Bean

2002 Dr Stephen Lucas

## 1.9 Recipients of the ANZIAM Medal

The ANZIAM medal is awarded on the basis of

- Research achievements,
- Activities enhancing applied or industrial mathematics, or both, and
- Contributions to ANZIAM.

The first award was made at the 1995 ANZIAM conference.

1995 Professor Renfrey Burnard Potts

1997 Professor Ian Hugh Sloane

1999 Professor Ernie Oliver Tuck

2001 Associate Professor Charles E.M. Pearce



# Conference timetable

## 2.1 Speaker timetable

The three rooms to be used for presentations are ballroom **Centre**, **North** and **South**. All talks by **invited speakers** and all announcements will be given in the **Centre** Room. In each entry on the programme schedule giving the speaker and title, the page reference is to the page on which the abstract appears in this booklet. An asterisk marks a student talk.

Morning and afternoon teas and lunches are marked in the timetable. Teas will be served in the conference mezzanine on the first floor. All lunches will be at the Grand Chancellor.

## Posters

9:00–6:00	Poster Session in conference mezzanine
	BALL Metamorphosis of turbulence–shear flow dynamics in fusion plasmas p61
	GILL An Improvement to Situational Force Scoring for Adjudicating Attrition in Combined Arms Conflicts p61
	GUSTAFSON Regularising ill-posed integral equations using dual systems p62
	HAN Digital homeomorphic properties of the digital surface p62

## Sunday Evening

2:00-6:00	ANZIAM executive meeting (Norfolk Rm.)
3:00-6:00	Registration at the ANZIAM desk (Mezzanine)
7:00-?	<b>Barbecue.</b> Barbecue at the Grand Chancellor (Mezzanine) .

## Monday morning

	Centre	North	South
8:00–9:00	Registration at the ANZIAM desk		
8:45–9:00	Conference Opening		
9:00–10:00	<i>Chair: Forbes</i> <b>Invited talk: J. SEO</b> p18 Magnetic Resonance Electrical Impedance Tomography		
	<i>Chair: Forbes</i>	<i>Chair: Bode</i>	<i>Chair: Galloway</i>
10:00–10:30	BRIDESON p23 Winding patterns for biplanar Magnetic Resonance Imaging shim coils	ROBERTS M. p44 The type reproduction number for an infectious disease	CLARKE p26 Modulational instability in varying optical fibre
10:30–11:00	WHILE * p59 Stimulation of Nerves in the Body, due to MRI scans	LANDMAN p37 Cell colonisation on a growing domain	O'CONNOR p42 Efficient techniques for spectral line convolutions
11:05–11:30	Morning tea in conference mezzanine		
	<i>Chair: Cleary</i>	<i>Chair: Belward J.</i>	<i>Chair: Hill</i>
11:30–12:00	FORBES p31 Bi-planar coils in Magnetic Resonance Imaging	SIMPSON p45 Diffusive and Chemotactic Cellular Migration: Smooth and Discontinuous Travelling Wave Solutions	COX p27 The limiting ideal theory for shear-index cohesionless granular materials.
12:00–12:30	ANDERSSEN p21 Localization as a Strategy for Inverting Calibration-and- Prediction Data	LAING p36 Pattern formation in integral equations	THAMWATTANA * p58 Continuum mechanical modelling for highly frictional granular solids
12:30–1:00	WAKE p48 Activities at MISG2004	LANGDON p37 A wavenumber independent boundary element method for an acoustic scattering problem	WALSH * p59 Sandy feet: Coming in contact with granular media.
1:00–2:00	Lunch at the Grand Chancellor		

## Monday afternoon

	Centre	North	South
2:00–3:00	<i>Chair: Tuck</i> <b>Invited talk: SCHWARTZ</b> Recent Progress in Thin-Layer Fluid Mechanics <p style="text-align: right;">p19</p>		
	<i>Chair: Tuck</i>	<i>Chair: Simpson</i>	<i>Chair: Clarke</i>
3:00–3:30	GREEN * p52 Frequency response of atomic force microscope cantilevers immersed in viscous fluids	GIBSON p32 Modelling the contractile process in blood vessels	DEAKIN p28 The Motion of Projectiles in a Resistant Medium
3:30–4:00	DENIER p28 So what's new in boundary-layer theory?	BELWARD S. p22 A three dimensional model for the settling of marine larvae	CALLAGHAN * p52 Rossby waves on a rotating sphere
4:00–4:30	Afternoon Tea in conference mezzanine		
	<i>Chair: Schwartz</i>	<i>Chair: Langdon</i>	<i>Chair: Deakin</i>
4:30–5:00	YEUNG p49 Nonlinear Viscosity Effects on Hydrodynamic Inertia and Damping	BODE p22 Reef connectivity: computations and applications	GALLOWAY p32 Axisymmetric Magnetoconvection and Convective Collapse
5:00–5:30	TUCK p47 Lifting circular discs	BELWARD J. p22 Surface fitting for the leaves of plants	MOLLEE * p55 Modelling solute transport through stratum corneum
5:30–6:00	NOVAK p42 Using Packet Pair Probing to Estimate Arrival-Rate and Packet Size	TACON * p58 Permeation and elimination in liver kinetics	MCCUE p40 Deformations of hypoplastic soils in one dimension

## Tuesday morning

	Centre	North	South
8:25–8:50	READ p43 Seepage face Lengths and Flow Paths for Hillslopes With a Horizontal Aquiclude	COSTA p27 A Markov Decision Problem Approach to a Simple Capacity Allocation Model	KROESE p36 The Cross-Entropy Method
9:00–10:00	<i>Chair: Roberts A.</i> <b>Invited talk:</b> BINDOFF p17 Simulating the Antarctic and Southern Ocean System		
	<i>Chair: A. Roberts</i>	<i>Chair: Anderssen</i>	<i>Chair: Cerone</i>
10:00–10:30	HITTI * p53 Multiphase Smoothed Particle Hydrodynamics	CLEARY p27 Simulation of processes in the metals value chain from mine to cast product	CARMINATI p25 A Comparative Study of Some Computer Algebra Packages which Determine the Lie Point Symmetries of Differential Equations
10:30–11:00	MONAGHAN p40 The dynamics of Toy Stars	TRIADIS * p58 Incorporating surface forces into the indentation of layered systems	HILL p34 Curve fitting, differential equations and the Riemann hypothesis
11:00–11:30	Morning tea in conference mezzanine		
11:30–12:00	<i>Chair: de Mestre</i> <b>Invited talk:</b> LUCAS p19 On cubic graphs and Hamiltonian cycles		
	<i>Chair: de Mestre</i>	<i>Chair: Johnston</i>	<i>Chair: Fraser</i>
12:00–12:30	HAJI * p53 Modelling Linear Viscoelasticity using a Kohlrausch Function for the Relaxation Modulus	MACASKILL p39 Semi-Lagrangian methods for vortex dynamics in irregularly shaped domains	BERTRAM * p51 Crossing the threshold of Brownian motion: a new model for Australian stock prices
12:30–1:00	LIM * p55 Modelling Volcanic Ashfall	SCHAERF * p57 Contour Crossings in Contour-Advective Semi-Lagrangian (CASL) Simulations	STUMP p47 Speeding Up The Milstein Method for SDE's: An Example from the Finance Industry
1:00–1:50	Lunch at the Grand Chancellor		
2:00	Tours Depart		
8:00	ANZIAM AGM, Ballroom Centre		

### Wednesday morning

	Centre	North	South
9:00–10:00	<i>Chair: Boland</i> <b>Invited talk:</b> TAYLOR p20 Capacity Reconfiguration in Logically Fully-Connected Loss Networks		
	<i>Chair: Boland</i>	<i>Chair: Landman</i>	<i>Chair: Lyness</i>
10:00–10:30	FRICKE * p52 A Column Generation Approach to Scheduling Problems.	FARRELL p30 Primary Alkaline Battery Cathodes: A Simplified Model for Porous Manganese Oxide Particle Discharge	SLOAN p45 Numerical Integration in Hundreds of Dimensions
10:30–11:00	LESMONO * p54 Optimal Timing of Political Elections	JOHANSEN * p54 Primary Alkaline Battery Cathodes: A Simplified Galvanostatic Discharge Model	JOMAA * p54 The role of boundary error in a finite-difference treatment of the Poisson equation in an irregular domain
11:00–11:30	Morning tea in conference mezzanine		
	<i>Chair: Taylor</i>	<i>Chair: Roberts M.</i>	<i>Chair: Sloan</i>
11:30–12:00	BOLAND p23 Cancer Radiation Treatment Planning Optimization	ALDIS p21 A model for the control of a smallpox outbreak	LYNESS p38 Evaluation of four dimensional Integrals arising in Galerkin boundary element methods.
12:00–12:30	RAMAKRISHNAN * p56 Allocation of bandwidth in a communications network	BRADSHAW-HAJEK * p51 Reaction-diffusion equations with explicit spatial dependence for population genetics	MUSTAPHA * p56 An $H^1$ Galerkin method with quadrature for nonlinear parabolic problems
12:30–1:00	RODADO * p57 Optimal Policies for The Inventory Problem with Multiple Truck Loads	HARTMANN * p53 Marine Reserves as a Learning Tool	JOHNSTON p35 Evaluation of Nearly Singular Integrals in the Boundary Element Method
1:00–2:00	Lunch at the Grand Chancellor		

### Wednesday afternoon

	Centre	North	South
2:00–3:00	<i>Chair: Broadbridge</i> <b>Invited talk: JOSHI</b> p18 Bisons, Butterflies and Bread Raising (Painlevé) Equations		
	<i>Chair: Broadbridge</i>	<i>Chair: Hocking</i>	<i>Chair: Gray</i>
3:00–3:30	DERRICK p29 Characterizing the domains of attraction of stable stationary solutions of semilinear parabolic equations	LOOKER * p55 The hydrodynamics of an oscillating porous particle	NELSON p41 Analysis of an immobilised enzyme reactor
3:30–4:00	HICKMAN p34 Shifts and Integrability Conditions	MUNRO * p56 Sonoluminescence in a gas bubble in a fluid	WEBER p48 Multiple Drifting Flame Balls
4:00–4:30	Afternoon Tea in conference mezzanine		
	<i>Chair: Joshi</i>	<i>Chair: Lucas</i>	<i>Chair: Weber</i>
4:30–5:00	BROADBRIDGE p24 Exact Axisymmetric Solutions for Temperature-Dependent Compressible Navier-Stokes Equations	CERONE p26 On odd Zeta and other special function bounds	BUCKMASTER p24 Heterogeneous propellant combustion calculations as a subgrid component of rocket motor simulations
5:00–5:30	KOBAYASHI p36 Wavelets, FFTs and Histograms in Data Stream Mining	DRAGOMIR p29 A General Divergence Measure for Monotonic Functions and Applications in Information Theory	GRAY p33 The role of self-heating in the estimation of kinetic constants for thermally unstable materials using differential scanning calorimetry (DSC)
5:30–6:00	LANGLANDS p38 Spatio-Temporal Patterning and Turbulence in Fractional Activator-Inhibitor Systems	BUTCHER p25 Practical general linear methods for ordinary differential equations	HENRY p33 Dendritic Branching Complexity of Neurons
7:30pm 8:00–12:00pm	Pre-dinner drinks and Conference Banquet in Meehans Restaurant		

**Thursday morning**

	<b>Centre</b>	<b>North</b>	<b>South</b>
9:00–10:00	<i>Chair: Wake</i> <b>Invited talk: KING</b> Moving contact lines and active cell motion <p style="text-align: right;">p19</p>		
	<i>Chair: Wake</i>	<i>Chair: Forbes</i>	<i>Chair: Neame</i>
10:00–10:30	CLEARY p26 Simulation of geophysical flows using DEM and SPH	HOCKING p35 Unsteady withdrawal through a point sink near a vertical wall	MAK p39 Facets for the cardinality constrained quadratic knapsack problem and the quadratic selective travelling salesman problem
10:30–11:00	SPENCER p46 Multiple Sensor Surface Vibrations Analysis for Monitoring Tumbling Mill Performance	STOKES p46 Three-dimensional free surface flows induced by a submerged ring sink.	SORLI p45 A 0–1 linear programming model for even harmonic numbers
11:00–11:30	Morning tea in conference mezzanine		
	<i>Chair: de Hoog</i>	<i>Chair: Belward S.</i>	<i>Chair: Mak</i>
11:30–12:00	WAKE p48 The challenge of micromechanics modelling of hair	FARROW p31 Direct numerical simulation of withdrawal from a stratified fluid	ZHOU p49 The ring routing problem
12:00–12:30	FACKRELL p30 Minimum and maximum algebraic degree of phase-type distributions	ROBERTS A. p44 The concentration field does not model Brownian bugs	NEAME p41 Modified Column Generation for Set Partitioning Problems
12:30–1:00	FRASER p31 A localized instability in the ring-spinning balloon	DE MESTRE p28 Skipping Stones, Bouncing Bombs and Water Polo Balls	PODHAISKY p43 On implementing general linear methods
1:00	Conference Ends Bus departs for Hobart Airport: Time to be announced		



