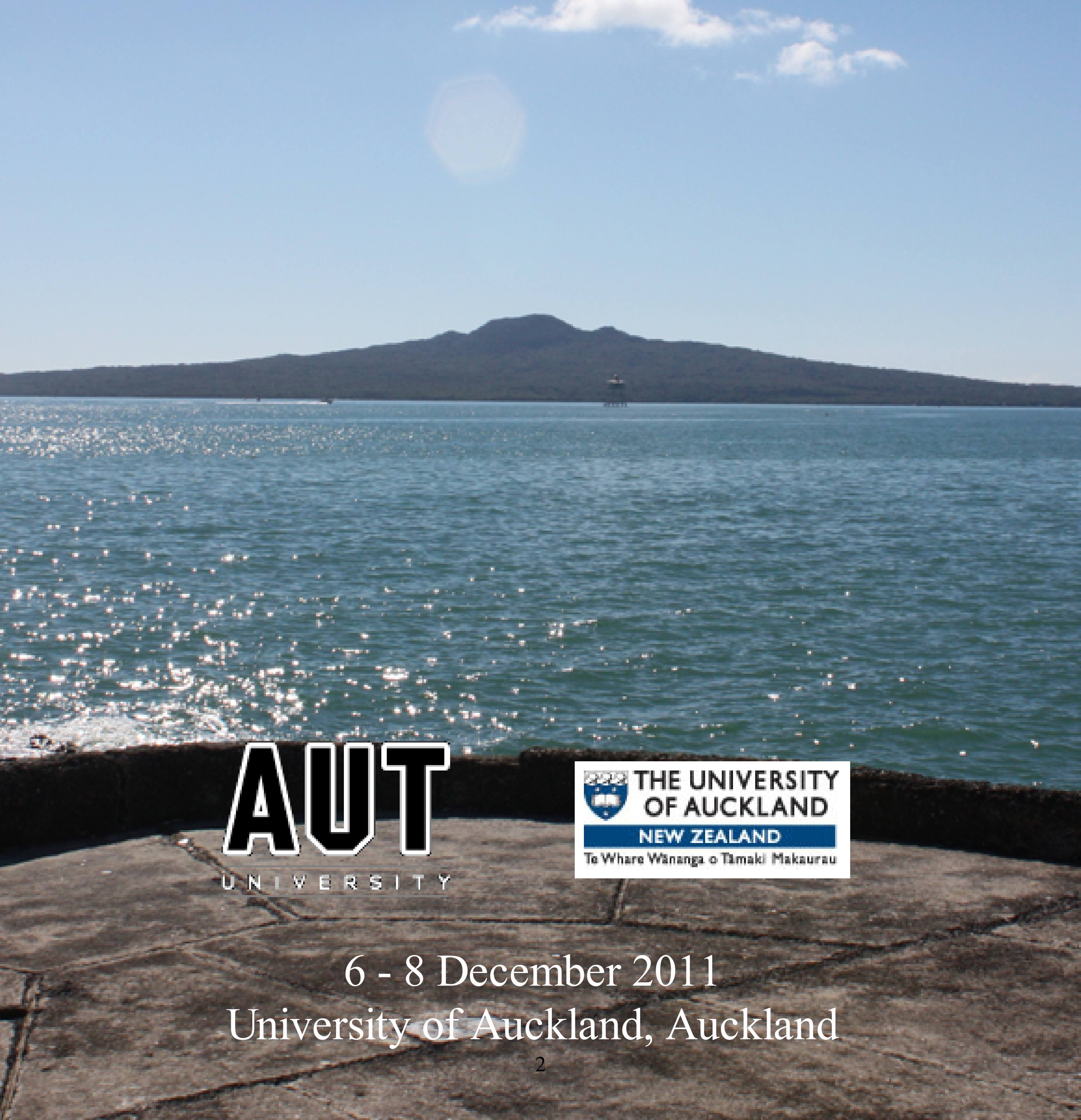
New Zealand Mathematical Society Colloquium 2011

Programme

and

Abstracts



6 - 8 December 2011

University of Auckland, Auckland

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Welcome

Welcome to the New Zealand Mathematics Colloquium 2011, hosted by the University of Auckland and AUT University. There is an excellent programme of lectures and events, and we hope that you will enjoy the conference. We are very grateful for sponsorship from:

- The University of Auckland
- AUT University
- The New Zealand Mathematical Society
- New Zealand Institute of Mathematics and its Applications
- NZIAS (New Zealand Institute for Advanced Study)
- ANZIAM (Australia and New Zealand Industrial and Applied Mathematics)

We also want to thank the contributions made to the running of the conference by: Guanghua Lian, Lily Liow, Olita Moala, Guinevere Nalder, Lynda Pitcaithly and Jaya Venugopalan. Extra special thanks are due to John Shanks of the NZMS for running the conference webpage and registration system.

Steven Galbraith, Jeff Hunter and Hyuck Chung (Organising Commitee)

Conference Programme Committee

Jiling Cao	Tom ter Elst
Steven Galbraith	Rod Gover
Jeff Hunter	Sergiy Klymchuk
Greg Oates	Shixiao Wang

Talks and Prizes

All lectures and social events will be held in the Engineering department buildings on Symonds Street, with the exception of the conference dinner.

Contributed talks have been allocated 25 minutes and speakers are advised that their talks should run for 20 minutes. Session chairs are listed on the conference programme. Session chairs will ensure that sessions run on time by using yellow and red cards:

Yellow card: Thee minutes to go. Show after 17 minutes.

Red card: Time up. Show after 20 minutes if speaker is still talking. Speaker is permitted one additional minute to conclude talk.

Secret trapdoor: Activated after 25 minutes. Speaker will be sucked into the bowels of the Engineering department.

The **Aitken prize** ($500) is awarded by the New Zealand Mathematical Society for the best contributed talk by a student at the Colloquium. Entrants must be enrolled (or have been enrolled) for a degree in mathematics at a university or other tertiary institution in New Zealand in 2011. The Aitken Prize honours the New Zealand-born mathematician A. C. Aitken.

The **ANZIAM poster prize** ($200) is awarded to the best poster by an early career researcher (i.e., the first author of the paper must be either a student, or within 5 years of the completion of their highest degree).

The prizes will be awarded at the Conference Dinner on Wednesday night.

Local Information

If you have any questions then please ask one of the local helpers. They will have a yellow name badge.

In case of medical emergencies then go to:

QuayMed Accident and Medical
Ground floor of QuayPark Health
68 Beach Road, Central Auckland
Phone: (09) 919 2555

Internet

There will be wireless internet access in the conference area. You can select either of the wireless services `UoA-WiFi` or `UoA-Guest-WiFi` .

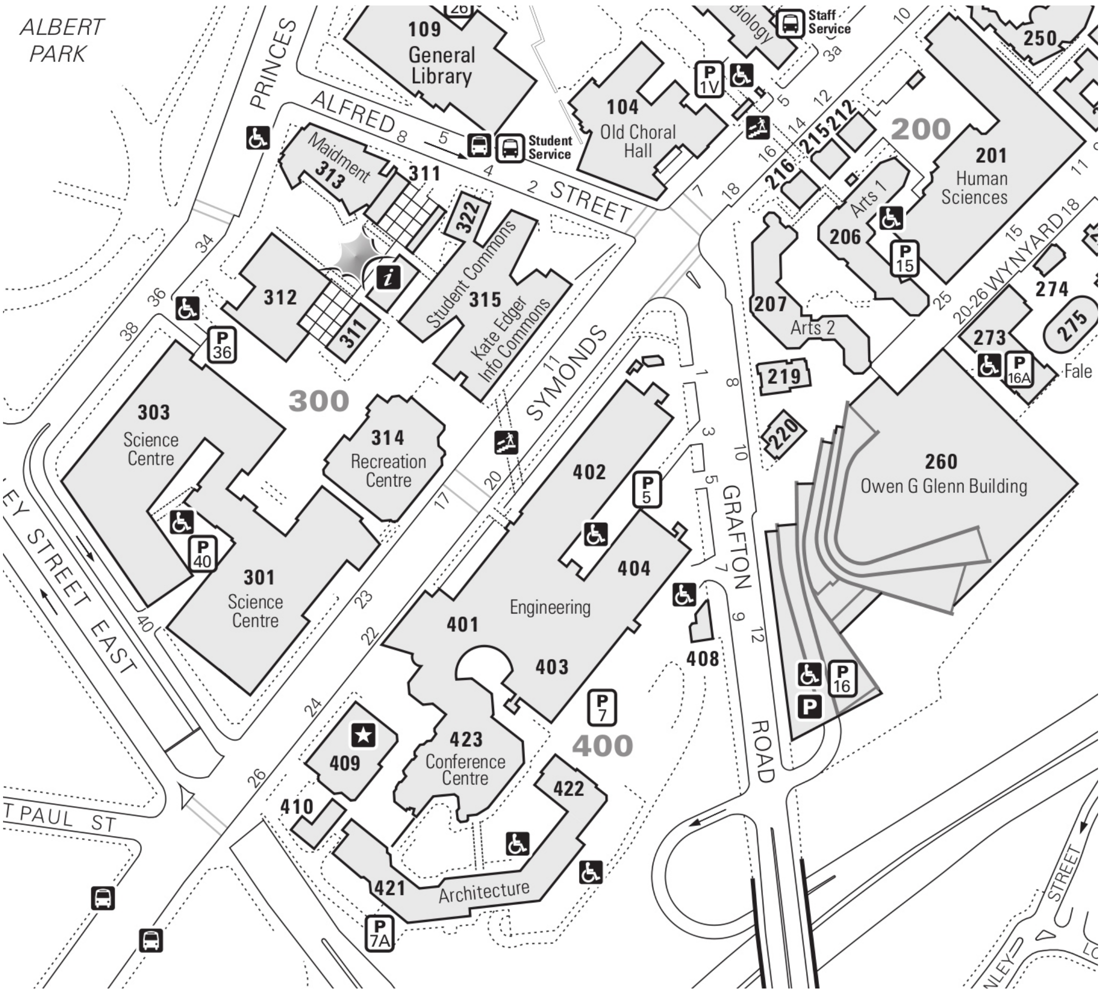
When you open a web browser then you will be asked to login to the university system. You may use any of the below.

