School of Mathematics and Statistics

Postgraduate Conference 2023

Book of Abstracts

Welcome to the
10th Annual Postgraduate Conference!

Friday 11 August

Colombo Theatres, UNSW

Welcome!

Welcome to the 10th annual School Postgraduate Conference, an eagerly awaited gathering that celebrates the indomitable spirit of research pursued. Embarking on a PhD or MSc journey is far more than a solitary endeavour of sifting through digital papers or analysing data. It entails the vital exchange of ideas with peers, a symphony of intellectual collaboration, and the opportunity to present one's own findings to a live audience.

We are delighted to welcome most of our students back on campus for this momentous event, providing a much-needed opportunity for them to showcase their ground-breaking work to an enthusiastic audience for the first time. While we understand that some students are unable to join us physically, we have thoughtfully arranged pre-recorded talks, ensuring that everyone's research and insights receive the attention they deserve. Rest assured, we aim to engage with these students and foster meaningful discussions even after their presentations.

The conference will include a blend of oral and poster presentations, offering participants various opportunities to present their research and participate in valuable discussions. Throughout the day, we will feature talks from the Applied Mathematics, Pure Mathematics, and Statistics departments, and we will honour outstanding presentations with well-deserved awards, in keeping with tradition. Your active participation in voting and staying updated on schedule changes and you can access all relevant information via the following link: https://unswmathstatspgconf2023.github.io/.

Let us relish this day of academic camaraderie, where intellectual brilliance converges and propels us all to greater heights of knowledge and discovery. Enjoy the conference to the fullest, as we celebrate the accomplishments and embrace the aspirations of our inspiring postgraduate community!

Time	Colombo A	Colombo B	Colombo C
8:50-9:00	Welcome		
9:00-9:30	**Eva-Maria Hekkelman** The noncommutative space we live in Colombo A Chair: Christian Bagshaw		
Session 1	Chair: Joshua Connor	Chair: Abi Srikumar	Chair: Kevin Pan
9:35-9:50	**Hongzhi Liao** Douglas-Rachford method is the best!	**Bill Deng** The $RO(G)$-graded cohomology of $E_{\Sigma_2}C_2$	**Michelle Lim** Estimating effect size in multivariate analysis using bootstrap inversion
9:55-10:10	**Saman Forouzandeh** Health-aware Food Recommendation System with Dual Attention in Heterogeneous Graphs	**Joshua Ham** Kunneth formulae in Motivic Cohomology	**Rianti Siswi Utami** Joint Model for Longitudinal and Multi-state Responses with Functional Predictors
10:15-10:30	**Dan Boettger** An energetic signature for breaking inception in surface gravity waves	**Zhi Yee Chng** Ramsey numbers for trees versus the generalised wheel graph	**Anant Mathur** New Methods for Grouped Variable Selection
10:35-10:50	**Sam Mason** Spatio-temporal Species Distribution Models	**Hongyin Zhao** Perturbation theory, spectral theory of commuting self-adjoint operators and related topics	**Honghui Wang** Pedestrian Trajectory Prediction Using Dynamics-based Deep Learning
10:50-11:30	Coffee Break		
Session 2	Chair: Saman Forouzandeh	Chair: Eva-Maria Hekkelman	Chair: Ahmad Hakiim Jamaluddin
11:30-11:45	**Stuart-James Burney** Analytical Solutions of Delay Differential Equations	**Dilshan Wijesena** Irreducible Pythagorean representations of Thompson's groups and the Cuntz algebra	**Yiyi Ma** A comparison study of likelihood-free inference algorithms
11:50-12:05	**Joshua Connor** Kelvin Wake Fingerprinting	**Ryan Seelig** Simplicity of forest-skein groups	**Hanwen Xuan** Stochastic and Sequential Variational Bayes for GARCH Models
12:10-12:25	**Samudra Lamahewage** Mixed Integer Linear Programming and Game Theoretic Techniques in Closed-Loop Supply Chain Network Designing	**Christian De Nicola Larsen** Rigidity of Groups Constructed Using Jones' Technology	**Anson MacDonald** Hybrid kernel Stein variational gradient descent
12:30-13:30	Lunch		
Session 3	Chair: Samudra Lamahewage	Chair: Christian De Nicola Larsen	Chair: Zhi Yee Chng
13:30-13:45	**Josef Bisits** Does cabbeling shape the thermohaline structure of high-latitude oceans?	**Christian Bagshaw** Lattices in function fields	**Kevin Pan** Statistical Analysis of Sampled Network Data