# Conference delegates

Mr Yekini Abiodun	soomthlyebony4u@yahoo.co.uk
Dr Geoffrey Aldis	g.aldis@adfa.edu.au
Mr Chris Alford	chris.alford@c031.aone.net.au
Dr Robert Anderssen	bob.anderssen@csiro.au
Dr Graham Baird	bairdg@wasm.curtin.edu.au
Dr Rowena Ball	Rowena.Ball@anu.edu.au
Dr Noel Barton	junoba@bigpond.com
Prof Murray Batchelor	murrayb@maths.anu.edu.au
Dr John Belward	jab@maths.uq.edu.au
Dr Shaun Belward	shaun.belward@jcu.edu.au
Mr William Bertram	williamb@maths.usyd.edu.au
Dr Elizabeth Billington	ejb@maths.uq.edu.au
A/Prof Nathan Bindoff	n.bindoff@utas.edu.au
Dr Lance Bode	Lance.Bode@jcu.edu.au
Dr Natashia Boland	natashia@unimelb.edu.au
Mrs Bronwyn Bradshaw-Hajek	bhb02@uow.edu.au
Dr Michael Brideson	Michael.Brideson@utas.edu.au
Prof Phil Broadbridge	pbroad@math.udel.edu
Dr Gerald Brown	ggbrown@nps.navy.mil
Prof John Buckmaster	limey@uiuc.edu
Prof John Butcher	butcher@math.auckland.ac.nz
Mr Tim Callaghan	Timothy.Callaghan@utas.edu.au
Dr John Carminati	jcarm@deakin.edu.au
A/Prof Pietro Cerone	pc@csm.vu.edu.au
Dr Simon Clarke	simon.clarke@sci.monash.edu.au
Dr Paul Cleary	paul.cleary@csiro.au
Dr Andre Costa	acosta@maths.adelaide.edu.au
Dr Grant Cox	gcox@uow.edu.au
Dr Frank de Hoog	frank.dehoog@csiro.au
Prof Neville de Mestre	neville_de_mestre@bond.edu.au
Dr Michael Deakin	michael.deakin@sci.monash.edu.au
Dr Jim Denier	jdenier@maths.adelaide.edu.au
Dr William Derrick	derrick@selway.umd.edu
Mr Oluwaseyi. a Diyaolu	seyi_diyaolu@yahoo.com
Prof Sever Silvestru Dragomir	Sever.Dragomir@vu.edu.au
Ms Emily Duane	e.duane@ms.unimelb.edu.au
Mrs Zari Dzalilov	z.dzalilov@ballarat.edu.au
Prof David Elliott	elliott@hilbert.maths.utas.edu.au
Dr Mark Fackrell	mfackrel@ms.unimelb.edu.au
Dr Troy Farrell	t.farrell@qut.edu.au
Dr Duncan Farrow	d.farrow@murdoch.edu.au
Prof Larry Forbes	Larry.Forbes@utas.edu.au

Dr W. Barrie Fraser	Barrief@maths.usyd.edu.au
Mr Chris Fricke	c.fricke@pgrad.unimelb.edu.au
Dr Gary Froyland	gary.a.froyland@bhpbilliton.com
Dr David Galloway	dave@maths.usyd.edu.au
A/Prof Bill Gibson	billg@maths.usyd.edu.au
Dr Andrew Gill	andrew.gill@dsto.defence.gov.au
Dr Stephen Goulter	steveg@maths.usyd.edu.au
Prof Brian Gray	bfgrayaus@hotmail.com
Mr Christopher Green	C.Green@ms.unimelb.edu.au
Prof Sven-Åke Gustafson	sven-a@ux.his.no
Prof Tony Guttmann	tonyg@ms.unimelb.edu.au
Mr Pol Haji	Pol.Haji@maths.anu.edu.au
Ms Norhayati Hamzah	yatibhs@hotmail.com
Prof Sang-Eon Han	sehan@honam.ac.kr
Klaas Hartmann	klaas@kavenga.com
Mr Aiman Hatamleh	aimdadsar@yahoo.com
A/Prof Bruce Henry	b.henry@unsw.edu.au
Dr Mark Hickman	M.Hickman@math.canterbury.ac.nz
Dr James Hill	jhill@uow.edu.au
Mr John Hitti	john.hitti@sci.monash.edu.au
A/Prof Graeme Hocking	G.Hocking@murdoch.edu.au
Mr Jonathan Johansen	j.johansen@student.qut.edu.au
Dr Peter Johnston	p.johnston@griffith.edu.au
Mr Ziad Jomaa	ziadj@maths.usyd.edu.au
Prof Nalini Joshi	nalini@maths.usyd.edu.au
Prof John King	John.King@nottingham.ac.uk
Dr Mei Kobayashi	MEI@jp.ibm.com
Dr Dirk Kroese	kroese@maths.uq.edu.au
Dr Carlo Laing	c.r.laing@massey.ac.nz
A/Prof Kerry Landman	k.landman@ms.unimelb.edu.au
Dr Stephen Langdon	steve@maths.unsw.edu.au
Dr Trevor Langlands	t.langlands@unsw.edu.au
Mr Dharma Lesmono	dlesmono@maths.uq.edu.au
Ms Leng Leng Lim	l.l.lim@massey.ac.nz
Mr Jason Looker	jrlooker@ms.unimelb.edu.au
Dr Stephen Lucas	stephen.lucas@unisa.edu.au
Dr James Lyness	lyness@mcs.anl.gov
A/Prof Charlie Macaskill	c.macaskill@maths.usyd.edu.au
Dr Vicky Mak	vmak@ms.unimelb.edu.au
Dr Geordie McBain	geordie.mcbain@aeromech.usyd.edu.au
Dr Scott McCue	mccue@uow.edu.au
Prof Robert McKibbin	R.McKibbin@massey.ac.nz
Dr Geoff Mercer	g.mercer@adfa.edu.au
Mr Mustapha Mohammed	mustamud@yahoo.co.uk
Mr Thomas Mollee	mollee@maths.uq.edu.au
Prof Joe Monaghan	joe.monaghan@sci.monash.edu.au
Mr Angus Munro	munroa@postoffice.utas.edu.au
Mr Kassem Mustapha	kassim@maths.unsw.edu.au
Dr Philip Neame	Philip.Neame@uts.edu.au
Dr Mark Nelson	mnelson@uow.edu.au
Ms Ana Novak	ananovak@pacific.net.au
Dr Tony O'Connor	t.oconnor@griffith.edu.au

Dr Michael Opare	masherifa@yahoo.co.uk
A/Prof Charles Pearce	cpearce@maths.adelaide.edu.au
Dr Helmut Podhaisky	hpod@math.auckland.ac.nz
Mr Kumam Poom	poomkumam@yahoo.com
Ms Maya Ramakrishnan	m.ramakrishnan@ms.unimelb.edu.au
Dr Wayne Read	wayne.read@jcu.edu.au
A/Prof Mick Roberts	m.g.roberts@massey.ac.nz
Prof Tony Roberts	aroberts@usqDOTedu.au
Mr Armando Rodado	a.rodado@ms.unimelb.edu.au
Mr David Ruxton	d.ruxton@cqu.edu.au
Mr Teerapol Saleewong	teerapol.sal@kmutt.ac.th
Mr Timothy Schaerf	tschaerf@maths.usyd.edu.au
Prof Len Schwartz	schwartz@ME.UDel.Edu
Dr Bryan Scott	bryan.scott@hydro.com.au
Prof Jin Kuen Seo	seoj@yonsei.ac.kr
Mr Matthew Simpson	m.simpson@ms.unimelb.edu.au
Prof Ian Sloan	i.sloan@unsw.edu.au
Dr Ronald Sorli	Ron.Sorli@uts.edu.au
Mr Gabriele Sorrentino	gabriele@sci.vu.edu.au
Dr Steven Spencer	steven.spencer@csiro.au
Dr Tim Stokes	stokes@math.waikato.ac.nz
Dr David Stump	David_Stump@national.com.au
Dr William Summerfield	william@frey.newcastle.edu.au
Mr Geoffrey Tacon	gt@maths.uq.edu.au
Prof Peter Taylor	p.taylor@ms.unimelb.edu.au
Ms Natalie Thamwattana	nt59@uow.edu.au
Ms Jan Thomas	jan.thomas@amsi.org.au
Dr Kouichi Toda	toda@pu-toyama.ac.jp
Dr Elliot Tonkes	ejt@maths.uq.edu.au
Mr Dimetre Triadis	D.Triadis@ms.unimelb.edu.au
Dr Peter Trotter	Peter.Trotter@utas.edu.au
Prof Ernie Tuck	etuck@maths.adelaide.edu.au
Dr Bruce van Brunt	b.vanbrunt@massey.ac.nz
Prof Graeme Wake	g.c.wake@massey.ac.nz
Mr Stuart Walsh	swalsh@ms.unimelb.edu.au
A/Prof Rodney Weber	r.weber@adfa.edu.au
Mr Peter While	pwhile@postoffice.utas.edu.au
Dr Simon Wotherspoon	Simon.Wotherspoon@utas.edu.au
Prof Ron Yeung	rwyeung@socrates.Berkeley.edu
Dr Sanming Zhou	smzhou@ms.unimelb.edu.au



# Abstracts of invited presentations

## Simulating the Antarctic and Southern Ocean System

Nathan Bindoff, Jason Roberts, Petra Heil and Steve Phipps  
Tasmanian Partnership for Advanced Computing

The Southern Ocean, Atmosphere and Antarctic Sea-Ice are key components of the Antarctic System. It is essential that we are able to simulate these component systems, both as separate entities and also as coupled systems for understanding past, current and future climates. The relevant timescales of these systems range from millennia to inter-annual periods in order that we can confidently study past ice-ages, future climates and man induced climate change.

The development of ocean, sea-ice and atmosphere models over last three years that parallelise and scale to hundreds of processors means that we are now able to utilize the compute power of modern cluster machines. As a consequence we are able now to resolve important ocean and sea-ice processes, and undertake long term numerical experiments of past and future climates.

We present a range of results from coupled ocean-atmosphere and sea-ice models. These include past ice ages and climate change scenarios for the current century in response to rising concentrations of CO<sub>2</sub> in the atmosphere. The detection of climate change from observations and the preferred modes of variation associated with climate change. The interaction of sea-ice with bottom water formation in the Adelie Land region of Antarctica, and finally the results from our global simulation of the ocean at high resolution ( $1/8 \times 1/8$  degree) resolving mesoscale eddies and short term modes of variability in the Southern Ocean.

# Magnetic Resonance Electrical Impedance Tomography

Jin Keun Seo

Department of Mathematics, Yonsei University,  
Seoul 120-749, Korea  
seoj@yonsei.ac.kr

Magnetic Resonance Electrical Impedance Tomography (MREIT) is a new medical imaging modality providing high resolution conductivity images based on the current injection MRI technique. The electrical conductivity and permittivity of a biological tissue change with cell concentration, cellular structure, molecular composition, membrane capacitance, and so on. Therefore, these properties manifest structural, functional, metabolic, and pathological conditions of the tissue providing valuable diagnostic information. Hence, cross-sectional imaging of electrical conductivity distributions within a human body has been an important research goal in medical imaging.

MREIT was motivated to deal with the well-known severe ill-posedness of the image reconstruction problem in Electrical Impedance Tomography (EIT). EIT reveals technical difficulties in producing high-resolution conductivity images. This stems from the inherent insensitivity problem that perturbations of an internal conductivity distribution deliver relatively small changes of the measured boundary voltage data in a highly nonlinear way. This motivated us to look for a new way of incorporating more information so that we can avoid this ill-posed nature of the inverse problem.

In MREIT, we inject electrical currents into the subject through surface electrodes and measure the induced the  $z$ -component  $B_z$  of the induced magnetic flux density due to an injection current. internal magnetic flux density using an MRI scanner. Here,  $z$  is the direction of the main magnetic field of the MRI scanner. We formulate the conductivity image reconstruction problem in MREIT from a careful analysis of the relationship between the injection current and the induced magnetic flux density  $B_z$ . Based on the novel mathematical formulation, we propose the conductivity image reconstruction algorithm taking advantage of this additional internal information. Once we have reconstructed images of conductivity distributions, we can produce images of internal current density distributions for any given injection currents. Phantom experiments in MREIT show that excellent contrast resolution can be achievable among biological tissue.

## Bisons, Butterflies and Bread Raising (Painlevé) Equations

Nalini Joshi

School of Mathematics and Statistics  
University of Sydney

Most mathematical models using reaction-diffusion equations assume that the reaction term is spatially homogeneous. Even a simple dependence on the space variable leads to very different behaviours. We show how the first Painlevé equation miraculously appears in population models and how its butterfly-like, exponentially sensitive solutions may matter.

## **Moving contact lines and active cell motion**

**John King**

Theoretical Mechanics, School of Mathematical Sciences  
University of Nottingham, UK

The application of thin-film asymptotics to two-phase models describing the crawling of mammalian cells over a substrate will be described (the study being motivated by, for example, the initial stages of tissue regrowth over a medical implant). Whilst the process is an extremely complex one, even the simplest such models can exhibit some intriguing phenomena in which the local behaviour at the contact line plays a crucial role. The relationship of the results to those arising for the high-order degenerate parabolic models which describe the surface-tension-driven spreading of conventional fluid droplets will accordingly also be noted.