NetID/UPI	Password
conf9011	m@th0011
conf9012	m@th0012
conf9013	m@th0013
conf9014	m@th0014
conf9015	m@th0015

There are no guest computers available, sorry. But these logins will also work on the desktop computers in the lecture rooms.

<u>Food and local facilities.</u>

- You can find banks, post-office, bookshop and a mini-supermarket in the Kate Edger Information Commons (315 on campus map).
- Auckland University student foodcourt (311 and 312 on campus map): Various take-away food stalls, including Sushi, Chinese, Indian, Kebabs, Pies etc.
- STRATA restaurant, fourth floor of Kate Edger Information Commons (315 on student map): Good quality hot food.
- Relax lounge cafe (312 on map): Nice outside seating facing Albert Park.
- There is also a wide range of restaurants and cafes towards the city (I recommend High street and Lorne street). For those who want a more "funky" cafe experience then head up Symonds street and turn right onto K-road.



Wednesday Afternoon

Suggested activities near the university

- Stroll the university campus. For background see:
  `http://www.auckland.ac.nz/uoa/places-of-interest/`
  I also recommend the Gus Fisher gallery on Shortland St (open 10am-5pm).
- Visit the recently refurbished Auckland Art Gallery in Albert park. Free entry. Open 10am-5pm every day.
- Visit the Auckland War Memorial Museum. Open 10am to 5pm. Entry $10, or free to Aucklanders.
  It takes about 10-15 minutes to walk from the Engineering buildings to the museum: Go down Grafton Rd and continue straight ahead to the "Centennial Walk" up into the Domain.
  It is best to allow at least 2 hours to visit the museum.

How to get to Tamaki yacht club

'**A**' marks the Tamaki Yacht Club.

- It takes around 1 hour to briskly walk from the conference venue along Tamaki drive to the Tamaki yacht club.
- There are plenty of buses that go along Tamaki drive starting at Quay street. There is a bus every 10 minutes or so, the journey time is about 10 minutes and the cost is $3.40. You can catch a bus on Tyler Street (between Britomart and Quay street), the bus numbers are 745, 755, 756, 767, 769. There is a bus stop near Kelly Tarlton's and the next bus stop is at the point very near Tamaki yacht club.
  For more bus information visit `http://www.maxx.co.nz/`
- Car: There are parking spaces along Tamaki Drive and at the Tamaki yacht club.
- Taxi. The telephone number for Green Cabs is 0508 447 336.
- Please contact the conference organiser if you require assistance to the venue.

Suggested activities for Wednesday afternoon near the venue for the conference dinner

- Kelly Tarlton's Underwater World (open until 5:30pm; last entry 4:30pm).

  We have arranged a special 20% discount for conference participants. This is valid for entry only between 3:30 and 4:30 on Wednesday December 7th. To get the discount just say that you are attending the New Zealand Mathematics Colloquium. This discount reduces the entry price from $34.00 to $27.20.

  It takes less than 5 minutes to walk from Kelly Tarlton's to the Tamaki yacht club.

- Bastion Point and the Savage Memorial. There are some great views over the harbour and Hauraki gulf. From Tamaki drive go up Hapimana Street.

- Mission Bay is a 5-10 minute walk from the Tamaki yacht club. It has a nice beach and plenty of cafes.

The buffet dinner will be served on Wednesday night from 7:00pm. Please try to arrive at the yacht club between 6:00pm and 6:45pm.

'**A**' marks the Tamaki Yacht Club.

Monday December 5, 2011

10:00-17:00	Number Theory Satellite Meeting Engineering 403-404

17:00-20:00	Registration and welcome reception Engineering foyer Food and drinks from 18:00 Sponsor: New Zealand Institute of Advanced Study

Tuesday December 6, 2011

8:30-9:10	Registration

9:10-9:15	Opening Remarks

9:15-10:10 Room 401-401	NZMS Research Award Winner Plenary Lecture **Charles Semple** *Realizing phylogenies with local information* (Chair: Marston Conder)

10:10-10:40	Coffee

	Modelling natural events (Chair: Philip Sharp) room: 403-404	Topology (Chair: Jiling Cao) room: 403-403	Algebra and graphs (Chair: Jianbei An) room 403-402
10:40-11:05	**Mick Roberts** *Epidemic models with uncertainty*	**David Holgate** *Topology in a category - neighbourhood operators*	**Dimitri Leemans** *Symmetric groups and polytopes*
11:10-11:35	**Robert McKibbin** *Mathematical modelling of volcanic eruption plumes*	**Sina Greenwood** *Connected generalised inverse limits*	**Tim Stokes** *Comparison semigroups*
11:40-12:05	**Tammy Lynch** *The effect of cracks and a steam cap on hydrothermal eruptions*	**Michael Lockyer** *Generalised inverse limits of tent maps*	**Astrid an Huef** *Algebras associated to higher-rank graphs*

	Lunch

13:30-14:25 Room 401-401	NZIAS Plenary Lecture **Alan McIntosh** *The square root problem of Kato for elliptic operators* *A survey with emphasis on related first order systems* (Chair: Gaven Martin)

14:25-14:50	Coffee

	Numerical analysis (Chair: Shixiao Wang) room: 403-404	Analysis (Chair: Iain Raeburn) room: 403-403	Mathematical physics (Chair: Rod Gover) room 403-402
14:50-15:15	**John Butcher** *Dealing with parasitic behaviour in G-symplectic integrators*	**Anuj Bhowmik** *Characterizations of Walrasian expectations equilibrium in economies with infinitely many commodities*	**Graham Weir** *Variable gravitational and cosmological parameters in General Relativity*
15:20-15:45	**Gulshad Imran** *Effective order and symplectic integrators*	**Igor Klep** *Values of free noncommutative polynomials and Lie ideals*	**Matthew Randall** *Local obstructions to 2-dim projective structures admitting skew-symmetric Ricci tensor*

	Dynamics (Chair: Claire Postlethwaite) room: 403-404	Probability (Chair: Jeff Hunter) room: 403-403	Foundations of analysis (Chair: Sina Greenwood) room 403-402
15:55-16:20	**Pablo Aguirre** *Both sides of the story: turning a cylinder into a Möbius strip (and vice versa) at homoclinic flip bifurcations*	**Mark Holmes** *Percolation without coffee*	**Maarten McKubre-Jordens** *Constructing weak solutions of the Dirichlet problem*
16:25-16:50	**Stefanie Hittmeyer** *Interacting invariant sets in a 2D noninvertible map model of wild chaos*	**William Newman** *Independent random events and the appearance of order: clustering, hierarchy formation and universal scaling*	**Alexander Melnikov** *Isometric computability structures on metric spaces*

17:00-18:00	NZMS and Colloquium AGM Room 401-401

18:20-18:30	An invitation to a radical idea ($\sqrt{2} < x < I$, where Rad(I) = I) **Bill Barton**

18:30-21:00	Reception Sponsor: NZIMA Engineering foyer
18:45-19:30	Poster session Engineering foyer

Wednesday December 7, 2011

9:10-10:05 Room 401-401	Plenary Lecture **Kiran Kedlaya** *The Sato-Tate conjecture for elliptic and hyperelliptic curves* (Chair: Steven Galbraith)

10:05-10:30	Coffee

	Numerical analysis (Chair: Bernd Krauskopf) room: 403-404	Applied algebra & number theory (Chair: Ben Martin) room: 403-403	Analysis (Chair: Astrid an Huef) room 403-402
10:30-10:55	**Philip Sharp** *Optimal extended explicit Pouzet Runge-Kutta pairs for Volterra integral equations of the second kind*	**Edoardo Persichetti** *Coding theory and cryptography: New perspectives*	**Tom ter Elst** *Partial Gaussian bounds for degenerate differential operators*
11:00-11:25	**Muhammad Amer Qureshi** *High order explicit Runge-Kutta Nystrom pairs*	**Kevin Byard** *A class of combinatorial arrays with good correlation properties*	**Manfred Sauter** *A weak trace for Sobolev functions on rough domains*

	Num analysis and dynamics (Chair: Steve Taylor) room: 403-404	Applications of combinatorics (Chair: Dimitri Leemans) room: 403-403	Analysis and number theory (Chair: Kevin Broughan) room 403-402
11:30-11:55	**Saghir Ahmad** *Efficient solution of stiff problems using Radau IIA and other methods*	**Christopher Tuffley** *Scheduling matches to allow shared transport, or How to get free tickets to your local team's home games*	**Robert Akscyn** *On the number of composites less than a given magnitude*
12:00-12:25	**Winston Sweatman** *Dynamics of some few-body problems with symmetry*	**Joshua Collins** *Constructing phylogenetic networks*	**Shaun Cooper** *Development of elliptic functions according to Ramanujan*

12:30-13:30	Lunch ANZIAM AGM Room: 401-401

13:30-14:25 Room 401-401	Plenary Lecture **John Mason** *Making Connections: shadows, crossed ladders, couriers, Ceva and parallel sums* (Chair: Bill Barton)

	Mathematical biology (Chair:Graham Donovan) room: 403-404	Convection in porous media (Chair: Robert McKibbin) room: 403-403	Topology and analysis (Chair: David Gauld) room: 403-402	Mathematics education (Chair: Judy Paterson) room: 403-401
14:30-14:55	**Shawn Means** *Realistic geometry for modeling: An Acinar salivary gland*	**Amjad Ali** *Modelling pollution transport in phreatic aquifers*	**Jiling Cao** *Bornologies and hyperspaces*	**Mary Beisiegel** *Preparing future mathematicians for teaching tertiary math*
15:00-15:25	**Kate Patterson** *A mathematical model of the salivary duct*	**Donald Nield** *Modelling convection in porous media: Some current developments*	**Ittay Weiss** *Metric 1-spaces*	**Bill Barton** *Videoing lectures research: Where it has taken me*

	Free afternoon

18:00-22:00	Drinks and Conference Dinner (Dinner starting 7:00pm) Tamaki Yacht Club

Thursday December 8, 2011

9:10-10:05 Room 401-401	ANZIAM Plenary Lecture **Graeme Wake** *Mathematics in Medicine: Enhancing your health* (Chair: Alona Ben-Tal)