Time	Colombo A	Colombo B	Colombo C
13:50-14:05	**Aayush Bhattacharya** Presentations of the q-Schur algebra of type B	**Madeleine Kyng** A new algorithm for computing zeta functions of algebraic curves	**Ahmad Hakiim Jamaluddin** Symbolic data: small, efficient and accurate
14:10-14:25	**Brock Sherlock** Constraining Stochastic Models Using Multiple Data Sets: An Algorithmic Approach	**Yerlan Nessipbayev** Compactness in quasi-Banach spaces associated with a non-commutative torus	**Qian Jin** Generalized Partial Least Square in Deep Neural Network
14:25-14:45	Coffee Break		
14:45-15:15	**Kai Yi** Graph Denoising Diffusion for Inverse Protein Folding Colombo A Chair: Ryan Seelig		
15:20-15:50	**Abi Srikumar** Multilevel quasi-Monte Carlo methods for kernel-based interpolation Colombo A Chair: Hongzhi Liao		
15:55-16:20	Hello Session		
16:20 – 16:30	Final Comments and Prizes		
16:30-17:30	Post-event Drinks		

Counting bounded matrices

15:55
Hello Session

Muhammad Afifurrahman

Counting integer matrices with bounded heights with some prescribed properties have always been an active area of study. Compared to the scalar case, there have been less tools available for counting matrices. Here I will consider some new problems of this flavor. Besides integer matrices, I will also state some related problems over other sets, such as rational matrices and matrices with entries in the function field $\mathbb{F}_q[t]$.

Supervisor(s): Alina Ostafe, Igor Shparlinski

Keyword(s): number theory; matrices

13:30
Theatre B

Lattices in function fields

Christian Bagshaw

In 1896, Minkowski's "Geometry of Numbers" introduced a number of fundamental results regarding lattices and their relationships with convex bodies. These have been used to prove countless results in number theory, such as the fact that every positive integer can be expressed as the sum of four squares. It is then natural to ask whether we can develop similar tools to tackle problems in other spaces. In this talk we will give a very gentle introduction to an analogue of the Geometry of Numbers in rational function fields over finite fields, and discuss some recent applications.

Supervisor(s): Igor Shparlinski and Bryce Kerr

Keyword(s): number theory

Presentations of the q-Schur algebra of type B

13:50
Theatre A

Aayush Bhattacharya

The Schur-Weyl duality relates representations of quantum groups and Hecke algebras. One structure involved in this is the q-Schur algebra, the endomorphism algebra of permutation modules of the Hecke algebra. The Schur-Weyl duality provides a presentation by generators and relations of the q-Schur algebra. A recent result due to Bao and Wang generalises the Schur-Weyl duality to the type-B case by replacing the quantum group with certain coideal subalgebras we call i-quantum groups. We use this result to find a presentation for the q-Schur algebra of type B.

Supervisor(s): Jie Du

Keyword(s): noncommutative rings

13:30
Theatre A
Poster

Does cabbeling shape the thermohaline structure of high-latitude oceans?

Josef Bisits

The vertical exchange of heat is a key aspect of how the ocean helps regulate the global climate. Convection, an important driver of near surface mixing, occurs when dense water overlies light water and is usually generated by surface buoyancy loss. Fofonoff (1957) pointed out that warm-saline deep waters in the Southern Ocean become denser as they mix with relatively light cold-fresh near surface water and hypothesised that this nonlinear effect, known as cabbeling, and the temperature and salinity of deep waters create a rate limiting value for the density of the near surface water. Here, we investigate if cabbeling and the properties of deep water create a static density difference threshold in temperature inverted profiles and the consequential role cabbeling plays in shaping the nature of temperature inverted profiles in the global ocean. A one-dimensional water column model demonstrates that once the static density difference threshold for a temperature inverted profile is breached, cabbeling creates an instability. Analysis of data constrained global circulation model output and high quality in-situ observational data provides evidence that the static density difference threshold is controlling the magnitude of the maximum static density dif- ference of temperature inverted profiles with probabilities of approximately 1 and 0.88 respectively given a temperature difference of $0.5°C$. Fixing the static density difference shows this probability increases as the magnitude of the temperature difference increases suggesting that weakening temperature stratification increases density stratification. Our results suggest cabbeling may shape the thermohaline structure of the polar and sub-polar ocean where cold-fresh overlays warm-saline water.