## **On cubic graphs and Hamiltonian cycles**

**Stephen Lucas**

School of Mathematics and Statistics  
University of South Australia, Mawson Lakes, SA 5095

The first half of this seminar will exhibit a characteristic structure of the class of all cubic graphs that stems from the spectral properties of their adjacency matrices. Since the structure appears to be novel and has a threadlike appearance, we call it the multifilar structure, and provide an algebraic explanation of this structure. The second half will detail some recent investigations of the Hamiltonian cycle problem using symbolic algebra.

## **Recent Progress in Thin-Layer Fluid Mechanics**

**Len Schwartz**

Departments of Mechanical Engineering and Mathematical Sciences  
University of Delaware, Newark, DE 19716, USA

We have developed theoretical and numerical techniques for predicting the slow free-surface flow of liquids on solid substrates with a variety of driving mechanisms. Such flows have many industrial applications. An obvious application is the flow behavior of paint and other liquids.

Using the lubrication approximation, the three-dimensional unsteady motion of both Newtonian and Generalized Newtonian liquid layers and isolated droplets is simulated. We introduce a so-called “disjoining pressure term” into the flow equations. This allows interfacial energetics to influence the flow via the specification of equilibrium contact angles. This is a particularly attractive technique for simulating wetting and spreading behavior since apparent contact lines appear naturally in a time-dependent simulation without the need for explicit front tracking.

Topics include the approximate treatment of non-planar substrates, the development of “fingers”, evaporation/drying modeling with developed Marangoni flow effects, and the role of surfactants. Some unpublished and highly-speculative results relevant to biological cell division will also be included.

# Capacity Reconfiguration in Logically Fully-Connected Loss Networks

Peter Taylor

Department of Mathematics and Statistics,  
University of Melbourne, Vic 3010.

One of the problems faced by providers of telecommunications services is that of providing a capacitated path across a network between the origin and destination of a call. In a network with *complete sharing*, a call is accepted if there are sufficiently many free circuits on all the links along its route to meet its resource requirements. An alternative strategy might be to partition the capacity on the physical links to create a *logically fully-connected network* which overlies the original network. Such a network could be expected to have a reduced level of performance because calls might be rejected when they could have been accommodated, but the trade-off could be worthwhile in terms of simplicity of management.

In a logically fully-connected network, it is essential that logical capacities be assigned to the links in the correct manner. Given a fixed underlying physical network and traffic loads, it is easy to formulate this as an optimisation problem which can be solved by a number of methods. One which works surprisingly well is a greedy algorithm called XFG, due to Berezner and Krzesinski. Under realistic traffic loads, the performance of such a network is not far below that of a network with complete sharing.

The performance of such a network can be further improved if we introduce methods for reconfiguring capacity in response to changes in traffic loads or even in response to stochastic fluctuations. In this talk, I shall discuss a number of different schemes for doing this. They are all distributed in nature and result in the network itself acting like an intelligent entity. I shall also describe some solved and unsolved mathematical problems that have arisen in the course of the work.

# Abstracts of contributed presentations

## **A model for the control of a smallpox outbreak**

**Geoff Aldis** and Mick Roberts  
PEMS, UNSW at ADFA, Canberra, ACT  
IIMS, Massey University, Albany, NZ

There is renewed interest in the effectiveness of control measures following an accidental or deliberate release of smallpox. A structured integral equation model of an epidemic is described with four types of transmission: household, workplace, the community and hospital. A finite incubation period and realistic infectivity function are easily incorporated in this type of model. Linearisation is appropriate for a small epidemic, enabling some useful analytic results to be obtained. Numerical solutions of the full model can also be obtained for comparison. The comparative effectiveness of isolating cases, and quarantining and vaccinating household and work contacts are obtained, as a guide to the most effective intervention strategy.

## **Localization as a Strategy for Inverting Calibration-and-Prediction Data**

**Bob Anderssen**  
CSIRO Mathematical and Information Sciences  
GPO Box 664, Canberra, ACT 2601  
and Markus Hegland  
Mathematical Sciences Institute  
Australian National University, Canberra, ACT 0200

When the complexity of a situation is such that it is not possible and/or appropriate to formulate a mathematical model that relates the inputs to the outputs, a popular alternative is to invoke a calibration-and-prediction (CAP) strategy. Indirect measurements of the phenomenon of interest are recorded for a large number of samples in conjunction with corresponding laboratory measurements of the property under investigation. In the calibration step, a (linear) model, that defines the property as a function of the indirect measurements, is fitted to the calibration data. This calibration model then becomes the “predictor” for the property. The need to perform laboratory measurements is thereby circumvented. An alternative method, to the popular partial least squares and neural networks, for performing the calibration, is “localization”. Its logic is simple, convincing and appealing. It is clear that the localization performs a regularization. For a new indirect measurement, the predictor is a linear functional. It is this fact that can be exploited to place “localization” on a rigorous footing.

## Surface fitting for the leaves of plants

**John Belward** and Birgit Loch  
Advanced Computational Modelling Centre  
University of Queensland

In modelling the growth and development of plants, the function of leaves is often of prime importance. Information about the leaf canopy has bearing on energy uptake, micro-climate, pesticide and nutrient deposition. We will present work on the measurement and synthesis of leaf surfaces.

## A three dimensional model for the settling of marine larvae

**Shaun Belward** and Lance Bode  
School of Mathematical and Physical Sciences  
James Cook University

Most models for spatial population dynamics of marine organisms are two dimensional. Marine larvae are assumed to move at some depth averaged velocity and settle on a coast or reef where they enter their adult phase and reproduce. Biologists claim this assumption leads to conclusions prone to error.

In order to investigate this claim we consider settling of larvae on a coastline with a simple geometry under differing ocean currents. These currents have variation in the vertical coordinate. This allows comparison of settling rates with previous two-dimensional models.

In the simplest steady case the problem reduces to a linear diffusion equation with nonlinear boundary conditions.

## Reef connectivity: computations and applications

**Lance Bode**, Michael Bode and Paul Armsworth  
School of Mathematical and Physical Sciences  
James Cook University, Townsville, QLD

Larval dispersal for reef fish is poorly understood, although information about such processes may have future use in marine resource management. Larvae are released by reef-bound adults and are exposed to ocean currents, potentially dispersing hundreds of km. Field investigation of reef-to-reef “connectivity” is difficult and expensive, and can only occur over limited scales. Numerical ocean models, incorporating appropriate biological components (e.g., adult population dynamics, larval behaviour), permit exploration of species dynamics over appropriate spatial and temporal scales. We have developed models that quantify dispersal by connectivity matrices. Population models based on these matrices suggest certain reefs are crucial to long-term sustainability of fish populations. The matrices also provide the basis for investigating other ecological questions, which are considered briefly.

# Cancer Radiation Treatment Planning Optimization

**Natashia Boland**

Department of Mathematics and Statistics  
The University of Melbourne  
Parkville, VIC, 3010, Australia

Intensity modulated radiation therapy (IMRT) is widely recognized as one of the best treatments for many forms of cancer, in particular for head, neck and prostate cancers. In radiation therapy, beams of radiation are directed at the patient from various angles, all focussed on the tumour. In this way the tumour cells receive all of the radiation emitted, whilst surrounding healthy tissue only receives some of it. Head, neck, and prostate tumours often reside very close to critical organs that are sensitive to radiation, so in treating these cancers, the beams of radiation must be carefully shaped, and modulated, so that radiation isodose curves conform closely to the tumour, with critical organs protected from high levels of radiation. This is achieved with IMRT by solving an optimization problem. For each possible point source of radiation, there is a variable indicating the length of time radiation should be emitted from that source. The radiation received at any point in the patient's body can be calculated as a linear function of these variables. The function for optimization is usually constructed as a penalty function, with penalties applied to deviation from the radiation oncologist's goals. However, these goals are difficult to model linearly, and current optimization methods can only achieve locally optimal solutions. This talk reports on recent experiments with alternative optimization strategies done in collaboration with the Physical Sciences Department at the Peter MacCallum Cancer Centre.

# Winding patterns for biplanar Magnetic Resonance Imaging shim coils

**Michael Brideson**, Larry Forbes, and Stuart Crozier  
School of Mathematics & Physics, University of Tasmania,  
Hobart, Tasmania.

In magnetic resonance systems homogeneity of the applied magnetic fields is of paramount importance for obtaining accurate information about the object under investigation. In imaging systems (MRI), homogeneity of the main static magnetic field must be of the order of a few parts per million. To achieve this level of purity, independent shim coils are employed to cancel out spherical harmonic inhomogeneities.

A method is presented for computing the winding patterns required to design independent zonal and tesseral biplanar shim coils for MRI. Streamline, target-field, Fourier-integral and Fourier-series methods are utilised. Spherical harmonic analysis on field calculations from example shim coils indicate that the model and theory are well matched.

# Exact Axisymmetric Solutions for Temperature-Dependent Compressible Navier-Stokes Equations

Philip Broadbridge

Department of Mathematical Sciences  
University of Delaware, Newark, DE, 19716, USA

Lie symmetry analysis determines those temperature-dependent viscosity and thermal conductivity functions that admit explicit solution of the steady axisymmetric Navier-Stokes system for momentum, density and temperature. In this system, the only heat source is that due to viscous dissipation. Exact solutions are constructed for steady Couette flow or vortex flow of a compressible Boltzmann gas with viscosity and conductivity increasing with temperature, and of incompressible water-like liquids whose viscosity decreases with temperature. The vortex flows in temperature-dependent fluids are generalizations of the Lamb-Oseen vortex with nonvanishing vorticity. The temperature of a vortex is predicted to be positive only in the exterior of a thin cylindrical core whose small radius is determined uniquely. A core of exclusion, of the same magnitude as in the Boltzmann gas, exists also in the vortex of an ideal compressible gas with temperature-independent properties. The two-dimensional steady flow solution cannot exist inside the core, wherein there must be more general transport mechanisms such as upwelling, or more general non-frictional heat sources such as latent heat release. A similar result is obtained for an incompressible liquid, with viscosity decreasing with temperature.

## Heterogeneous propellant combustion calculations as a subgrid component of rocket motor simulations

J. Buckmaster, T.L.Jackson, L.Massa  
Aerospace Engineering,  
University of Illinois, Urbana, IL USA

In the numerical simulation of heterogeneous solid propellant rockets one has to deal with the fact that the 3-dimensional combustion description is subgrid on the scale of the flow computations. And so, given a combustion code which generates unsteady 3-dimensional solutions on the 2 micron scale, how does one spatially average the description over the centimeter scale to generate an unsteady quasi-1-dimensional description which can be coupled with the chamber flow code? Averaged nonlinear terms must be examined for their importance, and modelled should they need to be retained. And appropriate look-up tables must be generated from the subgrid description, to be used on the grid scale. There are various ways in which all of this can be done, and the talk will examine the most successful.

## **Practical general linear methods for ordinary differential equations**

**John Butcher**

Department of Mathematics  
The University of Auckland  
Private Bag 92019, Auckland, New Zealand

General linear methods for solving differential equations include large classes of traditional methods as special cases. It is hoped to find new methods which have significant advantages. For large problems arising from modelling applications, stiffness is often a significant feature and this leads to special challenges in the identification of suitable methods and in the construction of efficient software. This talk reviews recent work in collaboration with Will Wright and Zdzisław Jackiewicz on the construction and properties of a family of new general linear methods suitable for efficient implementation. A project to build software based on these methods also involves a collaboration with Helmut Podhaisky and others. Helmut will speak on this new project in another talk in this Conference.

## **A Comparative Study of Some Computer Algebra Packages which Determine the Lie Point Symmetries of Differential Equations**

**J. Carminati**, K.T. Vu, and J. Butcher.

Mathematics and Computational Theory Group,  
School of Information Technology,  
Deakin University, Waurn Ponds, Vic. 3217, Australia.

I shall discuss the results of a recent study which sought to determine which of five computer algebra packages was best at finding the Lie point symmetries of systems of partial differential equations with minimal user intervention. The chosen packages were LIEPDE and DIMSYM for REDUCE, LIE and BIGLIE for MUMATH, DESOLV for MAPLE, and MATHLIE for MATHEMATICA. A series of systems of well known partial differential equations were used in the study. I conclude that while all of the computer packages were useful, DESOLV appears to be the most successful system at determining the complete set of Lie point symmetries of systems of partial differential equations. In addition, I shall also illustrate some new integration functionality that has recently been added to DESOLV

## On odd Zeta and other special function bounds

P. Cerone

School of Computer Science and Mathematics  
Victoria University of Technology, Melbourne Australia.

Accurate bounds are obtained for estimating the zeta function at odd integer values in terms of the known zeta function at even integer values. This is accomplished from an identity involving the zeta function at a distance of one apart. Approximating classical special functions, which may be expressed as integrals of products functions, is investigated using some recent results involving the Čebyšev functional. The techniques are used to obtain novel and useful bounds for the Bessel function of the first kind, the Beta function and the Zeta function.

## Modulational instability in varying optical fibre

Simon Clarke

School of Mathematical Sciences  
Monash University, Vic.