10:05-10:30	Coffee

	Industrial mathematics (Chair: Winston Sweatman) room: 403-404	Number theory (Chair: Shaun Cooper) room: 403-403	Analysis (Chair: Tom ter Elst) room 403-402
10:30-10:55	**Vitali Babakov** *Initial stage of mass flow through a plane hopper*	**Heung Yeung Lam** *On the Diophantine equation* $n^2 = x^2+by^2+cz^2$	**Iain Raeburn** *Toeplitz algebras of semigroups*
11:00-11:25	**Hyuck Chung** *Computation of the surge motion of a floating elastic plate*	**Ali Jaballah** *The spectrum of a maximal non-integrally closed domain*	**Sanjiv Kumar Gupta** *Asymmetry of multipliers on Lie groups*

	PDEs (Chair: Don Nield) room: 403-404	Markov models (Chair: Mark Holmes) room: 403-403	Analysis (Chair: Igor Klep) room: 403-402	Mathematics Education (Chair: Bill Barton) room: 403-401
11:30-11:55	**Bruce van Brunt** *Probability density function solutions to a Bessel type pantograph equation*	**Ivo Siekmann** *Identity slip-Algebraic problems in aggregated Markov models*	**Peter Donelan** *Hyperbolic pseudo-inverses and the Euclidean group*	**Chris Sangwin** *Automatic assessment of mathematics with Maxima*
12:00-12:25	**Shixiao Wang** *Rotational flow stability: from Rayleigh's theory to the non-linear theory*	**Guanghua Lian** *Consistent modeling of SPX and VIX options: Efficient evaluation in Gatheral's three-factor model*	**Patrick Ion** *Geometry and the discrete Fourier transform*	**Bill McCallum** *Klein vignettes*

12:30-13:30	Lunch

	Optimisation and combinatorics (Chair: Peter Donelan) room: 403-404	Modelling (Chair: John Butcher) room: 403-403	Geometry and AMS standards (Chair: Ernie Kalnins) room 403-402
13:30-13:55	**Alastair McNaughton** *Lagrange optimization of quartic forms*	**Jiří Kunovský** *Parallel computations based on numerical integration methods*	**Ben Whale** *A physically motivated boundary for space-time and its relation to Cauchy completions*
14:00-14:25	**Ben Martin** *Lattices in automorphism groups of trees*	**Dion O'Neale** *Patents and power law distributions: how to find them, fake them and fudge them*	**Patrick Ion** *Mathematics subject classification: The MSC2010 revision and new standards (MathML and SKOS)*

14:30-15:25 Room 401-401	Plenary Lecture **Hinke Osinga** *The role of global manifolds in the transition to chaos in the Lorenz system* (Chair: Vivien Kirk)

15:25-15:30	Closing remarks

Plenary Lectures

Kiran Kedlaya

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The Sato-Tate conjecture for elliptic and hyperelliptic curves

Consider a system of polynomial equations with integer coefficients. For each prime number p, we may reduce modulo p to obtain a system of polynomials over the field of p elements, and then count the number of solutions. It is generally difficult to describe this count as an exact function of p, so instead we take a statistical point of view, treating the count as a random variable and asking for its limiting distribution as we consider increasingly large ranges of primes. Conjecturally, this distribution can be described in terms of the conjugacy classes of a certain compact Lie group. We illustrate this in three examples: polynomials in one variable, where everything is explained in terms of Galois theory by the Chebotarev density theorem; elliptic curves, where the dichotomy of outcomes is predicted by the recently proved Sato-Tate conjecture; and hyperelliptic curves of genus 2, where even the conjectural list of outcomes was only found still more recently.

John Mason

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Making Connections: shadows, crossed ladders, couriers, Ceva and parallel sums

Exploration of connections between apparently disparate elementary problems leads to a little known theorem in geometry and provides an opportunity to experience the role of shifts of attention in teaching and learning mathematics at Secondary level.

Alan McIntosh

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The square root problem of Kato for elliptic operators – a survey with emphasis on related first order systems

The first order Cauchy Riemann equations have long been used in the study of harmonic boundary value problems in plane domains. The Dirac operator can sometimes be employed in higher dimensions. First order systems provide insight into the solution of the Kato square-root problem for second order elliptic operators. I shall present a survey of this material, including the historical background, and recent progress.

Hinke Osinga

University of Auckland

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The role of global manifolds in the transition to chaos in the Lorenz system

The Lorenz system still fascinates many people because of the simplicity of the equations that generate such complicated dynamics on the famous butterfly attractor. This talk addresses the role of the stable and unstable manifolds in organising the dynamics more globally. A main object of interest is the stable manifold of the origin of the Lorenz system, also known as the Lorenz manifold. This two-dimensional manifold and associated manifolds of saddle periodic orbits can be computed accurately with numerical methods based on the continuation of orbit segments, defined as solutions of suitable boundary value problems. We use these techniques to give a precise geometrical and topological characterisation of global manifolds during the transition from simple dynamics, via preturbulence to chaotic dynamics, as the Rayleigh parameter of the Lorenz system is increased.

This is joint work with Bernd Krauskopf (University of Auckland) and Eusebius Doedel (Concordia University, Montreal).

Charles Semple

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Realizing phylogenies with local information

Results that say local information is enough to guarantee global information provide the theoretical underpinnings of many reconstruction algorithms in evolutionary biology. Such results include Buneman's Splits-Equivalence Theorem and the Tree-Metric Theorem. The first result says that, for a collection $\mathcal{C}$ of binary characters, pairwise compatibility is enough to guarantee compatibility for $\mathcal{C}$, that is, there is a phylogenetic (evolutionary) tree that realizes $\mathcal{C}$. The second result says that, for a distance matrix D, if every 4×4 distance submatrix of D is realizable by an edge-weighted phylogenetic tree, then D itself is realizable by such a tree. In this talk, we investigate these and other results of this type. Furthermore, we explore the closely-related task of determining how much information is enough to reconstruct the correct phylogenetic tree.

Graeme Wake

Massey University, Auckland

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Mathematics in Medicine: Enhancing your health

Mathematical models use the language of mathematics to very effectively describe, understand and evaluate systems. Medical science was a comparative late starter in this process, largely because the two groups were not "talking together". This has now changed and startling progress is being achieved worldwide. Mathematics-in-Medicine Study Groups are forming all around the world. The term "Systems Biology" captures the activity that we are doing in the National Research Centre for Growth and Development which is one of New Zealand's Centres of Research Excellence. We are currently involved in growth models, life-history model development, epigenetic models, developmental genetic models, cancer growth: to name just a few areas. Some of these will be described in this talk. Many of these do give rise to "New Maths". Especially notable in this respect is the work on non-local ordinary differential equations. An overview of this work will be given in this lecture.

Contributed Talks

Pablo Aguirre

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Both sides of the story: turning a cylinder into a Möbius strip (and vice versa) at homoclinic flip bifurcations

At a codimension-one homoclinic bifurcation of a three-dimensional vector field, the stable manifold of the saddle equilibrium associated to the homoclinic orbit is either an orientable (topological cylinder) or nonorientable (Möbius strip) two-dimensional surface. The change in orientability may occur at two kinds of codimension-two bifurcations, called inclination and orbit flip. At either of these flip points, the stable manifold is neither orientable nor nonorientable, but just at the transition between both states.

In this talk I show the organization of the three-dimensional phase space in the global sense near flip points of type **A**, where a single stable periodic orbit bifurcates. More precisely, I focus on the role of the two-dimensional global stable manifold of the saddle as it changes its orientability at the flip bifurcations and reorganizes the way it separates the phase space. In particular, I show how the basin of attraction of the stable periodic orbit can be organized in different ways by the stable manifold of the saddle depending on the (non)orientability of this surface. This study is performed on a model by Sandstede constructed with the specific aim to present different kinds of codimension-two homoclinic bifurcations including inclination and orbit flip points.

Saghir Ahmad

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Efficient solution of stiff problems using Radau IIA and other methods

Many differential equation systems arising in the modelling of scientific problems are stiff; and numerical methods for this type of problem are needed. Because suitable methods are necessarily implicit, they are difficult to implement efficiently and this is especially true for multistage Runge-Kutta methods. Other important issues, in addition to the computation of the implicit stages, include error estimation and stepsize control.

Radau IIA methods are one of the most successful approaches for the solution of stiff problems. The famous Radau code by E. Hairer will be surveyed with an emphasis on the difficult design questions and techniques for dealing with the difficult aspects of their implementation that have to be solved, using heuristic arguments if no rigorous theory is available.

Recent approaches and developments in numerical methods for various kinds of ODEs are leading towards the most general form of methods known as general linear methods (GLMs). These multistage, multi-value methods are expected to lead to some improvements in the available implementation techniques and possibly more efficient performance.

Robert Akscyn

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On the number of composites less than a given magnitude

We present and prove an iterated function system for the prime counting function $\pi(n)$. The core of the formulation is a recurrence relation for p-rough integers (integers whose least prime is not less than p); a recurrence highly-similar to classical approaches (Meissel ...) but one whose definition is one-prime-more informed. Using this approach, the composites are tallied via a series of iterated function systems; each with a different seed (the hyperbola n/p), each exhibiting a recursively-nested, hyperbolic fractal structure. While the formulation is exact (tested up to $\pi(10^{14})$), the motivation for the approach is more pining: to lead to a logarithmic series representation for $\pi(x)$ as stepping-stone for subsequent representation of the difference $\pi(x) - Li(x)$, ideally as a series converging not greater than $\sqrt{x}\ln(n)$. In addition to the main thread, we highlight the strong similarities with the Meissel line of work, with emphasis on the bifurcated fractal structure the growth of the composites both approaches exhibit – posited as the underlying deterministic mechanism for the Prime Number Theorem result $\pi(x) \sim x/\ln(x)$.

Amjad Ali

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Modelling pollution transport in phreatic aquifers

Chemical species such as tracers or dissolved pollutants are dispersed by water flowing within a permeable matrix. The species disperse in all directions along with flowing downstream with the fluid. The rate of dispersion depends on the porous structure and the fluid speed.

Generally, groundwater systems are composed of layered structures determined by different events in the geological processes that formed them. The layers in a system have different physical properties, and their thicknesses are not uniformly constant. The phreatic surface attained by the fluid, in such phreatic aquifers depends mainly on the layer properties such as thicknesses and permeabilities in addition to the fluid volumetric flux. The advection-dispersion equations that model fluid and species transport then have coefficients that depend mainly on depth, but with a layer composition that changes with horizontal distance.