Supervisor(s): A/Prof Jan Zika

Keyword(s): ocean; climate; ACEAS

An energetic signature for breaking inception in surface gravity waves

10:30
Theatre A

Dan Boettger

A dynamical understanding of the physical process of surface gravity wave breaking remains an unresolved problem in fluid dynamics. Conceptually, breaking can be described by inception and onset, where breaking inception is the initiation of unknown irreversible processes within a wave crest that precede the visible manifestation of breaking onset. In the search for an energetic indicator of breaking inception, we use an ensemble of non-breaking and breaking crests evolving within unsteady wave packets simulated in a numerical wave tank to investigate the evolution of each term in the kinetic energy balance equation. We observe that breaking onset is preceded by around one quarter of a wave period by a rapid increase in the rate of convergence of kinetic energy that triggers an irreversible acceleration of the kinetic energy growth rate. This energetic signature, which is present only for crests that subsequently break, arises when the kinetic energy growth rate exceeds a critical threshold. At this point the additional kinetic energy convergence cannot be offset by converting excess kinetic energy to potential energy or by dissipation through friction. Our results suggest that the ratio of the leading terms of the kinetic energy balance equation at the time of this energetic signature is proportional to the strength of the breaking crest. Hence this energetic inception point both predicts the occurrence of breaking onset and indicates the strength of the breaking event.

Supervisor(s): Shane Keating

Keyword(s): fluid dynamics

11:30
Theatre A

Analytical Solutions of Delay Differential Equations

Stuart-James Burney

Delay differential equations are an interesting class of non-local equations that involve a function and its derivatives evaluated at different points in time. These types of equations have had some use in modelling and form interesting cases of dynamical systems. By introducing a new class of functions, we have been able to provide fundamental solutions for autonomous linear integer-order delay differential equations. These functions, referred to as delay functions, relate the power series solutions of ordinary differential and delay differential equations. The functions are also interesting in and of themselves, with analogues of exponential, trigonometric, and more complicated functions easily obtained. We also show that the delay functions have simple Laplace transforms and show how this allows for the solution of certain delay differential equations via transform methods. The delay function technique is also easily extended to more generalized series solutions. This allows us to obtain closed form solutions to some delay differential equations with periodic coefficients.

Supervisor(s): Christopher Angstmann

Keyword(s): dynamical systems

Ramsey numbers for trees versus the generalised wheel graph

10:15
Theatre B
Poster

Zhi Yee Chng

Given two simple graphs G and H, the Ramsey number $R(G, H)$ is the smallest integer n such that, for any graph of order n, either the graph contains G or its complement contains H. Let T_n be a tree graph of order n and $W_{s,m}$ be the generalised wheel graph $K_s + C_m$. We show that for $n \geq 5$, $R(T_n, W_{s,6}) = (s+1)(n-1)+1$ when $s \geq 2$ and $R(T_n, W_{s,7}) = (s+2)(n-1)+1$ when $s \geq 1$. We also determine the exact value of $R(T_n, W_{s,m})$ for large n and s. Next, we look at Ramsey-type results on trees of order n with maximum degree at least $n-5$ versus the wheel graph of order nine, $W_{1,8}$ or W_8. The Ramsey numbers $R(T_n, W_8)$ are determined for each tree graph T_n of order $n \geq 7$ and maximum degree $\Delta(T_n)$ equal to either $n-4$ or $n-5$. These numbers indicate strong support for the conjecture, due to Chen, Zhang and Zhang and to Hafidh and Baskoro, that $R(T_n, W_m) = 2n-1$ for each tree graph T_n of order $n \geq m-1$ with $\Delta(T_n) \leq n-m+2$ when $m \geq 4$ is even.