The propagation of a wave packet in a varying optical fibre is considered, in particular the limit of a plane wave propagating from a region of normal dispersion to one of anomalous dispersion. This can be modelled by the variable coefficient Nonlinear Schrödinger equation. Slowly varying solutions of this equation are compared against ensemble numerical solutions. Saturation of the continuous wave instability is shown to occur for large initial amplitude and finite higher order dispersion. This leads to a cascade of energy to lower wavenumbers, i.e. solitons, while the high wavenumber spectrum is undisturbed.

## Simulation of geophysical flows using DEM and SPH

Paul Cleary and Mahesh Prakash

CSIRO Mathematical and Information Sciences,  
Private Bag 10, Clayton Sth, Vic, 3169. Australia.

Environmental fluid and particulate flows can be characterised as large scale and transient with complex free surface behaviour upon geometrically complex topography with multiple types of physics on multiple scales with significant convective transport. Particle based methods have specific advantages over traditional grid or mesh based continuum methods for these types of problems. Two such methods that are particularly well suited are Smoothed Particle Hydrodynamics (SPH) for modelling flowing fluids and the Discrete Element Method (DEM) for modelling the flow of particulate solids. Examples of 3D flows on realistic topography illustrate the environmental application of these methods. These include flooding of a river valley as the result of the collapse of a dam, coastal inundation by a tsunami, volcanic lava flow and landslides.

## **Simulation of processes in the metals value chain from mine to cast product**

**Paul Cleary** Matt Sinnott, Joseph Ha, and Mahesh Prakash  
CSIRO Mathematical and Information Sciences,  
Private Bag 10, Clayton Sth, Vic, 3169. Australia.

Finished metallic products begin life as metallic ore which is processed through many stages involving both coarse particulates and fluid states. Smoothed Particle Hydrodynamics (SPH) has specific advantages for modelling the complex free surface and multi-physics flows that occur in these processes whilst the Discrete Element Method (DEM) is ideal for modelling the flow of coarse particulate solids.

Applications from across the metals processing value chain from mining and comminution of ores, through separation and smelting to ingot and then finished product casting will be demonstrated. The specific advantages of these modelling techniques for these applications will be highlighted.

## **A Markov Decision Problem Approach to a Simple Capacity Allocation Model**

**Andre Costa**  
Department of Mathematics and Statistics  
University of Melbourne

We are interested in capacity re-allocation schemes for telecommunications networks. To gain some insight, we consider a simple single-link model for which we can formulate and solve a Markov decision problem. This decision problem is constructed from the underlying continuous-time process, where the single-stage costs are calculated using a class of revenue loss functions proposed recently by Chiera and Taylor. We discuss how the insights gained from the solution of this simple problem can be used in the design of a capacity allocation scheme for a logically fully connected network, in which direct routes can trade capacity with multiple-link “transit” routes.

## **The limiting ideal theory for shear-index cohesionless granular materials.**

**Grant Cox** and Jim Hill  
School of Mathematics and Applied Statistics,  
University of Wollongong, Wollongong, NSW.

To model cohesionless granular flow using continuum theory, the usual approach is to assume yield according to the cohesionless Coulomb-Mohr yield condition, where the angle of internal friction is constant. However, according to experimental evidence the angle of internal friction is not constant, but decreases for decreasing normal stress component. Thus, we consider the more general yield condition for shear-index granular materials, where the angle of internal friction varies with the normal component of stress. In this case, failure due to frictional slip occurs when the components of stress satisfy the Warren Spring equation. Here, we examine the cohesionless shear-index theory for the problem of two-dimensional gravity flow of granular materials.

## **The Motion of Projectiles in a Resistant Medium**

**Michael A B Deakin**  
Monash University

The path taken by a Projectile in a resistant medium is analysed. It is found that a cubic law describes the path extremely accurately in many instances, even quite extreme ones.

## **Skipping Stones, Bouncing Bombs and Water Polo Balls**

**Neville de Mestre**  
Bond University

This talk discusses the latest developments in the physics and mathematics of an object bouncing off a water surface. Ever since Lord Nelson discovered by accident that cannon balls could bounce off the surface of the sea, and young boys and girls have managed to bounce certain types of stones off the surface of a river or lake, the problem has intrigued many scientists. A well-known application was the Dambuster Raid in 1943, but the problem is also of interest in the sport of water polo where players endeavour to deceive the goalkeeper by bouncing the ball off the water surface into the goal mouth.

## **So what's new in boundary-layer theory?**

**Jim Denier**  
University of Adelaide

This year marks the centenary of Prandtl's ground breaking paper on the fluid dynamical boundary layer. This talk will present some new results on the development of algebraically growing disturbances in boundary layer flows. Such disturbances have been conjectured as playing an important role in transition to turbulence in a wide variety of fluid flows. In the present case they will be shown to be intimately linked with numerical singularities which arise when solving for the streamwise development of the boundary-layer flow.

## Characterizing the domains of attraction of stable stationary solutions of semilinear parabolic equations

William Derrick, Leonid Kalachev and Joseph Cima  
 Department of Mathematics  
 University of Montana, Missoula, MT, USA

We discuss the initial-Neumann-boundary value problem  $u_t = D\Delta u + f(u)$ , with  $u_\nu|_{\partial\Omega} = 0$  and  $u(x, 0) = \phi(x)$ , in a bounded domain  $\Omega \in R^m$ , with  $m \geq 1$ ,  $D > 0$ . Under mild assumptions on the nonlinear term  $f$ , we prove that if  $0 \leq \phi < \lambda v$  with  $\lambda < 1$ , the global solutions of this problem decay exponentially, while if  $\phi > \lambda v$  with  $\lambda > 1$ , then the solutions must grow at least exponentially, and may blow up in finite time, where the  $v$  are positive solutions of  $D\Delta v + f(v) = 0$ , with  $v_\nu|_{\partial\Omega} = 0$ . The method used in this paper provides an easily verifiable sufficient condition for the initial function to belong to the domain of attraction of a stable constant stationary solution of the original problem.

## A General Divergence Measure for Monotonic Functions and Applications in Information Theory

Sever S. Dragomir  
 School of Computer Science and Mathematics,  
 Victoria University, Melbourne

The main aim of this paper is to introduce a general divergence measure between two probability density functions generated by a monotonic mapping and to study some of its fundamental properties. The connections with the classical f-divergence considered by I. Csiszar in early sixties of the last century that has many particular instances of crucial importance in Information Theory, such as: the Kullback-Liebler Divergence, J-Divergence, Hellinger Discrimination, Triangular Discrimination, Chi-Square Divergence, Symmetric Chi-Square Divergence, Bhattacharyya Distance, Harmonic Mean Divergence, Matusita, Jeffreys-Matusita, Arimoto, and Puri-Vincze Divergences are explored as well.

## Minimum and maximum algebraic degree of phase-type distributions

Mark Fackrell and Peter Taylor  
 Department of Mathematics and Statistics  
 University of Melbourne, Victoria 3010

Phase-type distributions were first introduced by Neuts (1975) and (1981). They constitute a versatile class of distributions that have been used extensively in stochastic modelling. An order  $p$  representation for a phase-type distribution is defined by a  $1 \times p$  probability vector  $\alpha$  and a  $p \times p$  generator matrix  $\mathbf{T}$ . The Laplace transform of a phase-type distribution is a rational function, and we define the distribution's algebraic degree as the degree of the denominator when the Laplace transform is expressed as the ratio of two coprime polynomials.

An interesting question is as follows: given a generator matrix  $\mathbf{T}$ , how can we find an  $\alpha$  that minimizes the distribution's algebraic degree? Trivially, setting  $\alpha$  to be the left eigenvector of  $\mathbf{T}$  corresponding its eigenvalue of maximal real part, gives an algebraic degree of one. However, some of the phases in the resultant representation may be superfluous, that is, it is reducible. In this talk we discuss the problem, for a given  $\mathbf{T}$ , of finding  $\alpha$  so that the distribution's algebraic degree is minimized while maintaining an irreducible representation. We also discuss the problem of maximizing the algebraic degree.

1. Neuts, M. F. Probability distributions of phase type. In *Liber Amicorum Prof. Emeritus H. Florin*, pages 173–206, Department of Mathematics, University of Louvain, Belgium, 1975.
2. Neuts, M. F. *Matrix-Geometric Solutions in Stochastic Models: An Algorithmic Approach*. The John Hopkins University Press, Baltimore, 1981.

## Primary Alkaline Battery Cathodes: A Simplified Model for Porous Manganese Oxide Particle Discharge

Troy Farrell and Colin Please  
 School of Mathematical Sciences Queensland University of Technology  
 GPO Box 2434 Brisbane 4001 Qld

A mathematical model for the galvanostatic discharge of a porous, manganese oxide particle, similar to those found within primary alkaline battery cathodes, is presented. Asymptotic techniques are employed to obtain the leading order spatial and temporal behaviour of the particle. It is found that there is an initial rapid transient adjustment within the oxide crystals that form the particle, followed by a prolonged, relatively uniform, discharge regime. The late-time behaviour is rapid and non-uniform and its onset determines oxide utilization. Analytical solutions are found for most of the discharge behaviour and these are supplemented by simple numerical solutions where required. A comparison of the results with those obtained by previous more complete and accurate models is presented.

## **Direct numerical simulation of withdrawal from a stratified fluid**

**Duncan Farrow** and Graeme Hocking  
Mathematics and Statistics  
Murdoch University Murdoch WA 6150

The results of a series of numerical simulations are presented for the problem of withdrawal of a two-layer fluid with a finite thickness interface in a rectangular cavity through a hole in the base. A SIMPLE type scheme is used to solve the full Navier-Stokes equations. The details of the start up flow, the intermediate ‘wavy’ flow and eventual drawdown are considered. The effects of various factors on the flow are considered and the results compared with idealised results.

## **Bi-planar coils in Magnetic Resonance Imaging**

**Larry Forbes** and Stuart Crozier  
School of Mathematics and Physics  
University of Tasmania

Magnetic Resonance Imaging (MRI) is now used routinely in many hospitals. The patient is placed inside a narrow cylindrical tube, surrounded by the super-conducting magnets, coils and radio-frequency probes needed for the MRI scan. Not surprisingly, some patients find the experience quite claustrophobic. One way to relieve this sensation is to design new types of open magnets and coils that do not completely enclose the patient. This talk will describe a method for designing open, bi-planar coils. An ill-conditioned integral equation is solved numerically using regularization. A stream-function is used to generate the winding patterns from the solution.

## **A localized instability in the ring-spinning balloon**

**W. Barrie Fraser**  
School of Mathematics and Statistics,  
The University of Sydney, NSW 2006

Ring-spinning is a method for inserting twist into yarns made from staple fibres such as cotton or wool. Ring-spinning is important because it is the method that produces the finest quality yarns. The ring-spindle inserts twist into a rotating loop of yarn as the yarn passes through the spinner. The stability of this yarn loop is crucial to the successful operation of the ring-spindle.

In this talk I shall describe the snarling instability that can occur at a localized point on the yarn loop. I shall derive the critical condition for this instability which can be analysed as an internal layer using matched asymptotic expansions.

## **Axisymmetric Magnetoconvection and Convective Collapse**

**David Galloway** and Robert Cameron  
School of Mathematics & Statistics  
University of Sydney NSW 2006 Australia

Convective collapse is a process whereby a solar magnetic flux tube can evolve to a high field strength by undergoing an instability in which the gas is evacuated from the tube. Until now it has only been studied using the so-called “thin flux tube” approximation in which convection motions are ignored even though there is a background superadiabatic density stratification. Here we describe attempts to reproduce the phenomenon in the context of a series of magnetoconvection calculations where these motions are included self-consistently. The results suggest that something resembling convective collapse can be made to happen but that more typically, different mechanisms may limit the growth of the field strength in most regions of the solar convection zone.

## **Modelling the contractile process in blood vessels**

**Bill Gibson**, Les Farnell and Max Bennett  
School of Mathematics and Statistics  
University of Sydney

Stimulation of nerves connected to the muscular wall of a blood vessel can cause contraction or dilation of that vessel and hence regulate blood pressure and flow. We have developed a mathematical model of contraction in the rat-tail artery following release of the neurotransmitter noradrenaline from nerve terminals on the outer surface of the artery. This substance diffuses through the artery wall and binds to receptors on the individual smooth muscle cells that constitute the wall. A cascade of events leads to the release of calcium ions from internal stores in the muscle cells and this calcium then catalyses the phosphorylation of light chain myosin, which activates contraction.

## The role of self-heating in the estimation of kinetic constants for thermally unstable materials using differential scanning calorimetry (DSC)

B.F. Gray and C. Macaskill

Department of Chemistry, Macquarie University  
School of Mathematics and Statistics, University of Sydney

Many practical problems of economic importance involve self-heating to destruction of large quantities of materials where the critical ambient temperature can be as low as 30 – 400°C. The small sample quantities used in DSCs produce measurable effects only at much higher temperatures of the order of 2000°C. Therefore the very significant extrapolation to the industrially important scale that is required (the primary purpose of ASTM E698-01) can amplify minor errors in estimation of these parameters.

The standard method for calculation of the kinetic constants from DSC data assumes that the temperature throughout the sample is spatially uniform. The purpose of this paper is to investigate the conditions under which this assumption begins to break down and the extent to which this leads to significant errors in the values of the kinetic constants. The model used to do this uses the heat conduction equation for the sample and explicitly takes into account the rate of generation of heat by the exothermic chemical reaction under investigation, as in standard thermal ignition theory. It also includes the compensation for thermal lag occurring in a typical DSC.