Fluid flow is assumed horizontal where lateral extent of the aquifer is assumed large as compared to its total thickness. In case of non-homogeneous multi-layered aquifers, varying thicknesses of the layers and different permeabilities cause interlayer fluid transfer carrying pollutant along with it. Pollutant dispersive flux across the layer interfaces may also occur due to difference in pollutant concentrations in neighbouring layers. Some illustrative examples are presented.

Astrid an Huef

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Algebras associated to higher-rank graphs

The Leavitt path algebras, introduced by Abrams and Aranda Pino in 2005, are purely algebraic analogues of the C*-algebras of directed graphs. There are striking connections between the properties of the algebras and the underlying graph. The higher-rank graph C*-algebras, introduced by Kumjian and Pask in 2000, have provided many new and interesting examples of tractable C*-algebras. Here I will talk about an analogue of the Leavitt path algebras for higher-rank graphs which we call the Kumjian-Pask algebras. I'll start by explaining what a higher-rank graph is and how to visualise it. Then I'll discuss the universal property of the Kumjian-Pask algebras, and the uniqueness theorems which say when a representation of this algebra is injective. This is joint work with Gonzalo Aranda Pino, John Clark and Iain Raeburn.

Vitali Babakov and Alla Shymanska

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Initial stage of mass flow through a plane hopper

The problem of continuum movement in a hopper is investigated. The pressure required to move continuum through a hopper is of great practical and theoretical interest. This work, in contrast to previous work which assumed symmetric flow, assumes a realistic asymmetric flow field comprising triangular rigid blocks separated by rupture lines. By optimizing the number of blocks and the position of the rupture lines, the value of pressure is minimized. The problem of the equilibrium in a hopper has been asymmetrically solved by the top estimation method. An algorithm has been developed to simulate asymmetric flow on the basis of the geometry of the channel. Experiments confirm the acceptance of the method for solving this problem.

Bill Barton

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Videoing lectures research: Where it has taken me

At previous conferences I have reported on research involving videoing ourselves lecturing and then discussing it together. In this session I will talk about where this has taken me personally. What lessons have I learned and what I will change about my lecturing.

Mary Beisiegel

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Preparing future mathematicians for teaching tertiary mathematics - What are potential barriers and challenges?

The purpose of this study was to uncover the challenges that are experienced as mathematics graduate students (i.e., future mathematicians) develop views of their roles as teachers of university mathematics. During an academic year, interviews and conversations were held with mathematics graduate students at a large, research university exploring their experiences and perspectives of mathematics teaching. Each of the study participants had been assigned to help students one-on-one with homework exercises in tutoring centres, to grade homework assignments and exams, or to lead one-hour tutorial sessions. Using thematic analysis, the conversations were analysed and interpreted with attention to themes and experiences that had the potential to influence the graduate students' ideas about and approaches to teaching. Themes that will be explored in this session are: the structures of teaching assistant work, the construed nature of calculus instruction, and the tacitly accepted form of tertiary mathematics instruction. These themes had a significant influence on the study participants' views of mathematics teaching; so much so that resistance to alternate ways of teaching is expected with little motivation to engage in new ways of teaching or to connect with mathematics learners.

Anuj Bhowmik

Auckland University of Technology

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Characterizations of Walrasian expectations equilibrium in economies with infinitely many commodities

In this talk, we consider an exchange economy with asymmetric information, which consists of an atomless measure space of agents and has a separable Banach lattice as the commodity space. It is shown that a feasible allocation is a Walrasian expectations allocation if and only if it is not privately blocked by any coalition.

Bruce van Brunt

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Probability density function solutions to a Bessel type pantograph equation

In 1989 a simple model for cell growth was devised to describe steady size distributions (SSDs) of cell cohorts structured by size (measured by DNA content). The SSDs were observed in plant tissue and later in human tumour cell lines. The original model entailed a first order pantograph functional differential equation for a probability density function. The model was then extended to include dispersion using a Fokker-Planck equation. The simplest case (constant dispersion, growth and splitting) for the resulting second order pantograph equation was solved in 2000, but no analytical solutions were known for other cases.

In this talk we study the second order pantograph equation for a certain choice of nonconstant coefficients that correspond to dispersion, growth and splitting rates. This choice of coefficients leads to a Bessel type operator, and it is shown that there is a unique probability density function that solves the equation. The solution is constructed using the Mellin transform and is given in terms of an infinite series of modified Bessel functions.

John Butcher

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Dealing with parasitic behaviour in G-symplectic integrators

In G-sympletic integrators for mechanical problems, expressed in Hamiltonian form, parasitic behaviour is a serious obstacle to obtaining reliable results over extended time periods. In collaboration with Yousaf Habib, two approaches to overcoming this obstacle have been investigated. The first approach is to attempt to cancel the effect by using compositions of two methods where the growth factors have opposite signs. It is also possible to construct special methods for which the growth factor is zero.

Kevin Byard

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A class of combinatorial arrays with good correlation properties.

A new general class of two-dimensional combinatorial arrays with good correlation properties is described. The arrays have applications in fields such as signal and image processing, map matching and aperture synthesis. Using the properties of the nth power residue classes modulo an odd prime p where $n \geq 2$, the arrays are square, of dimension $p \times p$ and are conjectured to exist for all $p = nk + 1$ where k is a positive integer. The construction method of the new arrays is described and their efficacy for use in an imaging application is discussed.

Jiling Cao

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Bornologies and hyperspaces

A bornology $\mathcal{B}$ on a nonempty set X is a family of subsets of X that is closed under taking finite unions, that is hereditary, and that forms a cover of X. Bornologies have been widely applied in functional analysis and topology to form the general framework in the theory of locally convex spaces and to provide an axiomatic approach to boundedness in topology. Recently, there has been renewed interest in bornologies in topology, mainly stemming from hyperspace theory. In this talk, I shall present some recent results of mine and others on hyperspaces generated by various bornologies. I shall also discuss some open problems in this direction.

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Computation of the surge motion of a floating elastic plate

One difficulty with computing the surge of a floating elastic plate is that Green's function for the boundary value problem has singularities on the boundary and at the corners. This talk will show how to resolve the integrals over the corners using the Kummer transform to separate the singular part of Green's function. The resulting numerical computation avoids the singular parts altogether. In contrast, the zero-draft approximation does not allow surge motion, which is important in water-tank scaled experiments. Our computation method is efficient and accurate to study the surge motion in various frequency/wavelength regimes.

Joshua Collins

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Constructing phylogenetic networks

The problem of constructing evolutionary trees given some appropriate data is a problem with a long history in phylogenetics. However, it has become apparent that in many situations a tree structure is not appropriate to accurately model the evolutionary history of a set of organisms and thus attention is increasingly turning towards the problem of constructing networks for the same types of data. This talk will contain a comparison of such methods and an overview of the approach I am taking.

Shaun Cooper

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Development of Elliptic Functions According to Ramanujan

Elliptic functions arose approximately 200 years ago as the inverses of elliptic integrals, just as the sine function is the inverse of

$$\arcsin x = \int_0^x \frac{dt}{\sqrt{1-t^2}}.$$

They have applications in mechanics, geometry and classical applied mathematics. The study of elliptic functions stimulated the development of complex analysis and function theory in the 19th century. These days, elliptic functions are prominent in cryptography and number theory.

There are two main ways to study elliptic functions. One is the original method of inverting elliptic integrals due to Abel and Jacobi. The other way, commonly used today, is to work with double series as Eisenstein and Weierstrass did.

In this talk a third method will be outlined. It is based on q-series and uses the ideas of Ramanujan that were developed by Venkatachaliengar and have been refined in a book edited by the speaker.

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Hyperbolic pseudo-inverses and the Euclidean group

Control algorithms for serial robot manipulators generally use an inverse for the Jacobian of the forward kinematics, a mapping from the manipulator joint space to the Euclidean isometry group. For manipulators with fewer or greater than six actuated joints, and also at singularities of the kinematic mapping, the algorithms break down. The Moore-Penrose pseudo-inverse is frequently used as instead. However, in its usual form it is not invariant under change of coordinates in the manipulator components. Since the Euclidean Lie algebra carries a family of invariant indefinite bilinear forms, alternative pseudo-inverses may be available. The existence of these hyperbolic pseudo-inverses is explored and optimal choices made in terms of associated screw systems.

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Connected generalised inverse limits

Inverse limits have been studied by many mathematicians over a long period of time, whereas generalised inverse limits have only recently been introduced. Surprisingly few properties of inverse limits carry over to the generalised case. In this talk we consider an open question regarding the characterisation of connected generalised inverse limits.

Suppose that for each $i \geq 0$, I_i is an interval, and for each $i \geq 1$, $f_i : I_i \to 2^{I_{i-1}}$ is a surjective upper semi-continuous function with a connected graph G_i, such that $\pi_{i-1}(G_i) = I_{i-1}$ and $\pi_i(G_i) = I_i$ (π_{i-1} and π_i denote the respective projections of G_i to the intervals I_{i-1} and I_i). We consider conditions on the graphs that are necessary if $\varprojlim(I_i, f_i)$ is disconnected, and we give conditions on the graphs called a C-sequence and discuss the following: $\{f_i : i > 0\}$ has a C-sequence if and only if there exists a basic open set

$$U = \Pi_{0 \leq i < n} I_i \times \Pi_{n \leq i \leq m} U_i \times \Pi_{i=m+1}^{\infty} I_i$$

in $\Pi_{i=0}^{\infty} I_i$ containing a closed set

$$A = \Pi_{0 \leq i < n} I_i \times \Pi_{n \leq i \leq m} A_i \times \Pi_{i=m+1}^{\infty} I_i,$$

such that

$$\varprojlim(I_i, f_i) \cap U = \varprojlim(I_i, f_i) \cap A \neq \emptyset,$$

and $\varprojlim(I_i, f_i)$ is not a subset of U.