Supervisor(s): Dr. Thomas Britz

Keyword(s): Ramsey's theorem; graph theory

15:55
Hello Session
Poster

Sea Surface Temperature Distributions in the Tropics

Isabela Conde

Surface waters of the ocean carry the majority of the earth's heat budget; primarily, solar energy is absorbed around the equator warming tropical waters which is then distributed around the globe through atmospheric and oceanic circulation. A component of particular importance is the sea surface temperatures (SST), gradient across the Pacific, largely driven by atmosphere-ocean coupling; it oscillates unpredictably between warm and cold states, this process is described as El Nino-Southern Oscillation (ENSO). Our aim is to use quasi-lagrangian coordinates to describe SST in the tropical pacific, using this approach the distribution of temperatures will have less noise, lowering decadal variability, therefore identifying important trends will be clearer.

Supervisor(s): Jan Zika

Keyword(s): applied

Kelvin Wake Fingerprinting

11:50
Theatre A

Joshua Connor

The cloaking abilities of modern submarines are finding success over the current technologies used to detect them, namely acoustic based technologies. Satellite networks and the emergence of machine learning and artificial intelligence, has opened the door to image-based detection methods. Following the work of Rabaud & Moisy, a vessels Froude number (the ratio of inertial and gravitational forces) is known to alter its Kelvin wake, a far-field wave train that can be identified through satellite imagery. The breakthrough work of Chapman & Vanden-Broeck and Lustri & Chapman, applied the technique of exponential asymptotics, and uncovered the exponentially small amplitude waves that make up this far-field wake. We will present an overview of this technique and how we are extending the application to more complex geometries, as well as some of the future applications given the success of this method.

Supervisor(s): Shane Keating, Christopher Lustri, Scott Sisson, Jean Jacques Masionneuve

Keyword(s): uDASH; defence innovation network; applied mathematics

15:55
Hello Session
Poster

A (Very Brief) Introduction to Non-Commutative Probability

Daniel Czapski

Classical probability theory occurs in measure spaces $(\Omega, \mathcal{F}, \mathbb{P})$ with total measure 1. The main objects of study are complex-valued measurable functions: random variables. The theory is rich and well-studied, and includes many important and well-known results, such as the central limit theorem. Non-commutative probability theory arises from a natural generalisation of the classical notion of a random variable; more technically, we move from the commutative von Neumann algebra $L^\infty(\Omega, \mathcal{F}, \mathbb{P})$ to potentially non-commutative von Neumann algebras $\mathcal{A}$ of "non-commuting random variables". Von Neumann algebras, being the basis of a non-commutative measure theory, provide a natural setting for this study. A matter of great interest is what aspects of classical probability theory can be replicated in non-commutative probability spaces, and under what circumstances. This poster aims to introduce some of the non-commutative analogues to classical concepts which have been studied and some of those still being examined, including the broad aim of my project.

Supervisor(s): Dmitriy Zanin

Keyword(s): probability; non-commutative; non-commutative probability; free probability; analysis; measure theory

Rigidity of Groups Constructed Using Jones' Technology

12:10
Theatre B

Christian De Nicola Larsen

About a decade ago, Vaughan Jones developed a powerful framework, now referred to as Jones' technology, which has been used to produce a myriad of actions of Richard Thompson's group V on structures such as Hilbert spaces and groups. Discovered by Richard Thompson in 1965, Thompson's group V continues to draw significant attention due to its fascinating properties.

The group V can be viewed as an abstraction of the group of permutations of a set X that are constructed using a fixed bijection $R : X \to X \times X$. One straightforward example is the permutation $R^{-1} \circ \sigma \circ R$ of X, where σ is the transposition $(12) \in \mathrm{Sym}_2$, acting on $X \times X$ via swapping coordinates. From X and $R : X \to X \times X$ we obtain a group homomorphism from V to the permutations of X, i.e. an action $V \curvearrowright X$.

We can then ask what happens if we endow X with extra structure, requiring that R is an isomorphism in the suitable category. In this talk we will see what happens when X is endowed with a group structure, necessitating $R : X \to X \times X$ to be an isomorphism of groups. Under such conditions the action $V \curvearrowright X$ leads to a new group, the semidirect product $G = X \rtimes V$.