The leading-order approximation that follows from this model corresponds to the classical approximation used in DSC theory. However, the present theory also allows determination of correction terms and thereby evaluates the conditions under which such corrections are negligible. Only then can the classical method of calculation of the kinetic constants be relied on. The basic result is that current practice is reasonably accurate when the Frank-Kamenetskii parameter, familiar in thermal ignition studies, is  $\ll 1$ .

## Dendritic Branching Complexity of Neurons

B.I. Henry, P.R. Hof, K. Kelliher, D. Kabaso, A. Rodriguez, P. Rothnie, & S.L. Wearne

School of Mathematics  
University of New South Wales  
Sydney NSW 2052

There is a growing body of research that establishes that the dendritic branching complexity of neurons is important to the way in which they function. In this talk we describe a set of scaling exponents that we have introduced to characterize the dendritic branching complexity of neurons for functional discrimination. We first illustrate the application of the new scaling exponents for characterizing mass distribution, branching and taper in computer generated self-similar binary trees. We then describe measurements of the scaling exponents obtained from digitized tracings of neocortical pyramidal neurons from macaque monkeys. The scaling exponents that we have introduced are better discriminants of functionally distinct properties of neurons than scaling exponents obtained from Sholl analysis and mass fractal analysis.

## Shifts and Integrability Conditions

Mark Hickman

Department of Mathematics & Statistics  
University of Canterbury  
Christchurch, New Zealand

Differential-Difference equations (DDEs) arise in a number of situations; in modelling, in numerical studies and in theoretical considerations. Symmetry analysis has been developed for DDEs that parallel the symmetry analysis of ODEs and PDEs. In this paper we discuss the integrability conditions that arise from symmetry analysis of DDEs and show that they can be factored into a shift type operator and a standard differential operator. This factorization allow standard symbolic software to be applied, in part, to solve the integrability conditions.

## Curve fitting, differential equations and the Riemann hypothesis

Professor James M Hill

School of Mathematics and Applied Statistics,  
University of Wollongong.

Perhaps the most famous outstanding problem of modern mathematics is the Riemann hypothesis, formulated by Bernhard Riemann in 1859. Riemann's hypothesis asserts that, "all the complex zeros of the zeta function  $\zeta(s)$  in the region  $0 < \text{Re}(s) < 1$ , known as the critical strip, lie on the line  $\text{Re}(s) = 1/2$ ". In this talk we present some general background, as well as some recent analytical and numerical results. It is known that the Riemann zeta function  $\zeta(s)$  in the critical strip  $0 < \text{Re}(s) < 1$ , may be represented as the Mellin transform of a certain function  $\phi(x)$  which is related to one of the theta functions. The function  $\phi(x)$  satisfies a well known functional equation, and guided by this property we deduce a family of approximating functions involving an arbitrary parameter  $\alpha$ . The approximating function corresponding to the value of  $\alpha = 2$  gives rise to a particularly accurate numerical approximation to the function  $\phi(x)$ . Another approximation to  $\phi(x)$ , which is based upon the first one, is obtained by solving a certain differential equation. Yet another approximating function may be determined as a simple extension of the first. All three approximations, when used in conjunction with the Mellin transform expression for  $\zeta(s)$  in the critical strip, give rise to an explicit expression from which it is clear that  $\text{Re}(s) = 1/2$  is a necessary and sufficient condition for the vanishing of the imaginary part of the integral, the real part of which is non-zero. Accordingly, the analogy with the Riemann hypothesis is only partial, but nevertheless  $\text{Re}(s) = 1/2$  emerges from the analysis in a fairly explicit manner. While it can be generally proved that the imaginary part of the Mellin transform must vanish along  $\text{Re}(s) = 1/2$ , the major contribution of the talk is the presentation of the actual calculation for three functions which approximate  $\phi(x)$ .

## Unsteady withdrawal through a point sink near a vertical wall

G.C. Hocking and L.K. Forbes

Mathematics and Statistics, Murdoch University, WA, 6150

School of Mathematics and Statistics, University of Tasmania, Tas.

Many modern reservoirs withdraw water for town supply from a tower offset from the dam wall. The flow generated by a point sink near a wall is thus of interest in reservoir management and planning and in determining water quality. Computations of steady flow have shown that there are two flow regimes that depend on the distance from the wall relative to depth. In fact, no nonlinear, steady solutions were obtained if the wall separation distance,  $D$ , was such that  $D < \frac{1}{\sqrt{2}}$ . Linearised solutions indicate a fundamental change of behaviour at this value of separation. Here we describe an investigation using full unsteady simulations that should explain the reasons for the failure of the steady solution method in this situation.

## Evaluation of Nearly Singular Integrals in the Boundary Element Method

Peter Johnston, David Elliott and Barbara Johnston,

School of Science, Griffith University,

Nathan, Queensland, 4111.

An implementation of the boundary element method requires the accurate evaluation of many integrals. When the source point is far from the boundary element under consideration, a straight forward application of Gaussian quadrature suffices to evaluate the integrals as the integrands are reasonably flat. When the source point is on the element, the integrand becomes singular and accurate evaluation can be obtained using the same Gaussian points transformed under a polynomial transformation which has zero Jacobian at the singular point.

A class of integrals which lies between these two extremes is that of nearly singular integrals. Here the source point is close to, but not on, the element and the integrand remains finite at all points. However, instead of remaining flat, the integrand develops a sharp peak as the source point moves closer to the element, thus rendering accurate evaluation of the integral difficult.

This talk will present a transformation, based on the sinh function, which automatically takes into account the position of the nearly singular point and the distance from the source point to the element. The transformation again clusters the points towards the nearly singular point, but does not have a zero Jacobian.

Numerical experimentation for the two dimensional boundary element method shows that several orders of magnitude improvement in relative error can be obtained using this transformation compared to a conventional implementation of Gaussian quadrature. We have also performed an error analysis to obtain truncation errors. Finally, preliminary results show that the same transformation can be applied to the three dimensional boundary element method with similar improvements.

## Wavelets, FFTs and Histograms in Data Stream Mining

Mei Kobayashi

IBM Research, Tokyo Research Laboratory  
1623-14 Shimotsuruma, Yamato-shi, Kanagawa-ken 242-8502 Japan  
e-mail: mei@jp.ibm.com

Data stream mining, i.e., the on-line processing and analysis of rapidly and continuously arriving large volumes of data, has emerged as an exciting new area of research. Application domains include financial transactions, sensor network measurements, and telecom networks. A new generation of mining algorithms are needed for real-time analysis and query response in these applications, since most conventional data mining algorithms can only be applied to static data sets that may be updated periodically in large chunks, but not to continuous streams of data. This talk reviews how some classical tools from statistical analysis and signal analysis have been modified and enhanced to enable fast computation of high quality summaries, known as “*synopses*”, of information in data streams.

## The Cross-Entropy Method

Dirk P. Kroese

Department of Mathematics, The University of Queensland  
Brisbane 4072, QLD

The cross-entropy (CE) method [1] is a versatile and powerful new technique for efficient Monte Carlo simulation and optimisation. The method derives its name from the cross-entropy (or Kullback-Leibler) distance, a well-known measure of “information”, which has been successfully employed in diverse fields of engineering, science and statistics.

In this talk I would like to give a gentle introduction to the CE method, via two simple examples: one in rare event simulation and the other in combinatorial optimisation. I will conclude with a more elaborate application in combinatorial optimisation.

[1] R.Y. Rubinstein and D.P. Kroese (2004). *The Cross-Entropy Method: A Unified Approach to Combinatorial Optimization, Monte-Carlo Simulation and Machine Learning*. Springer-Verlag, New York.

## Pattern formation in integral equations

Carlo R. Laing

IIMS, Massey University,  
Auckland, New Zealand

Time-dependent partial integro-differential equations arise in the study of spatial pattern formation in the cortex. Although the cortex is essentially two-dimensional, most previous work has concentrated on the case of one spatial dimension. I will discuss recent progress in the study of patterns on two-dimensional domains. The main result involves the approximation of an integral equation by a PDE.

## Cell colonisation on a growing domain

Kerry Landman, Graeme Pettet, and Don Newgreen  
Department of Mathematics and Statistics  
University of Melbourne

During the development of vertebrate embryos, cell migrations occur on an underlying tissue domain in response to growth factors. Over the cell migration time scale, the underlying tissue is itself growing. Consequently cell migration and colonisation are strongly affected by the tissue domain growth. A mathematical model of migrating cells on a growing domain will be presented. The crucial question concerns how long it takes the wave of cells to colonise the whole tissue, or indeed whether it is possible, while the tissue is itself expanding. This project is built around understanding the normal and abnormal development of the nervous system in the gastrointestinal tract.

## A wavenumber independent boundary element method for an acoustic scattering problem

Stephen Langdon and Simon Chandler-Wilde  
School of Mathematics,  
The University of New South Wales, Sydney 2052

This talk is concerned with the numerical solution of the impedance boundary value problem for the Helmholtz equation in a half-plane with piecewise constant boundary data, a problem which models, for example, outdoor sound propagation over inhomogeneous flat terrain. To achieve good approximation at high frequencies with a relatively low number of degrees of freedom we propose a novel Galerkin boundary element method, using a graded mesh with smaller elements adjacent to discontinuities in impedance and a special set of basis functions so that, on each element, the approximation space contains polynomials (of degree  $\nu$ ) multiplied by traces of plane waves on the boundary. We prove stability and convergence, and show that the error in computing the total acoustic field is of order  $N^{-(\nu+1)} \log^{1/2} N$ , where the number of degrees of freedom is proportional to  $N \log N$ . This error estimate is independent of the wavenumber, and thus the number of degrees of freedom required to achieve a prescribed level of accuracy does not increase as the wavenumber tends to infinity.

## **Spatio-Temporal Patterning and Turbulence in Fractional Activator-Inhibitor Systems**

B.I. Henry, **T.A.M. Langlands** and S.L. Wearne  
Department of Applied Mathematics, School of Mathematics,  
University of New South Wales

Activator-inhibitor systems of reaction-diffusion equations have been used to describe pattern formation in numerous applications in biology, chemistry and physics. Examples in biology include, spatial migration patterns, mammalian coat patterns and nerve cell signalling. The complexity of the diffusing medium in all these applications is manifest in the single parameter of the diffusion constant. Here we consider activator-inhibitor systems in which the diffusion is anomalous, and the complexity of the diffusing medium is manifest in a diffusion constant and a diffusion exponent. A consideration of this problem from Continuous Time Random Walks leads to a fractional activator-inhibitor model. We consider one such model system, the fractional Geirer-Meinhardt system, in detail. Through a combined algebraic and numerical analysis of this model we identify Turing instabilities over a full range of the model parameters including anomalous diffusion. We also show that the Turing instability results in complex spatio-temporal patterning characterized by a surface roughness exponent that varies from unity (smooth) to one-half (white noise) as the anomalous diffusion exponent varies from unity (standard diffusion) towards zero (extreme sub-diffusion).

## **Evaluation of four dimensional Integrals arising in Galerkin boundary element methods.**

**James N. Lyness** and G.Monegato  
School of Mathematics, University of NSW

When applying boundary Galerkin methods to hypersingular integral equations defined on surfaces, many four dimensional integrals over a hypercube or over "product triangles" have to be evaluated. Some of these integrals, those difficult to compute, involve integrands having singular behaviour at vertices and along "edges". The number of these integrals is of order  $n$ , where  $n$  denotes the dimension of the Galerkin matrix. This number may be quite high, let us say of order one million.

Work is in progress to investigate the feasibility of using extrapolation quadrature for some of these integrals. We plan to report on apparently new results now available.

## **Semi-Lagrangian methods for vortex dynamics in irregularly shaped domains**

C. Macaskill and Z. Jomaa

School of Mathematics and Statistics, University of Sydney

The CASL (Contour Advected Semi-Lagrangian) algorithm of Dritschel and Ambaum is a modification of the contour dynamics technique that gives very efficient code while maintaining high horizontal resolution. In the oceanic context it can be used to deal with 3D stratified flows where the quasi-geostrophic approximation is appropriate. Here we describe a version of the method that can deal with strongly nonlinear vortex interactions in irregularly shaped domains. For some 2D cases, we investigate the way in which local boundary geometry strongly influences such interactions.

## **Facets for the cardinality constrained quadratic knapsack problem and the quadratic selective travelling salesman problem**

Vicky Mak and Tommy Thomadsen

vmak@ms.unimelb.edu.au

tt@imm.dtu.dk

In this talk, we present our work on the cardinality constrained quadratic knapsack problem (CCQKP) and the quadratic selective travelling salesman problem (QSTSP). The QSTSP arose from the building of telecommunication networks and is closely related to the CCQKP. We discuss how these problems are related, and demonstrate how they can be modeled as integer linear programs (ILPs). We then present a few classes of new inequalities for these problems. Last of all, we present our polyhedral results on the dimensions of the polytopes of these ILPs, and our facet-defining results on these newly found inequalities.