Sanjiv Kumar Gupta

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Asymmetry of multipliers on Lie groups

De Leeuw's multiplier theorem relates the multiplier on the circle group $\mathbf{T}$ and the real line $\mathbf{R}$ in a spectacular way. This result has been generalised in many ways in the context of non-commutative harmonic analysis, most notably by Coifman and Weiss. Let G be a real rank one semi–simple Lie group and $G = KAN$ be its Iwasawa decomposition and M be the centraliser of A in K. An analogue of De Leeuw's theorem was proved by Rice, Dooley and Gaudry for the pair $(K/M, N)$ for $G = SO(p, 1)$. But the transference of multipliers from N to K/M part was not the exact converse of the transference from K/M to N. In De Leeuw's original theorem, transference from $\mathbf{R}$ to $\mathbf{T}$ and from $\mathbf{T}$ to $\mathbf{R}$ are exact converse to each other. Ricci and Rubin proved the transference from K/M to N for $G = SU(2, 1)$ but N to K/M case remained open. In this talk, I will present an exact analogue of De Leeuw's theorem for $G = SU(p, 1)$. Our work resolves a conjecture of C. Herz. This is joint work with A. Dooley and F. Ricci.

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Interacting invariant sets in a 2D noninvertible map model of wild chaos

We study a noninvertible planar map that has been suggested by Bamon, Kiwi and Rivera as a model for a new type of chaotic dynamics in continuous-time dynamical systems of dimension at least five; one also speaks of wild Lorenz-like chaos. This map opens up the origin (the critical point) to an open disk and wraps the plane twice around it; inside this disk there are no preimages. The bounding critical circle and its images, together with the critical point and its preimages form the so-called critical set. This set interacts with a saddle fixed point and its stable and unstable sets.

Advanced numerical techniques enable us to study how the (un)stable sets change as a parameter is varied along a path towards the chaotic regime. We find two types of bifurcation sequences. First, there are bifurcations that also occur in invertible maps, such as homoclinic tangencies. Second, we find bifurcations specific to nonivertible maps: interactions of the (un)stable sets with the critical set, which also cause changes (e.g. self-intersections) of the topology of these global invariant sets. Overall, a consistent sequence of both types of bifurcations emerges, which we present as a first attempt towards explaining the geometry of wild chaos.

David Holgate

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Topology in a category - neighbourhood operators

While there is extensive literature on closure operators in categories, less has been done in terms of their "dual" – interior and neighbourhood operators. In this talk we will give a brief overview of neighbourhood operators defined in a category, discuss their correspondence with interior and closure operators and explore how they allow definitions and theorems from general topology to be studied in arbitrary categories.

The notions of closure, interior and neighbourhood are essentially equivalent in general topology, the categorical analysis highlights subtle differences which allow novel proofs and divergent results in general.

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Percolation without coffee

In engineering and coffee-making,"percolation" represents the flow of fluids through porous media. In mathematics and statistical physics, "percolation theory" describes the behaviour of connected clusters in special kinds of random graphs.

One such model is that of bond percolation on the square lattice, which was introduced by Broadbent and Hammersley in 1957. In this model, each edge/bond in the lattice is (independent of all other edges) open with probability p, and closed with probability $1-p$. The main question of interest is: Can you get from the origin to infinity by following open edges? It turns out that there is a critical value of p, below which this infinite connection cannot occur, and above which it occurs with positive probability. This critical value is known in 2 dimensions, but not in 3 dimensions.

This talk will be an introduction to the subject of percolation theory.

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Effective order and symplectic integrators

The order of Runge–Kutta methods can be enhanced by conjugacy in the group theory sense. This procedure, known as "effective order", was also referred to as "processing" by Sanz-Serna et al. It is shown how to construct a symplectic Runge–Kutta method with effective order 4 which is capable of efficient implementation on parallel computers. This has potential applications to the numerical solution of large conservative mechanical systems.

Patrick Ion

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Geometry and the discrete Fourier transform

There is a relationship between some elementary geometry of the plane and the Discrete Fourier Transform, explored by J. Douglas , which offers a starting point for discussions of polynomials (Siebeck and Marden theorems), circulant matrices and interpolation (Steiner interpolation), and even for sculpture by I. J. Schoenberg. Analysis of the orbits of mechanical systems, such as N-body problems, based on this offers some interesting visualisations as well.

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Mathematics Subject Classification

The talk will discuss the MSC2010 revision and some new standards for mathematics (MathML and SKOS).

Ali Jaballah

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The spectrum of a maximal non-integrally closed domain

Let R be an integral domain, let $qf(R)$ be the quotient field of R, and let $Spec(R)$ denotes the spectrum of R,i.e. the set of prime ideals of R. A ring T such that $R \subset T \subset qf(R)$ is called an overring of R. For a given ring theoretic property P, R is said to be a maximal non-P subring of $qf(R)$ if R does not satisfy P while every subring of $qf(R)$ properly containing R satisfies P. Several integral domains have been characterized in the last few decades by properties satisfied by their overrings. On the other hand only few papers investigated domains R that are maximal subrings of their quotient field not satisfying a given property P. Recently there has been an increasing interest in such studies. We consider in this paper maximal non-integrally closed subrings, then obtain several equivalent statements for these rings. This enables us to establish results on the spectra of maximal non-integrally closed subrings R and their integral closure R'. We show for example that either $Spec(R)$ and $Spec(R')$ are both chains of the same dimension, or $Spec(R)$ is order isomorphic to a "kite graph", while $Spec(R')$ is order isomorphic to a "Y-graph".

Igor Klep

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Values of free noncommutative polynomials and Lie ideals

This talk concerns polynomials in freely noncommuting variables, i.e., elements of a free algebra $\mathbb{C}\langle \underline{X} \rangle = \mathbb{C}\langle X_1, \ldots, X_n \rangle$. Given an algebra $\mathcal{A}$ and a polynomial $f = f(X_1, \ldots, X_n) \in \mathbb{C}\langle \underline{X} \rangle$, we investigate the values f attains in $\mathcal{A}$. An important sample problem is the following: What is the linear span

$$\mathcal{L} := \operatorname{span}\left\{ f(a_1, \ldots, a_n) \mid a_1, \ldots, a_n \in \mathcal{A} \right\}$$

of the values of f in $\mathcal{A}$? We show that $\mathcal{L}$ is always a Lie ideal in $\mathcal{A}$. In particular, if $\mathcal{A}$ is the full matrix algebra $M_d(\mathbb{C})$, this observation allows us to categorize polynomials f into four classes according to their values.

Now let $\mathcal{H}$ be an infinite-dimensional Hilbert space, and let $B(\mathcal{H})$ and $K(\mathcal{H})$ denote the algebras of all bounded and compact linear operators on $\mathcal{H}$, respectively. What is the linear span of polynomial values in $B(\mathcal{H})$ and $K(\mathcal{H})$? A very special (but decisive) case of this question was settled by Halmos and Pearcy & Topping: Every operator in $B(\mathcal{H})$ and $K(\mathcal{H})$, respectively, is a sum of commutators. That is, the linear span of values of the polynomial $f = X_1X_2 - X_2X_1$ on $B(\mathcal{H})$ and $K(\mathcal{H})$ is all of $B(\mathcal{H})$ and $K(\mathcal{H})$, respectively. We will prove that the same is true for *every* nonconstant polynomial.

The talk is based on joint works with M. Brešar.

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Parallel computations based on numerical integration methods

(Joint work with S. Szollos and M. Kraus.)

In this work we mainly focus on numerical methods for ordinary differential equations. The basic concept of numerical integration with brief description of one-step and multi-step numerical integration methods which is necessary for explaining of the entire concept of parallel cooperation of microprocessors will be presented. This parallel cooperation of independent multiprocessors may be designed using arbitrary chosen numerical integration formula. Including Euler's method, 2nd, 3rd and 4th order Runge-Kutta methods, Adams-Bashforth methods, Milne methods etc. Taylor series explicit and implicit methods are also together with simulation language TKSL a part of the paper. Recurrence formulae for Taylor series coefficients have also been derived and used to calculate, step by step the Taylor series coefficients of the solution to a given technical initial problems.

An important problem that every program calculating a numerical solution to a initial problems faces is the choice of an appropriate stopping rule, that is a rule that decides that no other step needs to be undertaken since the set accuracy requirements are satisfied. Various methods can be devised, more or less ingenious, but the basic question remains, namely, at a given point in calculation, how many subsequent steps must actually be "inspected".

Heung Yeung (Frederick) Lam

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On the Diophantine equation $n^2 = x^2 + by^2 + cz^2$

More than 100 years ago, A. Hurwitz stated and indicated a way to prove a formula for the number of solutions, in integers, of $n^2 = x^2 + y^2 + z^2$ for any given positive integer n. In this talk I will present four formulas for the number of solutions, in integers, of $n^2 = x^2 + y^2 + 2z^2$, $n^2 = x^2 + 2y^2 + 2z^2$, $n^2 = x^2 + y^2 + 3z^2$ and $n^2 = x^2 + 3y^2 + 3z^2$. Some conjectures will be showed at the end of the talk.

Joint work with Shaun Cooper (Massey University (Auckland)).

Dimitri Leemans

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Symmetric groups and polytopes

In the Atlas of abstract regular polytopes for small almost simple groups by Leemans and Vauthier, the polytopes whose automorphism group is a symmetric group S_n of degree $5 \leq n \leq 9$ are available. Two observations arise when we look at the results: (1) for $n \geq 5$, the $(n-1)$-simplex is, up to isomorphism, the unique regular $(n-1)$-polytope having S_n as automorphism group and, (2) for $n \geq 7$, there exists, up to isomorphism and duality, a unique regular $(n-2)$-polytope whose automorphism group is S_n. We prove that (1) is true for n not 4 and (2) is true for $n \geq 7$. Finally, we also prove that S_n acts regularly on at least one abstract polytope of rank r for every $3 \leq r \leq n-1$.

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Consistent modeling of SPX and VIX options: Efficient evaluation in Gatheral's three-factor model

It is an important issue to consistently price options written on S&P500 and VIX indices. Gatheral (2007, 2008) proposed a three-factor stochastic volatility model to achieve this goal. However, the non-affine structure of the model leads to the analytical intractability that closed-form pricing formula may not exist for S&P500 options, nor for VIX options. Monte Carlo simulation method adopted in Gatheral is rather inefficient in terms of calculation and model calibration. This study proposes two analytical asymptotic formulae to efficiently price S&P500 options and VIX options, respectively, based on Gatheral's three-factor stochastic volatility model. By applying singular perturbation techniques, our formulae are obtained by solving a set of partial differential equation systems. We then rigorously justified the convergence of the asymptotic formulae. We lastly present some numerical examples to demonstrate that our asymptotic formulae can achieve high efficiency and accuracy for a large class of options with relative short tenor.