## Deformations of hypoplastic soils in one dimension

Scott W. McCue

I. Kenneth Johnpillai and James M. Hill  
School of Mathematics and Applied Statistics  
University of Wollongong NSW

The behaviour of soils and other granular materials has been studied extensively with the use of classical plasticity and elastoplasticity theories. An alternate approach is hypoplasticity, which is a stress-rate theory of continuum mechanics with a constitutive law expressed in a single tensorial equation. In this talk, a particular version of hypoplasticity is employed to describe a class of one-dimensional granular deformations. By combining the constitutive law with the conservation laws of continuum mechanics, a system of four nonlinear PDEs is derived for the axial and lateral stresses, the velocity component and the void ratio. Under certain restrictions, three of the governing equations may be combined to yield ODEs, whose solutions can be calculated exactly. Several new analytical results are obtained which are applicable to one-dimensional compression tests. In general this approach is not possible, and analytic progress is sought via Lie symmetry analysis. A complete set or “optimal system” of group-invariant solutions is identified using the Olver method, where each element in the set is governed by a system of nonlinear ODEs. Included in the optimal system are travelling-wave solutions and similarity solutions, as well as some more exotic group-invariant solutions.

## To be announced

Terry Mills

Department of Mathematics  
La Trobe University

To be announced

## The dynamics of Toy Stars

Joe Monaghan

School of Mathematical Sciences  
Monash University

In this talk I will discuss a new class of bench mark systems we call Toy Stars. In these systems a mass of gas is pulled together by an attractive force. The force is not gravity, but it was discussed by Newton in the Principia. Each particle attracts every other particle with a force proportional to distance and along the line of centres. Remarkably, the total force on each particle then reduces to motion in a simple harmonic potential independent of the motion of the other particles.

In two dimensions the Toy Star system is analogous to the tidal oscillations of water in a paraboloidal basin. In three dimensions the solutions are new. They provide wonderful benchmarks for numerical simulations including some with magnetic fields. Comparisons between the exact results and recent simulations will be described.

# Modified Column Generation for Set Partitioning Problems

Phil Neame

Department of Mathematical Sciences  
University of Technology, Sydney

Set partitioning problems arise in many applications. For example, airlines wishing to efficiently assign crew to flights regularly search for solutions to massive set partitioning problems. Column generation allows near-optimal solutions to be found in reasonable time — these techniques have saved airlines around the world many millions of dollars. The aim is to use dual pricing information to consider only those combinations of crew and flights that are "useful". However, it has been observed that the column generation updates can be "unstable", in that dual prices vary excessively between iterations, and the algorithm produces many unnecessary columns. I will outline some methods for stabilizing the process, give some theoretical analysis of these methods and present preliminary numerical results.

## Analysis of an immobilised enzyme reactor

M.I. Nelson and X.D. Chen

School of Mathematics and Applied Statistics  
University of Wollongong

Immobilised enzyme technology (IET) is attractive to process industries in which the enzymes (biocatalysts) involved are expensive or if a large throughput of substrate is required. In this paper we investigate a model for an enzyme catalysed reaction occurring in an immobilised enzyme reactor (IER). The IER is modelled as a continuously stirred tank reactor. The substrate flows through the reactor whilst the reaction products flow out of it. However, enzyme species are constrained to remain within the reactor. The retention of an immobilised enzyme within a zone of a flow reactor is one of the main advantages of IET.

## Using Packet Pair Probing to Estimate Arrival-Rate and Packet Size

Ana Novak and Peter Taylor  
Mathematics and Statistics  
University of Melbourne, Melbourne, VIC

The appeal of the active probing is its intrinsically end-to-end nature which allows the non-privileged users to probe Internet traffic. Active probing may be used to extract various information from the network, such as: bandwidth, background or cross traffic rate, network load and packet size. This information is essential for the optimization and management of the Internet. However, extracting useful information is a difficult task due to complex nature of the Internet. The analysis has to accommodate differences between routers, diversity of Internet traffic and different types of links.

The goal of this presentation is to begin the development of a new approach to a packet-pair based measurement method, which can be used to estimate the size and arrival rate of the underlying network traffic. Specifically, this presentation will focus on a packet-pair based method used to estimate packet size and arrival rate on a singular link.

## Efficient techniques for spectral line convolutions

Tony O'Connor  
School of Science,  
Griffith University, Nathan, Qld 4111

The shapes of spectral lines in astrophysics and atmospheric science are often determined by independent several factors. Mathematically this requires the calculation of multiple convolution integrals at a variety of points. Typically these convolutions involve the Lorentzian ( $1/(x^2 + a^2)$ ), Gaussian and one other function.

Current methods are either based on the Fast Fourier Transform (FFT) or a number of ad-hoc approximation schemes for some of these integrals. FFT methods are not well suited to non uniformly spaced points while ad-hoc methods are often of limited accuracy.

Several recent 'analytical' methods turn out to be both flexible and capable of arbitrary accuracy. They include Weideman's rational eigenfunction approach for Lorentzian convolutions and a continuous version of the fast Gauss transform.

## On implementing general linear methods

Helmut Podhaisky

Department of Mathematics  
The University of Auckland  
Private Bag 92019, Auckland, New Zealand

During the recent years a comprehensive theory for a new type of multistep multi-stage time integration for stiff ODEs based on the concept of inherent Runge–Kutta stability (IRK stability) methods has been developed by J. C. Butcher and W. M. Wright. By having diagonally implicit stages *and* high stage order IRK-methods overcome a well known weakness of one-step Runge-Kutta methods. In addition, IRK methods share the favourable stability properties with Runge–Kutta methods which is superior to the stability of multistep methods (e.g. BDF methods). The construction of IRK methods and their properties will be explained in more detail in John Butcher’s talk. Here, we address issues of the implementation including the solution of the nonlinear systems, stepsize and order selection.

## Seepage face Lengths and Flow Paths for Hillslopes With a Horizontal Aquiclude

W. Wayne Read

James Cook University , Townsville, QLD

The seepage face on a hillslope under steady recharge delineates the saturated part of the soil surface. Consequently, the length of the seepage face is vitally important as it determines the extent of the hillslope useful for agriculture. In addition, contaminants such as salt will be advected and diffused principally through the seepage face. The problem can be formulated mathematically as a Laplacian free boundary problem, where the location of the water table (and hence seepage face length) is initially unknown. In this paper, I will present solutions for homogeneous hillslope aquifers with a horizontal aquiclude, undergoing steady (constant) discharge. I will discuss the relationships between surface slope, aspect ratio of the aquifer and recharge rate. I will also discuss the relationship between the seepage face length and the discharge length that is responsible for 90% of the flow out of the aquifer, as this is the region where most of the contaminant advection will occur.

## The type reproduction number for an infectious disease

Mick Roberts and Hans Heesterbeek  
IIMS, Massey University, Albany, NZ  
University of Utrecht, the Netherlands

A ubiquitous quantity in epidemic modelling is the basic reproduction number ( $R_0$ ). This became so popular in the 1990s that “All you need know is  $R_0$  !” became a familiar catch-phrase. The value of  $R_0$  defines the control effort needed to eliminate the infection from a homogeneous host population, but can be misleading when applied to a heterogeneous population. We have defined the type reproduction number ( $T_1$ ) for an infectious disease, and shown that this has the required threshold behaviour and correctly determines the critical control effort for heterogeneous populations. The two quantities coincide for homogeneous populations. As a byproduct, the calculation of  $T_1$  provides a method of determining those host types that act as a reservoir of infection.

## The concentration field does not model Brownian bugs

Tony Roberts  
Dept of Maths & Computing, University of Southern Queensland

Brownian particles just undergo a random walk. However, Brownian bugs also die and clone themselves to maintain population. Despite the bug concentration field satisfying the simple diffusion equation which predicts a spatially uniform distribution, the births are a source of correlation which results in the bugs forming striking patches. Appropriate continuum models of the system must also model the dynamics of the pair correlations, not just the concentration field. Perhaps the same is true for models of granular media. We need a method to detect from experimental data when a continuum model requires correlation as well as concentration. Here we explore the dimensionality of space-time patches of the concentration-correlation fields in order to detect significant correlation dynamics.

## **Diffusive and Chemotactic Cellular Migration: Smooth and Discontinuous Travelling Wave Solutions**

Matthew Simpson and Kerry Landman  
Department of Mathematics and Statistics  
University of Melbourne, Parkville 3010 Victoria Australia

A mathematical model describing cell migration by diffusion and chemotaxis is considered. The model gives rise to a suite of travelling wave solutions characterized by a minimum wave speed. Travelling wave solutions are observed regardless of whether migration is driven by pure diffusion, pure chemotaxis or a combination of the two mechanisms. Purely chemotactic migration yields both discontinuous solutions with shocks as well as smooth continuous solutions. Conversely, classical pure diffusion migration yields smooth solutions only. In all cases the travelling wave speed depends upon the initial distribution of migrating cells. The minimum wave speed is examined as a function of the migration parameters.

## **Numerical Integration in Hundreds of Dimensions**

Ian H Sloan  
University of New South Wales

This talk will be a rapid review of recent progress in designing numerical integration rules for the  $s$ -dimensional unit cube, where  $s$  may be in the hundreds.

## **A 0–1 linear programming model for even harmonic numbers**

Ronald M. Sorli  
Department of Mathematical Sciences  
University of Technology, Sydney

A natural number  $n$  is said to be harmonic if the harmonic mean,  $H(n)$ , of its positive divisors is an integer. Harmonic numbers were introduced by Ore in 1948 and are related to perfect and multiperfect numbers. No odd harmonic numbers have been found. A proof that none exist would constitute a proof that no odd perfect numbers exist (a long-standing unsolved problem).

While even harmonic numbers are plentiful, most of them can be generated from a relatively small set of harmonic seeds. All harmonic numbers  $n < 10^{12}$  and harmonic seeds  $n < 10^{15}$  have been found by searching. A recent computational study has found all harmonic numbers with  $H(n) \leq 300$ . All of these harmonic numbers have  $2^a$ ,  $a < 20$  as a component. Searching for examples of harmonic numbers with  $2^a$ ,  $a < 100$  as a component becomes less practical.

A different approach is to formulate and solve a linear programming model of a restricted class of harmonic numbers. This allows the theory (and practice) of linear programming to be applied to finding such numbers.

A 0–1 (decision) model is formulated where the size of the model is restricted using simple properties of harmonic numbers. The feasibility of the model is demonstrated by finding new harmonic numbers with specified components of  $2^a$  for all  $a < 100$ .

## **Multiple Sensor Surface Vibrations Analysis for Monitoring Tumbling Mill Performance**

**Steven Spencer**

CSIRO Minerals, Private Mail Bag 5,  
Menai, NSW 2234. E-mail: steven.spencer@csiro.au

Tumbling mills are large-scale grinding devices commonly used in mineral processing. Acoustic Emissions (AE) from multiple grinding media interactions detected as surface vibrations on a mill shell can be used as a non-intrusive means of monitoring ‘hidden’ process and machine condition variables.

An automated signal analysis system has been developed for AE source event location in industrial tumbling mills, based on multiple sensor surface vibration monitoring. The location and characteristics of each large AE source event are estimated on the basis of transducer arrival time differences. A surface geodesic wave path and fixed propagation speed for “Rayleigh-like” surface waves are assumed. An analysis of the stability and accuracy limits of the inverse problem for AE event source location is presented.

## **Three-dimensional free surface flows induced by a submerged ring sink.**

**Tim Stokes** and Graeme Hocking

Department of Mathematics  
University of Waikato, Hamilton, New Zealand

In three-dimensional free surface withdrawal problems, axisymmetry about a submerged point sink is generally assumed. In this talk the sink is instead assumed to be a horizontal ring sink with its centre on the axis of symmetry. It turns out that even in the linear theory, stagnation point steady flows have a secondary ring of stagnation points, if the radius of the ring sink is sufficiently large. A critical radius of  $\sqrt{2}$  times the submergence depth heralds the emergence of this stagnation ring. (In the point sink case, such stagnation rings are a highly non-linear phenomenon, existing only for large Froude numbers.) We also briefly consider the unsteady case for various Froude numbers.

# Speeding Up The Milstein Method for SDE's: An Example from the Finance Industry

David M Stump  
National Australia Bank  
Melbourne VIC 3000

Systems of stochastic differential equations arise within a variety of contexts in the finance industry. It is standard industrial practice to integrate these equations with Euler's method, which is only accurate to  $O(\sqrt{\Delta t})$ . The Milstein method is accurate to  $O(\Delta t)$ , but it can be much slower to implement due to the evaluation of a matrix of Karhunen-Loeve series

$$L_{ij} = \frac{1}{2\pi} \sum_{n=1}^{\infty} \frac{1}{n} \left\{ \zeta_{i,n}(\sqrt{2}\phi_j + \eta_{j,n}) - \zeta_{j,n}(\sqrt{2}\phi_i + \eta_{i,n}) \right\}$$

at each time step. Here  $\phi_i$ , and  $\phi_j$  are specified, and the  $\zeta$  and  $\eta$  terms are families of standard normal random variables. We present a method for approximating this complicated expression with a few random variable draws from moment matching distributions. This dramatically improves the speed of the Milstein scheme and allows it to be implemented within an industrial context with only a small loss in accuracy.

## Lifting circular discs

Ernie Tuck and Leo Lazauskas  
Applied Mathematics  
The University of Adelaide, SA5005

Wings with circular planforms are not common in aeronautics, but the frisbee is a significant non-aeronautical example. There are some semi-analytic approaches in the literature to solution for the flow over such lifting surfaces, which yield exact or nearly exact results for flat discs at angle of attack. These solutions are reviewed and compared with direct numerical solutions of the lifting surface integral equation. Solutions for non-flat discs are also discussed, including optimisation of twist or of frisbee shape to minimise induced drag.

## The challenge of micromechanics modelling of hair

**Graeme Wake**

John Hearle, Warren Bryson, Harry Liu, and Bernie Tsang,  
Centre for Mathematics in Industry,  
Massey University at Albany,  
Auckland, New Zealand

Better knowledge of fibre structure through advances in experimental techniques such as: X-ray diffraction, data processing, electron microscopy, thick section tomography, and Raman spectroscopy proteomics; has enabled us, by using modern modelling techniques, to predict macro-properties of fibres and fibre-assemblies based on the physiological micro-structure of the fibre. The microfibril structure ('rods' and 'helices') give rise to differential contraction on drying following fibre construction. Energy techniques enable predictions to be made for macro-properties of fibres like curvature and torsion. This work, developed in conjunction with the worldwide Canesis Network, has considerable commercial value in view of the fact that it is now possible to alter the microfibril structure genetically. Chemical intervention (via shampoos, etc) also can affect properties in a predictable and desired way. A survey of progress to date will be given.

## Activities at MISG2004

**Graeme Wake**

Director MISG2004  
Centre for Mathematics in Industry,  
Massey University at Albany,  
Auckland, New Zealand

A review of the activities and problems investigated at the Mathematics-in-Industry Study Group 2004 will be given.

## Multiple Drifting Flame Balls

**Rodney Weber**

N.A.Ansari, G.N.Mercer, H.S.Sidhu, and A.G.Tate  
School of Physical, Environmental and Mathematical Sciences  
University of New South Wales at ADFA  
Canberra ACT 2600, r.weber@adfa.edu.au

The equations for microgravity flame balls, both with a flame sheet model and with Arrhenius kinetics for the reaction, are shown to numerically admit solutions describing multiple flame balls. In the case of two flame balls, they can be of equal size or different size, but only the former is stable. For three flame balls, it seems again that only the equal size configuration is stable. This is consistent with the space shuttle experiments of recent years. We also report on progress in numerically observing flame balls drifting apart.

# Nonlinear Viscosity Effects on Hydrodynamic Inertia and Damping

Ron Yeung

University of Berkeley, USA

Classical treatment of a floating body in ocean waves involves the estimation of hydrodynamic inertia and wave damping based on the ideal-fluid assumption. Significant flow separation around bluff bodies or appendages with sharp edges will render such a treatment inaccurate. “FSRVM” is a special integral-equation vortex method developed at UC-Berkeley that can account for both surface-wave and vorticity-generation effects. The nonlinear solution utilizes an  $O(N)$  algorithm to track the interaction of shed vortices. Through this method, some rather surprising but explainable effects of viscosity are found. The talk provides a brief overview of the methodology and a comparison of the nonlinear results with those based on zero viscosity, and those based on a linear vorticity-diffusion theory in early 1990’s. Experimental verification is also described.

## The ring routing problem

Sanming Zhou

Department of Mathematics and Statistics

The University of Melbourne

Parkville, VIC 3010, Australia

E-mail: smzhou@ms.unimelb.edu.au

Given a network and a set of communication requests, a fundamental problem is to design a routing scheme (that is, a transmission route for each request) such that the maximum load on arcs/edges is minimized. I will talk about recent progress on this problem for rings (cycles) with emphasis on algorithms and computational complexity.



# Abstracts of student presentations

## **Crossing the threshold of Brownian motion: a new model for Australian stock prices**

**William Bertram** and Peter Buchen  
Mathematics and Statistics  
University of Sydney, NSW

The examination of high frequency equity data from the Australian Stock Exchange has unearthed many interesting phenomena. Of the behaviour detected, two effects stand out as being the most prominent. The first is the existence of strong periodic behaviour in the various measures of volatility, and the second is an effect called *zero return enhancement*, where a disproportionate number of trades have taken place at a constant price. This talk will introduce both the intraday volatility trend and the *zero return enhancement*, and discuss the causes of these effects. A threshold type model will be presented, which based on Geometric Brownian Motion and links the two previously mentioned phenomena. It will be shown that this new model provides a better description of real market behaviour than that afforded by Geometric Brownian Motion.

## **Reaction-diffusion equations with explicit spatial dependence for population genetics**

**B.H. Bradshaw-Hajek** and M.P. Edwards  
School of Mathematics and Applied Statistics  
University of Wollongong

In light of the recent developments in gene technology, it is timely that the mathematical modelling of changing gene proportions be re-examined. We extend the existing models to incorporate explicit spatial dependence of the reproductive success rates. The resulting reaction-diffusion equations are examined using classical and nonclassical symmetry methods, and some new exact solutions are constructed.

## Rossby waves on a rotating sphere

**Tim Callaghan**  
Maths-Physics Building  
University of Tasmania  
GPO Box 252-37  
Hobart, TAS 7001

Rossby waves are large-scale waves in the Earth's atmosphere with typical wavelengths of the order of thousands of kilometres. In this talk we present a mathematical approach that uses an exponential atmospheric lapse rate to aid in modelling Rossby waves on a spherical surface. A linearised model will be introduced and results from the analysis of this model will be presented with an emphasis on wavespeed vs amplitude relationships.

## A Column Generation Approach to Scheduling Problems.

**Chris Fricke** and **Natashia Boland**  
Department of Mathematics and Statistics  
University of Melbourne, VIC

Sequencing and scheduling problems arise in the planning phase of large, complex projects, when the project consists of many individual activities, and there is a substantial time horizon for completion of the project. Examples include resource-constrained project scheduling, mine production scheduling, and assembly line balancing. As the size of the project increases, the number of binary decision variables in a standard integer programming formulation makes direct solution of the model intractable. A reformulation of a standard scheduling integer program to allow solution using column generation will be presented. Preliminary results will be discussed.

## Frequency response of atomic force microscope cantilevers immersed in viscous fluids

**Christopher P. Green** and **John E. Sader**  
Department of Mathematics and Statistics,  
University of Melbourne

The natural frequencies of vibration of an object are known to depend strongly upon the medium in which it is immersed. In this talk, a theoretical model for the frequency response of an atomic force microscope (AFM) cantilever immersed in a viscous fluid is presented. This model, which rigorously accounts for both the geometry of the cantilever and the viscosity of the fluid, enables *a priori* calculation of the complete frequency response of AFM cantilevers. Important features of the model will be discussed, and a comparison with experimental results presented. Using the model, rapid non-invasive and non-destructive techniques to calibrate the spring constants of AFM cantilevers are obtained, and a discussion on the accuracy of these methods presented.

## **Modelling Linear Viscoelasticity using a Kohlrausch Function for the Relaxation Modulus**

**Pol Haji**

Centre for Mathematics and its Applications,  
Mathematical Sciences Institute,  
The Australian National University, Canberra, ACT

The Boltzmann model of linear viscoelasticity is an appropriate model for materials that simultaneously exhibit viscous and elastic behaviour. In the formulation of a Boltzmann model, the key consideration is the choice of the relaxation modulus. In a wide variety of applications, including the modelling of the glassy state of dense matter, polymer dynamics, and bone and muscle rheology, the Kohlrausch function has proved to be more appropriate in modelling the associated relaxation and decay processes than the standard exponential function. It is therefore an appropriate practical choice for the relaxation modulus. Some of the key properties of the Kohlrausch function will be discussed along with the recovery of Kohlrausch parameters from experimental measurements, in which the relaxation modulus is modelled as the sum of Kohlrausch functions.

## **Marine Reserves as a Learning Tool**

**Klaas Hartmann**, Lance Bode and Paul R. Armsworth  
School of Mathematical and Physical Sciences  
James Cook University, Townsville

Marine reserves are an emerging tool for the management of marine resources. Many of the benefits associated with reserves have been widely investigated and the field is currently an active area of research in theoretical ecology. One benefit of reserves that has remained largely overlooked is their value as a tool for learning about the population dynamics of a system. Both a Monte Carlo simulation and stochastic dynamic programming formulation for investigating this situation are presented. These methods have been used to demonstrate that in some situations the value of learning from a reserve may be significant. This value may be sufficient to make the creation of a reserve purely for learning about a system economically optimal.

## **Multiphase Smoothed Particle Hydrodynamics**

**John Hitti** and J.J. Monaghan

School of Mathematical Sciences, Monash University, Clayton, Victoria 3800,  
Australia  
john.hitti@sci.monash.edu.au

Results of multiphase flow are presented via Smoothed Particle Hydrodynamics modelling. A formulation has been developed for interactions between liquid, gas and solid phases. Initial results have shown close matching to experimental results for sedimentation of solid material in fluid in the dilute solids volume fraction limit. Qualitatively correct results for higher solid volume fractions and multi fluid systems have been achieved and will also be presented. The end problem of this research is to model geophysical problems, particularly pyroclastic flows. The Montserrat pyroclastic flows will be described and issues related to their modelling will be discussed.

## **Primary Alkaline Battery Cathodes: A Simplified Galvanostatic Discharge Model**

**Jon Johansen**, Troy Farrell and Colin Please

School of Mathematical Sciences Queensland University of Technology  
GPO Box 2434 Brisbane 4001 Qld

Improving the design of battery systems is beneficial for consumers and battery manufacturers alike. To this end, identifying the vital physical, chemical and electrochemical processes involved in the discharge of such systems is important. Farrell and Please have previously identified the key mechanisms that govern porous manganese oxide particle discharge (these results will be presented in a separate seminar at this conference). In this presentation we apply perturbation methods to present a simplified discharge model which extends the work of Farrell and Please into the domain of an entire porous cathode. We identify and quantify those key phenomena that govern porous cathode discharge and we compare the results of our simplified model with those obtained from previous, more complete and accurate models.

## **The role of boundary error in a finite-difference treatment of the Poisson equation in an irregular domain**

**Z. Jomaa** and C. Macaskill

School of Mathematics & Statistics, University of Sydney

We discuss a 2-D algorithm for inverting the Poisson equation for the stream function on an arbitrarily shaped domain, with non-zero Dirichlet boundary conditions, using finite differences with the domain embedded in a rectangular Cartesian grid. A linear treatment at the boundaries leads to a uniformly second-order accurate method, with a symmetric discrete operator. However the coefficient of error at the boundaries is significantly greater than at internal grid points. A quadratic boundary treatment gives error at the boundaries one order smaller than at internal grid points. For both cases we provide a 1-D theoretical analysis of the error and show how this can be used to approximate the 2-D boundary error, which dominates in the linear case. If the non-symmetric formulation can be used, the quadratic method is clearly superior.

## **Optimal Timing of Political Elections**

**Dharma Lesmono**

Department of Mathematics,  
The University of Queensland, Brisbane, QLD 4072

In the Majoritarian Parliamentary System, such as Australia, one important decision that should be taken by the Prime Minister is the best time to call an election. Making the right decision will give the government electoral longevity, however when the time is not right, the government can lose the office. In this talk, we present a mathematical model for the election problem and outline some results on the expected remaining life in government and the exercise boundary, which indicate whether or not an early election should be called, along with their properties.

## **Modelling Volcanic Ashfall**

**Leng Leng Lim**, Robert McKibbin and Winston Sweatman  
Institute of Information and Mathematical Sciences  
Massey University at Albany

This talk is about the development of a mathematical model to calculate the concentration of volcanic ash or other particulate releases in the atmosphere after an eruption and how it is eventually distributed on the ground.

Because of the complexity of atmospheric flows and the turbulence, we model the atmosphere as a horizontally-layered system; within each layer, which is assumed to be moving steadily and parallel to the ground, the velocity components, particle terminal speed and the dispersion coefficients are assumed uniform, but may be different for each layer. The resulting mathematical problem involves a set of coupled linear PDEs. Progress to date will be reported.

## **The hydrodynamics of an oscillating porous particle**

**Jason R. Looker** and Steven L. Carnie  
Department of Mathematics and Statistics,  
The University of Melbourne, Parkville, Victoria

Currently there is no satisfactory theory for the oscillatory motion of weakly permeable particles through viscous fluid. Such a theory is required before the electroacoustic characterization of suspensions of porous particles can be investigated. In this presentation I will show using homogenization and scaling arguments that the flow inside an oscillating weakly permeable particle may be modelled by Darcy's Law and that the Beavers-Joseph-Saffman (BJS) boundary condition still applies for oscillatory flows. The BJS boundary condition introduces a slip velocity and I will establish that the porous particle may be regarded as impermeable with a slip length independent of frequency. Results for a sphere will be presented that illustrate the significant impact of permeability on oscillatory flows.

## **Modelling solute transport through stratum corneum**

**Thomas Mollee**  
Department of Mathematics  
University of Queensland, Brisbane, Qld

Over recent decades, drug delivery through the skin has been investigated as a means of effecting prolonged and unattended drug delivery. For most neutral drugs the principle transport barrier is the stratum corneum (SC). This is the outermost skin layer consisting of terminally differentiated keratin rich epidermal cells (corneocytes) embedded in an intercellular lipid rich domain. The majority of models for solute transport through SC use the one dimensional diffusion equation, assuming transport is through a homogeneous membrane. In this talk I will outline a mathematical model that incorporates the structural features of SC, viewing transport through SC as diffusion with temporary trapping at a finite number of sites.