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Generalised inverse limits of tent maps

A surjective tent map is a continuous function $f : [0,1] \to [0,1]$ such that:

$$f(x) = \begin{cases} 2x & x \leq \frac{1}{2} \\ 2-2x & x > \frac{1}{2} \end{cases}$$

It is so called because the resulting graph resembles a 'tent' with a 'peak' at the point $\frac{1}{2}$. It is well known that the inverse limit of this tent map is the famous *Buckethandle Continuum* (or Knaster continuum), an example of an indecomposable continuum. If we alter the function slightly such that its graph retains the tent shape, but has its peak at $a \in (0,1)$, the resulting inverse limit is homeomorphic to the Buckethandle, so is (amongst other things) indecomposable.

Using the new techniques of generalised inverse limits, where the bonding maps are upper semicontinuous set valued functions, it is possible to obtain inverse limits of set valued tent maps with peaks at the extreme points of 0 and 1. The resulting inverse limits are very different from the Buckethandle. In this talk I will construct them and give some of their properties.

Tammy Lynch

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The Effect of Cracks and a Steam Cap on Hydrothermal Eruptions

Hydrothermal eruptions are naturally occurring violent events. Without warning, they can result in the eruption of large volumes of rock particles mixed with liquid water, water vapour, and other gases. These events frequently alter the immediate surroundings, sometimes felling trees, scorching foliage, damaging property and injuring or killing people. They occur all over the world and are relatively common in New Zealand. I will discuss the use of a shock-tube model for a hydrothermal eruption in a geothermal reservoir to simulate eruptions that have a steam phase present near the surface in the form of a steam cap or a large crack. Simulations are performed with various steam cap/crack depths and it is shown that the presence of a steam phase greatly reduces the size of an eruption. We show that a steam cap type eruption is physically unlikely because of the large pressure differences required to initiate an eruption, but conclude that rock cracking is potentially a viable initiation mechanism for a hydrothermal eruption.

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Klein Vignettes

Robert McKibbin

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Mathematical modelling of volcanic eruption plumes

Volcanic eruptions produce hot mixtures of gas and magma fragments. As the ejected gas/particle stream rises, buoyancy forces dominate; the upward movement is sustained by the density difference between the hotter gas and the cooler atmosphere. The upwardly-flowing gas, composed of the ejected volcanic gases and subsequently entrained air, provides lift forces on the rock fragments, but this varies with height due to the changing speed and density of the gas mixture as it rises into the atmosphere.

The maximum height to which particles of a given size can rise increases with decreasing fragment size; the height is determined by the condition that the dynamic lift is equal to the weight of the particles. The particles then leave the plume and are dispersed by atmospheric movement outside the plume column.

The conservation equations that apply to this multi-phase, multi-component, time-dependent problem are formulated. Some solutions for a plume that has reached a quasi-steady state are presented and discussed. The calculated plume height and shape are presented for some example parameters, and the tephra fallout levels computed for a range of particle sizes. Ideas for future development of such models are outlined.

Maarten McKubre-Jordens

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Constructing weak solutions of the Dirichlet problem

We present, first, a constructive proof of the existence of the weak solution to the Dirichlet problem when the domain is internally approximable by certain compact subsets, and, second, a Brouwerian example showing that the existence of a weak solution in the general case of the Dirichlet problem is an essentially nonconstructive proposition.

This is joint work with D.S. Bridges.

Alastair McNaughton

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Lagrange optimization of quartic forms

We investigate how to classify critical points of constrained optimization problems in which the quadratic terms all vanish.

Ben Martin

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Lattices in automorphism groups of trees

Let G be a topological group. A *lattice* in G is a subgroup Γ of G such that Γ is discrete ("is not too big") and has cofinite volume with respect to the Haar measure ("is not too small"). I will discuss spaces of lattices in $\mathrm{Aut}(X)$, where X is a regular locally finite tree, and in $\mathrm{PSL}_2(K)$, where K is a nonarchimedean local field. The link between these two cases is that $\mathrm{PSL}_2(K)$ acts on its Bruhat-Tits tree X_K, so $\mathrm{PSL}_2(K)$ is a subgroup of $\mathrm{Aut}(X_K)$. Part of the problem is to define what "space of lattices" should mean; here the theory of character varieties is helpful. This is joint work with Lisa Carbone (Rutgers).

Shawn Means

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Realistic geometry construction for modeling: An Acinar salivary gland

Preliminary simulations performed on an idealised geometric representation of an acinar salivary gland demonstrated potentially intriguing results where calcium oscillations in individual gland cells may have little overall effect on the production of saliva. Our idealised geometry, however, is perhaps too ideal; we obtained confocal microscopy images of an acinus in vitro and have reconstructed a surface of the intercellular tubular domains which perform saliva transport. We present here the procedure used for reconstructing a realistic geometry with readily available software packages. Our eventual aim is to perform simulations on the geometry and we briefly discuss the model itself.

Alexander Melnikov

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Isometric computability structures on metric spaces

We study computability structures on classical Polish spaces. We introduce the notion of computable categoricity for computable uncountable Polish spaces. Our approach is based on the classical notion of isometric structures due to Pour El and Richards. We say that a Polish space is computably categorical if every two computability structures are equivalent up to a surjective self-isometry of this space. The autodimension of a Polish space is the number of structures which are pairwise non-equivalent up to a surjective self-isometry. It follows that every Hilbert space is computably categorical as a metric space, but L_1 is not. We show that Cantor space is computably categorical, and so is the Urisohn space. We also show that $C[0, 1]$ is not computably categorical, and we characterize compact subspaces of $\mathbb{R}^n$. As a culmination, we give an example of a Polish space having autodimension 2.

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Independent random events and the appearance of order: clustering, hierarchy formation, and universal scaling

We employ methods derived from the theory of random graphs to explore clustering in space and time predicated upon nearest-neighbor associations. In one dimension, we prove using strictly analytic methods that all Markov processes produce clusters whose mean size is 3. In two and higher dimensions, we develop rapid Monte Carlo methods for simulating such stochastic events, and we observe that the mean cluster size increases with respect to dimension and assume quantitative values of approximately 3.0214, 3.1413, and 3.2316 for dimensions 2, 3, and 4, respectively. We offer the conjecture that the three dimensional value is π. We produce hierarchies from these clusters by exploring the properties of the centers of mass that emerge, and their centers of mass, and so on. We observe that the hierarchy produces self-similar scalings with log-normal distributions in mass, separation distance, cluster sizes, and other graph theoretic features as well. In addition to seismology, these results are applicable to condensed matter physics (percolation models, networks, and complex systems), astrophysics (cosmological structure), and psychology (memory and perception). The three papers upon which this work is based have been submitted to the journal Chaos: An International Journal of Nonlinear Science.

Donald Nield

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Modelling convection in porous media: Some current developments

Some recent work by the author and colleagues on modelling convection in porous media is discussed. Items of interest include a singular differential equation system arising from a linear stability analysis of the onset of convection of a medium saturated by power-law fluid, the modelling of a nanofluid, a Stability Exploration Package for Strong Heterogeneity, and solutions of a non-homogeneous Airy equation (that have been called Nield-Kuznetsov functions in the recent literature).

Dion O'Neale

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Patents and power law distributions: how to find them, fake them and fudge them

Patent data is a useful proxy for the amount of innovation taking place within countries. We study the distribution of patents amongst applicants for a range of countries and find that it is well described by a power law; that is the distribution has a long tail, with a number of applicants holding very large numbers of patents. We also observe that the best-fit power law exponent differs from country to country, implying that innovation rates are not simply a product of population (or population density). Motived by this, we use a generative model to simulate the process of applicants acquiring patents. The two key aspects of the model are growth (the number of applicants increases with simulation length) and preferential attachment (new patents are attached preferentially to those applicants who already hold large numbers of patents). Despite the simplicity of the model, we find that it manages to capture qualitative features of the empirical data. Adding an additional parameter (the rate of cessation of patenting) to the model leads to a better quantitative match between empirical and simulated results.

Kate Patterson

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A mathematical model of the salivary duct

Salivary gland dysfunction can lead to difficulty talking, eating, tooth decay, opportunistic infection and in severe cases death from malnutrition. The dysfunction xerostomia, or dry mouth, results when not enough saliva is secreted. Xerostomia can be caused by medication, disease, such as Sjögren's syndrome, or as a side effect of radiation therapy. A healthy salivary gland secretes saliva in two stages. First, acinar cells generate primary saliva, a plasma-like, isotonic fluid high in Na^+ and Cl^-. In the second stage, the ducts exchange Na^+ and Cl^- for K^+ and HCO_3^+, producing a hypotonic final saliva with no apparent loss in volume. We have developed a multi-compartment, advection-diffusion model of the salivary duct. Having validated the model against experimental data, we are now investigating novel treatments for xerostomia. In this talk I will present our model and some results.

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Coding theory and cryptography: New perspectives

The McEliece public key cryptosystem is based on algebraic coding theory. It is attractive as there are no known vulnerabilities against quantum computers, and it has a very fast and efficient encryption procedure. The original McEliece proposal uses binary Goppa codes. The public key is very large. Thus, during the last years, the research has focused mainly on finding a way to significantly reduce the size of the public key.

In this talk I will introduce a scheme that is based on Generalized Srivastava codes and is a generalization of the Quasi-Dyadic scheme proposed by Misoczki and Barreto, with two advantages: a better flexibility, and improved resistance to all the known attacks. I will also present recent work about an efficient implementation of the above scheme, and how to achieve higher security standards (i.e. CCA2 indistinguishability).

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Building a better weed control model for Tradescantia fluminensis Vell. (Commelinaceae)

Tradescantia fluminensis Vell. (Commelinaceae) is a concerning invasive weed within New Zealand. Branching process models; a stochastic method; are used to simulate multiple cases of individual, independent growth of T. fluminensis. A system of linear ordinary differential equations is used to check the validity of the simulations. The models are utilized to explore possible management strategies and ask "What can be known about the probabilities of controlling the growth of this plant, given the plausible ranges of branching rates and death rates?" The simulations show that it will take a large proportion of tip death to control T. fluminensis. This may recommend other forms of control may be more applicable. In this talk, branching process analysis will be presented in conjunction with the simulation algorithm; simulation output will be compared to an ODE approximation.

Muhammad Amer Qureshi

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High order explicit Runge-Kutta Nystrom pairs

Explicit Runge-Kutta Nystrom pairs provide an efficient way to find numerical solutions to second order initial value problems when the derivative is cheap to evaluate. We present new optimal pairs of order ten and twelve from existing families of pairs that are intended for accurate integrations in double precision arithmetic. We also present a summary of numerical comparisons between the new pairs on realistic models of the Solar System.

Iain Raeburn

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Toeplitz algebras of semigroups

By an isometry we mean a linear operator on Hilbert space which preserves the norm. A beautiful theorem of Coburn (1963) says that if the isometry is not unitary, then it generates the same C*-algebra as the unilateral shift. Viewing Coburn's theorem as a result about isometric representations of the semigroup of additive integers invites generalisation to isometric representations of other semigroups. These generalisations say that the C*-algebra generated by a particular "Toeplitz representation" is typical.

In this talk we will discuss this program, focusing on a particularly insightful family of examples introduced by Nica (1993), and a semigroup semidirect product built from the natural numbers which nontrivially fits Nica's mould. We will then discuss recent work with Marcelo Laca in which we study states on the C*-algebra generated by the Toeplitz representation.

Matthew Randall

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Local obstructions to 2-dimensional projective structures admitting skew-symmetric Ricci tensor

A projective surface is a 2-dimensional manifold equipped with a projective structure i.e. a class of torsion-free affine connections that have the same geodesics as unparameterised curves. Given any projective surface we can ask whether it admits a torsion-free affine connection (in its projective class) that has skew-symmetric Ricci tensor. This is equivalent to solving a particular semi-linear overdetermined partial differential equation. It turns out that there are local obstructions to solving the PDE in two dimensions. These obstructions are constructed out of local invariants of the projective structure.

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Epidemic models with uncertainty

One of the first quantities to be estimated at the start of an epidemic is the basic reproduction number, $\mathcal{R}_0$. The progress of an epidemic is sensitive to the value of $\mathcal{R}_0$, hence we need methods for exploring the consequences of uncertainty in the estimate. I will analyse the Kermack-McKendrick model, and its special case the *SIR* model, by expanding the state variable in orthogonal polynomials in uncertainty space. The resulting dynamical systems need only be solved once to produce a deterministic stochastic solution. The method will be applied to data from the New Zealand epidemic of H1N1 influenza in 2009, to demonstrate the level of uncertainty when making projections based on a limited amount of data.

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Automatic assessment of mathematics with Maxima

Many automatic assessment systems for mathematics use a computer algebra system (CAS) to automatically generate structured problems, establish the mathematical properties of students' answers and generate feedback. There are many different implementations, e.g. examples include MathWise, Aim, MapleTA, and STACK. CAS is usually designed to "do a calculation" rather than "establish a property of an object". These are subtly different problems, and existing desktop CAS are more or less suitable for establishing properties. In this talk we describe research into what properties are most useful for assessment of mathematics problems, and present an independent "Assessment Package" for the CAS Maxima which establishes them. This package has been factored out from the STACK CAA system. We also report some theoretical limits on the extent to which such algorithms can be guaranteed to terminate, and provide examples of their use.

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A weak trace for Sobolev functions on rough domains

A Sobolev space is a normed vector space of functions on a domain in $\mathbb{R}^d$ such that the functions have weak partial derivatives, and both function and weak derivatives are suitably integrable. Sobolev spaces have good analytic properties and are a natural setting for many differential operators. As a downside, Sobolev functions are only defined up to sets of measure zero.

To deal with boundary value problems, some notion of a *trace* is required, i.e., to give a meaning to the restriction of a Sobolev function to the boundary of the domain, which can be a set of measure zero. On suitably regular domains, every Sobolev function can be given a unique trace (in a sensible canonical way).

We study a *weak trace* that was recently introduced by Arendt and ter Elst in order to study the Dirichlet-to-Neumann operator on rough domains. It very naturally extends the trace for regular domains. For irregular domains, however, various degenerate behaviour can occur. Perhaps most strikingly, uniqueness is lost in general as elements can have multiple weak traces. We specifically study this phenomenon, as well as the elements with weak trace zero.

This is joint work in progress with A.F.M. ter Elst.

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Optimal extended explicit Pouzet Runge-Kutta pairs for Volterra integral equations of the second kind

Volterra integral equations of the second kind (VIE2) arise in many applications, particularly in population dynamics and financial modelling. We present optimal, extended explicit Pouzet Runge-Kutta pairs for non-stiff VIE2s. The selection of optimal pairs is noticeably more involved than that of explicit Runge-Kutta pairs for initial value ODEs because the abscissae of the Pouzet pair must satisfy the kernel conditions and the efficiency of the pair depends on the number of non-zero exterior weights.

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Identity slip-Algebraic problems in aggregated Markov models

The behaviour of ion channels can be investigated by measuring currents from single channels using the patch clamp technique. In this way a time series is obtained that indicates for each data point if the channel was open or closed. However, usually several open and closed states are required to generate a time course similar to the observations. Models of this type are called aggregated Markov models.

An important question is under which circumstances a model with several open and closed states can be inferred from a sequence of only open and closed events. In statistics, this is known as the identifiability problem. When fitting to a non-identifiable Markov model, not all rate constants can be determined unambiguously from the data. A closely related phenomenon is the equivalence of models with the same number of open and closed states but defined on different graphs connecting these states. The current limited understanding of equivalence makes model selection difficult since two seemingly different models may, in fact, be equivalent.

We present algebraic methods that can be used to study identifiability and equivalence of Markov models.

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Comparison semigroups.

The collection of binary relations $R(X)$ on a set X has much algebraic structure: it is a semigroup under composition, but also has several set-theoretic and other operations. There is no finite axiomatization of concrete relation algebras (subalgebras of $R(X)$ for some X) under all these operations, although restricting the operations can give finite axioms (e.g. if one restricts to composition only, one gets all semigroups!).

The set of partial functions $P(X)$ on X is closed under composition, plus *some* set-theoretic and other operations (such as intersection), leading to finite axioms for function semigroups equipped with some or all of them.

Aside from composition, there do not appear to be many further operations defined on the set $T(X)$ of all *transformations* of the set X (possibly the special case of most interest in mathematics generally). One such is *comparison*:

$$(f,g)[h,k](x) := \begin{cases} h(x) & \text{if } f(x) = g(x) \\ k(x) & \text{otherwise.} \end{cases}$$

In this talk I (finitely) axiomatize semigroups of transformations equipped with comparison. The same axioms capture semigroups of partial functions with a suitably generalised comparison operation, and when zero and identity elements are added, the resulting signature is rich enough to express most of the previously studied operations on semigroups of partial functions.

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Dynamics of some few-body problems with symmetry

The dynamics of few-body problems with symmetry is beautiful and instructive. By a few-body problem, we mean a number of point masses moving under their mutual gravitational attraction. Collisions are regularised whenever possible. We will look at some examples.

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Partial Gaussian bounds for degenerate differential operators

It is well known that the Laplacian on $\mathbb{R}^d$ generates the heat semigroup and that this semigroup has a kernel which satisfies Gaussian bounds. It was a major result of Nash and De Giorgi that similar results are also valid for strongly elliptic operators in divergence forms with bounded real measurable coefficients. The situation changes drastically if the operator is no longer strongly elliptic, but is degenerate. As an extreme case the operator might be the zero operator and the distributional kernel of the semigroup is no longer a bounded function. As an intermediate case, the matrix of coefficients might be strongly elliptic at some open set $\Omega \subset \mathbb{R}^d$. In that case a natural question is whether the distributional kernel of the semigroup S, restricted to $\Omega \times \Omega$, has Gaussian bounds. We shall show that this is indeed the case if Ω is a bounded Lipschitz domain, but for general Ω it fails. Nevertheless, if $\chi \in C_b^\infty(\mathbb{R}^d)$ and the matrix of coefficients is strongly elliptic on the support $\operatorname{supp} \chi$ of χ, then the operator $u \mapsto \chi\, S_t(\chi\, u)$ has a kernel K_t which satisfies a Gaussian bound. If, in addition, the coefficients are Hölder continuous in a neighbourhood of $\operatorname{supp} \chi$ then we also consider differentiability of the kernel.

Finally, we consider partial spectral multipliers and partial Riesz transforms for degenerate operators.

This is joint work with El Maati Ouhabaz.

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Scheduling matches to allow shared transport; or, How to get free tickets to your local team's home games

Consider a sports tournament with two divisions, in which each team is to play every other team in the same division, in a series of home and away games, one per week. Suppose moreover that every club with a team in division 1 also has a team in division 2, but not vice versa. If both teams from two clubs A and B play each other at the same venue in the same week, then the club with the away game will be able to arrange shared transport for its two teams; otherwise, separate transport arrangements will need to be made for each travelling team. How can we arrange the schedule to maximise the number of such "common fixtures"?

In January this year the Manawatu Rugby Union approached our department with an instance of this scheduling problem, and were so pleased with the schedule I provided that they gave me free tickets to the Manawatu Turbos' home games this year. I will explain my solution, so that you, too, have an opportunity to benefit a local sports league, the environment, *and* yourself through combinatorics.

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Rotational flow stability: from Rayleigh's theory (1916) to the nonlinear theory

A nonlinear stability theory of rotational flow is developed by using the Arnold energy-Casimir method. It has been shown, at the first time, that flow is nonlinear stable if it satisfies Rayleigh's linear stability criterion. This resolves a long-time standing problem. The nonlinear stability theory establishes a principle in physics of flow that can be applied to a wide range of flows to obtain upper bounds for the perturbation's kinetic energy.

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Variable gravitational and cosmological parameters in General Relativity

The Einstein equations of General Relativity are solved exactly within a Friedmann-Walker cosmological framework, allowing Newton's constant G and the cosmological constant Λ to be time dependent. The equation of state follows from both the Einstein tensor and the energy-momentum tensor having zero divergence, which imposes a differential relationship between G and Λ. We consider the epochs after which radiation has decoupled from the matter field, and assume the trace of the mixed energy-momentum tensor is zero. Then during the initial radiation-dominated epoch, G increases rapidly as t^6, and Λ decreases as t^{-2}, where t is epochal time. After the transition to the matter-dominated epoch, G becomes constant, and Λ decreases as t^{-4}. This exact solution is essentially free of parameters, although epochal time is only defined to within an arbitrary scaling factor.