## Sonoluminescence in a gas bubble in a fluid

Angus Munro

School of Mathematics and Physics, University of Tasmania

When a vapour bubble in a fluid is forced to oscillate (by an acoustic signal), non-linear effects can result in a very severe collapse phase for the motion. During this portion of the oscillation, the temperature may become so high that the gas in the bubble ionizes, and emits a flash of light. This is sonoluminescence. In this talk, a new model of the phenomenon will be presented. The dynamics of the system will be explored, and complicated behaviour, including chaos, may be observed.

## An $H^1$ Galerkin method with quadrature for nonlinear parabolic problems

Kassem Mustapha

School of Mathematics

The University of New South Wales

We propose and analyze a linearized extrapolated Crank-Nicolson  $H^1$ -Galerkin method with quadrature for a class of nonlinear parabolic problems. Our scheme is based on the semi-discrete least-squares  $H^2$  approximate solution method introduced by Thomeé and Wahlbin for the semilinear heat equation on smooth domains. We prove second order in time and optimal  $H^1$  norm convergence in space, of our computer implementable scheme. We demonstrate convergence in both  $L^2$  and  $H^1$  norms of the quadrature method for a nonlinear parabolic problem.

## Allocation of bandwidth in a communications network

Maya Ramakrishnan

Department of Mathematics and Statistics

The University of Melbourne

A telecommunications network consists of a set of nodes connected by physical links and routes which are non-empty subsets of these links. In order for traffic to travel along a route, capacity is required from every link on the route. The central question in this presentation concerns how capacity should be allocated between competing streams of traffic.

I will commence with an optimisation framework introduced by Kelly et al (1998); the problem that arises, one of centralisation. In moving towards decentralised algorithms, I will introduce a utility function which incorporates the stochastic nature of the system (Chiera and Taylor, 2002) and describe its role in a capacity trading scheme. The issue of whether this scheme achieves the global optimum will be discussed.

## Optimal Policies for The Inventory Problem with Multiple Truck Loads

Armando Rodado

Department of Mathematics and Statistics  
The University of Melbourne  
Parkville, VIC, 3010, Australia

In the 1960's, Scarf proved that  $(s, S)$  policies are optimal for a class of dynamic inventory models with stochastic demand and fixed ordering cost. Under a  $(s, S)$  policy, whenever the inventory level falls below  $s$ , the controller orders a sufficient quantity to bring the inventory level up to  $S$ . The assumption of fixed ordering cost is equivalent to saying that the transportation cost is either zero or constant, and so there is a "truck" with infinite capacity.

Clearly, in many real life cases this is not a reasonable assumption. We consider the inventory problem with stochastic demand in the situation where a fleet of trucks with finite capacity  $Q$  is available and the cost for using each truck is  $T$ . We show that the optimal policy for this problem has a particular structure, called a  $T$ - $Q$ -structure, in the process generalizing Scarf's result. A  $T$ - $Q$ -structure can be defined by a finite number of constants that partition the non-negative real line into an unbounded interval and a finite number of semi-closed intervals of length  $Q$ . We also discuss important properties of the family of functions with a  $T$ - $Q$ -structure and their relation to related concepts.

## Contour Crossings in Contour-Advective Semi-Lagrangian (CASL) Simulations

Timothy Schaerf

and Charlie Macaskill

School of Mathematics and Statistics,  
University of Sydney, NSW 2006

The Contour-Advective Semi-Lagrangian (CASL) algorithm is an efficient numerical scheme for the study of inviscid fluid motions, such as large scale vortex motion in the Earth's oceans and atmosphere. In the CASL method the vorticity, which is a measure of the local rotation of fluid elements, is represented by a series of contours. These contours are moved about according to the prevailing velocity of the flow being simulated.

Although the CASL algorithm is considered to be an accurate method it has been found that the contours that represent the vorticity field may cross, in violation of the equations of motion. This problem also exists in the CASL algorithms better known predecessor, Contour Dynamics.

This presentation will provide a brief introduction to the mathematical model and the contour representation used by the CASL method. Following that will be a discussion on the quantification of the number, size and effect of contour crossings in a CASL simulation.

## Permeation and elimination in liver kinetics

Geoffrey Tacon

Department of Mathematics, School of Physical Sciences  
University of Queensland, Brisbane, Qld

Substantial analytical modelling of liver kinetics has taken place over the last half century. This modelling describes the biological phenomena with varying degrees of success, adequately incorporating some features, but not others. More recent numerical modelling has been able to capture further aspects of liver kinetics. In this talk I will present a numerical model of the liver. Some results will also be presented, highlighting the effect on overall elimination of the branching and joining of veins, in the context of both linear and non-linear permeation and elimination kinetics. Concluding remarks will detail some present difficulties in the modelling.

## Continuum mechanical modelling for highly frictional granular solids

Ngamta Thamwattana and James M. Hill

School of Mathematics and Applied Statistics, University of Wollongong,  
Wollongong, NSW, 2522, Australia

It is well accepted that the Coulomb-Mohr yield condition provides a reasonable basis for the determination of the stress profiles for quasi-static flow of granular materials. This yield condition characterizes the two physical processes of inter-particle cohesion and inter-particle friction. The latter effect is quantified by the so-called angle of internal friction, denoted here by  $\phi$ . While the special case arising from zero angle of internal friction corresponds to the standard Tresca yield condition of metal plasticity, the special case of  $\phi = \pi/2$  gives rise to the idealized theory of ‘highly frictional’ materials. Here, we deal with those materials possessing angles of internal friction  $\phi$  for which  $1 - \sin \phi$  is close to zero. The advanced continuum mechanical theory of granular materials, together with the Coulomb-Mohr yield condition, is utilized to obtain the novel governing nonlinear partial differential equation, whose the solutions have been used to solve real industrial granular problems.

## Incorporating surface forces into the indentation of layered systems

Dimetre Triadis

Department of Mathematics and Statistics  
University of Melbourne

The theory of frictionless contact of smooth elastic solids is discussed and methods for incorporating surface forces and surface energies relevant to colloid and interface science considered. We show that for indentation of layered systems a set of dual integral equations result, the solution of which is aided by the established theory. Results for the indentation of finite layers with surface forces are compared to the established results where the layer is effectively assumed infinitely thick. Implications for the measurement of surface energy in such systems are considered. The work discussed has been done in collaboration with B. D. Hughes.

## **Sandy feet: Coming in contact with granular media.**

**Stuart D. C. Walsh** and Antoinette Tordesillas

Department of Mathematics and Statistics, The University of Melbourne  
Parkville Victoria, 3010

In 1885, a remarkable insight came to Osbourne Reynolds while he was walking along a beach. He noted that strongly compacted granular media (sand) responded to deformation by *increasing* in volume. This rather counter-intuitive observation was dubbed Reynold's principle of Dilatancy.

This presentation discusses two classic contact-mechanics problems for an idealised granular material model, and how they might help us understand Reynold's observation. While it would be presumptuous to claim this presentation walks in Reynold's shoes, it does at least attempt to predict what went on under them.

## **Stimulation of Nerves in the Body, due to MRI scans**

**Peter While** and Larry Forbes

School of Mathematics and Physics  
University of Tasmania

Magnetic Resonance Imaging (MRI) provides a means for imaging soft tissue. Protons (in water molecules) in the body are first aligned using a powerful electromagnet. The imaging process works by creating a unique magnetic field at each point using gradient magnets, and irradiating the body with radio-frequency signal. The gradient magnets are switched rapidly, as this enhances image resolution. These strongly varying magnetic fields induce electrical fields inside the body, and if they are strong enough, nerves near the skin may be stimulated. As a result, some patients experience an uncomfortable tingling sensation during scans. This talk presents an analytic solution for Maxwell's equations in the body, and shows that currents and spiking surface charge are induced on the skin.



# Abstracts of poster presentations

## **Metamorphosis of turbulence–shear flow dynamics in fusion plasmas**

**Rowena Ball**

Department of Theoretical Physics, RSPHysSE

Australian National University

Rowena.Ball@anu.edu.au

In magnetized fusion plasmas the dynamics of turbulent kinetic energy uptake by stable shear flows (L–H transitions) is dominated either by Reynolds stresses or bifurcation of induced electric fields. In this study, these two mechanisms are smoothly reconciled. A reduced model for plasma dynamics is extended to include a nonlinear shear flow driving rate. As the rate coefficient is tuned the system passes from a régime of hysteresis and associated limit cycles where the dynamics is essentially three-dimensional, to a qualitatively different hysteretic domain, dominated by the induced radial electric field. The smooth path between these two extremes passes through an intermediate domain where L–H transitions are oscillatory and hysteresis is locally forbidden. These results provide unification of previous disparate models for L–H transitions, and also suggest strategies for controlling access to high confinement states or manipulating oscillatory behaviour.

## **An Improvement to Situational Force Scoring for Adjudicating Attrition in Combined Arms Conflicts**

**Andrew Gill**

Defence Science and Technology Organisation

PO Box 1500 Edinburgh, Adelaide 5111

Situational Force Scoring is a threat assessment technique for examining potential military conflicts, whereby the relative strengths in various weapon categories are aggregated to a single numerical index taking into account various situational and tactical factors. However, examples are used here to show that in certain situations, nonsensical attrition results are predicted. A simple alteration to the general process is suggested as a remedy and the approaches are compared for a typical application whereby optimal force structures are sought. A game theory version of the analysis is also provided to illustrate the potential use of Situational Force Scoring in estimating robust force allocations.

## Regularising ill-posed integral equations using dual systems

Sven-Åke Gustafson  
Stavanger University  
Box 8002, Stavanger, Norway

The text of the abstract. We consider the problem of solving ill-posed linear integral equations where the right hand side is defined by a sparse set of measured values. Our goal is to evaluate certain linear functionals having the solution of the integral equation as an argument. This may be looked upon as a generalisation of the task of tabulating the solution at a grid. Using a generalisation of Fisher's information matrix formula we derive bounds for the errors in the calculated values. Numerical values from applications in the petroleum industry are presented including the so-called centrifuge equation for determination of capillary pressure and a Fredholm equation originating from NMR (nuclear magnetic resonance) measurements.

## Digital homeomorphic properties of the digital surface

Sang-Eon Han  
Applied Mathematics and Image Processing  
Honam University, Gwangju, Korea

The goal of this talk is to characterize the  $(k_0, k_1)$ -homeomorphic property of digital  $k_i$ -surface,  $i \in \{0, 1\}$ . A simple closed  $k$ -surface may be considered as a closed surface which does not have a singularity as a closed surfaces which does not fold upon itself with respect to  $k$ -adjacency. In this paper we investigate the topological invariant of a digital surface in terms of a  $(k_0, k_1)$ -homeomorphism e.g. digital linking number, digital topological number.



# Speaker index

Aldis, 21  
Anderssen, 21  
  
Ball, 61  
Belward J., 22  
Belward S., 22  
Bertram, 51  
Bindoff, 17  
Bode, 22  
Boland, 23  
Bradshaw-Hajek, 51  
Brideson, 23  
Broadbridge, 24  
Buckmaster, 24  
Butcher, 25  
  
Callaghan, 52  
Carminati, 25  
Cerone, 26  
Clarke, 26  
Cleary, 26, 27  
Costa, 27  
Cox, 27  
  
de Mestre, 28  
Deakin, 28  
Denier, 28  
Derrick, 29  
Dragomir, 29  
  
Fackrell, 30  
Farrell, 30  
Farrow, 31  
Forbes, 31  
Fraser, 31  
Fricke, 52  
  
Galloway, 32  
Gibson, 32  
Gill, 61  
Gray, 33  
Green, 52  
Gustafson, 62  
  
Haji, 53  
Han, 62  
  
Hartmann, 53  
Henry, 33  
Hickman, 34  
Hill, 34  
Hitti, 53  
Hocking, 35  
  
J. Seo, 18  
Johansen, 54  
Johnston, 35  
Jomaa, 54  
Joshi, 18  
  
King, 19  
Kobayashi, 36  
Kroese, 36  
  
Laing, 36  
Landman, 37  
Langdon, 37  
Langlands, 38  
Lesmono, 54  
Lim, 55  
Looker, 55  
Lucas, 19  
Lyness, 38  
  
Macaskill, 39  
Mak, 39  
McCue, 40  
Mills, 40  
Mollee, 55  
Monaghan, 40  
Munro, 56  
Mustapha, 56  
  
Neame, 41  
Nelson, 41  
Novak, 42  
  
O'Connor, 42  
  
Podhaisky, 43  
  
Ramakrishnan, 56  
Read, 43

Roberts A., 44  
Roberts M., 44  
Rodado, 57

Schaerf, 57  
Schwartz, 19  
Simpson, 45  
Sloan, 45  
Sorli, 45  
Spencer, 46  
Stokes, 46  
Stump, 47

Tacon, 58  
Taylor, 20  
Thamwattana, 58  
Triadis, 58  
Tuck, 47

Wake, 48  
Walsh, 59  
Weber, 48  
While, 59

Yeung, 49

Zhou, 49