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Metric 1-spaces

In 1906 Maurice Frechet introduced in his Ph.D. dissertation the concept of a metric space. The overwhelming unification of many concepts in functional analysis that was made possible by this abstraction, as well as its widespread applicability in countless other areas of mathematics, securely place Frechet among the founders of modern mathematics. The rest would have been history if it wasn't for a persistent difficulty with the metric axiomatization: the axiom of symmetry prohibits any non-symmetric distance from being modeled by a metric space. While some attempts were made to relax (or neglect) symmetry the accompanying topology of such non-symmetric metric spaces is not as impressive as the monumental pillar of the topology of ordinary metric spaces. I will perform a simple analysis of the Frechet axiomatization and present a new generalization of ordinary metric spaces which I call metric 1-spaces. I will also indicate how the accompanying topological properties of these metric 1-spaces naturally generalize the ordinary case and I will briefly contemplate metric n-spaces and relate metric 2-spaces to other concepts in metric geometry.

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A physically motivated boundary for space-time and its relation to Cauchy completions

During the 60s, Carter and Penrose proposed a method of attaching a boundary to an asymptotically flat Lorentzian manifold. This boundary has been hugely successful and has found applications in areas ranging from numerical relativity to semi-classical gravity. Since then relativists have searched for boundaries that can be attached to general Lorentzian manifolds which might be similarly successful. Currently there is no one accepted boundary; each of the various suggestions suffers from draw backs either mathematical or physical. I will present an overview of this field and explain how a particular suggestion, the Abstract Boundary, avoids the usual problems. The Abstract Boundary is, however, not a boundary in the traditional sense since it is a partially ordered set of equivalence classes. I will present a recent result explaining how the Abstract Boundary is related to Cauchy completions of the manifold.

Posters

Nurul Syaza Abdul Latif (Massey University)

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A Mathematical Model for Induced Resistance Mechanism Using Dynamical Systems

There is an increasing pressure for food production so as to meet the demand for a steady and healthy food supply for a growing number of people. This, in turn, increases disease pressure on crop plants. Therefore, there is a pressing need to control plant crop diseases and there are demands for new novel strategies. One method that has gained significant attention is that of induced resistance. In plant pathology this describes the way plants can be prepared for a defence response to a pathogen attack (of both virus and bacteria origin). However, the biggest challenge confronting researchers here is: how induced resistance is expressed and the effectiveness as a crop protection agent. From the mathematical point of view, the modelling of induced resistance will help understand the plant dynamics against a selected disease-causing plant pathogen. At present, there are almost no mathematical models that describe the phenomenon of induced resistance. This study focuses on this and develops a prototype induced-resistance-model. Later, this model will be extended and optimal control theory methods will be used to optimize the use of an applied abiotic compound (elicitor) to induce host resistance. This work is in association with Plant & Food Research scientists.

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Ramanujan-type series for $1/\pi$ *with quadratic irrationals.*

In 1914, Ramanujan discovered 17 series for $1/\pi$, 16 are rational and one is irrational. They are classified into four groups depending on a variable ℓ called the level, where ℓ=1,2,3 or 4. Since then, a total of 24 rational series and 14 irrational series have been found for these levels. In addition, 53 series have been found for other levels. In this poster, I classify the series that involve quadratic irrationals for levels 1, 2, 3 and 4. They were discovered by computer experimentations using Maple. A total of 62 series have been discovered, 17 of which will be presented in this poster.

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Modelling pollution transport in stratified groundwater aquifers

Chemical species such as tracers or dissolved pollutants are dispersed by water flowing within a permeable matrix. The species disperse in all directions along with flowing downstream with fluid. The rate of dispersion depends on the porous structure and the fluid speed.

Generally, groundwater systems are composed of layered structures determined by different events in the geological processes that formed them. The layers in a system have different physical properties, and their thicknesses are not uniformly constant. The advection-dispersion equations that model fluid and species transport then have coefficients that depend mainly on depth, but with a layer composition that changes with horizontal distance.

Layer thicknesses are assumed to be slowly varying and small in comparison to the lateral extent. Due to variations in the thickness and the permeabilities of layers, fluid flux occurs at the layer interfaces carrying pollutant along with it. Homogeneous aquifers are used for illustrations. An aquifer of varying thickness is used to illustrate fluid flow and pollutant transport within a single layer. Later the multi-layered approach is used to model the spread of pollution into an aquifer from a surface release.

Andrea Babylon (Massey University, Albany)

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Modelling sedimentation in rivers

Sedimentation is the process by which particles suspended in a fluid settle downward due to gravity. In the case of a river used to provide a water supply to a population, sediment particles may be considered a pollutant and so exploring its behaviour is of particular importance. This poster will present the mathematical equation used to model this problem and a simple numerical solution used to describe the behaviour that a quantity of sediment released at some point in a river exhibits as it is carried downstream.

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Calcium dynamics in human airway smooth muscle cells

Free cytoplasmic calcium ions in human airway smooth muscle cells are quite important in regulating the airway contraction that contributes to our normal breath. Experiments show that, after adding agonist (e.g. ACh and Histamine), the cytoplamsic calcium concentration changes in form of periodic oscillations and propagates in waves from one end of the fusiform airway smooth muscle cell to the other end. In addition, there is a lot of evidence showing that such calcium oscillations, instead of the level of the cytoplasmic calcium concentraion, are essential to lead to airway contraction via a pathway called crossbridge. Therefore, exploring what leads to the oscillatory behaviour is a way to understand how the calcium affects our breath, which will be quite useful to the research of pathology of asthma.

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A mathematical spatial temporal model of GnRH neurons

Gonadotropin-releasing hormone (GnRH) neurons are hypothalamic neurons that control the pulsatile release of GnRH that governs fertility and reproduction in mammals. The mechanisms underlying the pulsatile release of GnRH are not well understood. Some mathematical models have been developed previously to explain different aspects of these activities, such as the properties of burst electrical firing and their associated calcium transients. These previous works were based on experimental recording taken from the soma of GnRH neurons. However, emerging evidence shows that the dendrites of GnRH neurons play more important roles than previously appreciated. It was suggested that the site of action potential initiation in these neurons might be in dendrite. Our goal is to construct a mathematical model to understand how the dendrites of GnRH neurons contribute to burst firing of action potentials, and thus the pulsatile release of GnRH. By constructing mathematical models of electrical spiking and calcium oscillations in GnRH neurons, we shall try to understand better how secretion is controlled. Previous work mainly focused on temporal aspects, we try to work out some models including a detailed analysis of spatial effects. Specifically, we need to build a mathematical model combining both the soma and the dendrite.

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Understanding mathematical models with three or more distinct time scales

Many physiological systems have the property that some processes evolve much faster than others, and mathematical models of these systems are constructed to reflect this property. Methods for the analysis of models with two distinct timescales are now well-established, but little is known about the case of three or more timescales.

This poster will discuss progress that has been made on understanding two particular models with at least three time scales: a model of a GnRH neuron and a three-dimensional food chain model.

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Mathematical biology

tba

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A mathematical model of fluid secretion and calcium dynamics in the parotid acinar cell

We construct a mathematical model of the parotid acinar cell with the aim of investigating how the distribution of K+ channels and Ca2+ wave speed affects saliva production. Secretion of fluid is initiated by Ca2+ signals acting the Ca2+ dependent K+ and Cl- channels. The opening of these channels facilitates the movement of Cl- ions into the lumen which water follows by osmosis. We use recent results into both the release of Ca2+ from internal stores via the inositol (1,4,5)-trisphosphate receptor (IP3R) and IP3 dynamics to create a physiologically realistic Ca2+ model which is able to recreate important experimentally observed behaviours seen in parotid acinar cells. We show that maximum saliva production occurs when a small amount of K+ conductance is located at the apical membrane, with the majority in the basal membrane. We simulate Ca2+ waves as periodic functions of time at both the apical and basal membranes. This enables us in investigate how the phase difference of apical and basal Ca2+ signals affects fluid flow. We find maximum fluid flow when Ca2+ signals are in-sync, predicting increased cell efficiency with faster Ca2+ waves.

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Cryptography: Mathematics of crypts?

Our research focuses on public key cryptosystems based on erorr correcting codes. We study codes that have a compact representation, to reduce the public key size. So far, results obtained using quasi-dyadic codes provide a shrinking of up to 96% for a level of security of 280 bit operations.

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The Physiological Function of Respiratory Sinus Arrhythmia

Respiratory sinus arrhythmia (RSA) is a phenomenon where heart rate increases during inspiration and decreases during expiration. The mechanism of RSA and the factors affecting it have been studied extensively. However, the physiological significance of RSA remains unknown and controversial. We conducted a theoretical study of the physiological function of RSA by formulating an optimization problem and calculating the optimal HR function using techniques from optimal control theory. This calculation was done on simplified models that we derived from a previously published model of gas exchange in mammals. We found that the calculated HR was remarkably similar to RSA and that this similarity persisted when some of the assumptions were relaxed. We then conducted a series of numerical simulations using the previously published gas exchange model with prescribed HR functions and compared the results with published experiments on both humans and dogs. The study provides new insights into potential reasons for and benefits of RSA under physiological conditions.

Ivo Siekmann (The University of Auckland), Banu Baydil (Rensselaer Polytechnic Institute, NY, USA)

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The right whirl-Plankton under the influence of eddies

Despite its microscopic size, phytoplankton that lives on photosynthesis plays a crucial role in global geochemical cycles like the carbon cycle. Thus, understanding the dynamics of plankton distributions particularly important in a world threatened by climate change.

Traditionally, plankton is modelled at a spatial scale of several hundreds of metres. The influence of meso-scale vortices, so-called eddies, can then be neglected and it is assumed that the spatial spread of phyto- and zooplankton populations is governed by turbulence. The resulting random dispersal of phyto- and zooplankton has successfully been modelled by diffusion processes.

We extend classical plankton models to a finer spatial scale that takes into account eddy formation and movement by a stochastic phenomenological model.

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Influence diagrams to aid decision making

This poster relates to a mathematics-in-industry project from MISG 2010. The project explored the use of influence diagrams as a tool for decision making. Simple models can be understood as dynamical systems, making the decision support mechanisms more useable. Computer simulation is a useful tool.

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