We focus on describing the isomorphisms between these semidirect products, revealing a rigidity phenomenon that is rare among wreath products. The wreath products $X \rtimes V$ displaying this rigidity are constructed using Jones' technology. The talk will conclude with an examination of the automorphism groups of these wreath products.

Supervisor(s): Arnaud Brothier, Ian Doust, Pinhas Grossman

Keyword(s): group theory; Thompson's groups; wreath products

9:35
Theatre B

The $RO(G)$-graded cohomology of $E_{\Sigma_2}C_2$

Bill Deng

Singular cohomology and motivic cohomology can be extended to the equivariant setting to study spaces and varieties equipped with a G-action, where G is a finite group. In the topological case, $RO(G)$-graded cohomology has become an active area of research due to its recent application in resolving the long-standing Kervaire invariant one problem. In this talk, we present new results for the case where $G = K$ is the Klein four-group. We investigate the relationship between the equivariant motivic cohomology of the real field with a C_2-action, and its realisation in $RO(K)$-graded cohomology. In particular, we elucidate the structure of the Mackey-functor valued cohomology of the space $E_{\Sigma_2}C_2$ by studying the isotropy separation cofiber sequence.

Supervisor(s): Mircea Voineagu

Keyword(s): algebraic topology

Diagrammatics of the Spherical Category

15:55
Hello Session
Poster

Tasman Fell

Soergel Bimodules are certain bimodules over a polynomial ring. They categorify the Hecke algebra, a fundamental object in representation theory. This categorification provides extra structure (for example, morphism spaces between objects), which allows us to better understand the Hecke algebra. During the 2010's, a system was developed for working with Soergel Bimodules diagrammatically, which vastly simplifies calculations and has provided fuel for many advances in representation theory.

There are two very similar modules over the Hecke algebra, known as the Spherical and Anti-Spherical modules. Like the Hecke algebra, they each have a categorification: the Spherical and Anti-Spherical category. The morphism spaces in the Anti-Spherical category are now well-understood: they are free, and have a diagrammatic basis called the 'light-leaves'. In my thesis I will provide a similar diagrammatic description of morphism spaces in the Spherical category.

Supervisor(s): Anna Romanov, Geordie Williamson, Jie Du

Keyword(s): representation theory

9:55
Theatre A

Health-aware Food Recommendation System with Dual Attention in Heterogeneous Graphs

Saman Forouzandeh

Recommender systems (RS) have been increasingly applied to food and health. However, challenges still remain, including the effective incorporation of heterogeneous information and the discovery of meaningful relationships among entities in the context of food and health recommendation. To address these challenges, we propose a novel framework, the Health-aware Food Recommendation System with Dual Attention in Heterogeneous Graphs (HFRS-DA), for unsupervised representation learning on heterogeneous graph-structured data. HFRS-DA utilizes an attention technique to reconstruct node features and edges and employs a dual hierarchical attention mechanism for enhanced unsupervised learning of attributed graph representations. HFRS-DA addresses the challenge of effectively leveraging the heterogeneous information in the graph and discovering meaningful semantic relationships between entities. The framework analyzes food components and their neighbours in the heterogeneous graph and can discover popular and healthy foods, thereby promoting healthy eating habits. HFRS-DA also enhances the unsupervised learning of attributed graph representations, which is important in scenarios where labeled data is scarce or unavailable. HFRS-DA can generate node embeddings for unused data effectively, enabling both inductive and transductive learning. We report results from experiments on the Allrecipes dataset, comparing our method with 15 competing algorithms. We find that our method outperforms them across a number of commonly used metrics.

Supervisor(s): Dr. Pavel Krivitsky, Dr. Rohitash Chandra, Prof. Wenjie Zhang

Keyword(s): health food recommendation system; heterogeneous Information networks (HIN); attention mechanism; Graph Neural Network (GNA)

Kunneth formulae in Motivic Cohomology

9:55
Theatre B

Joshua Ham

The sharpened Eilenberg-Moore spectral sequence of Kriz and May was utilised by Joshua to derive a Künneth theorem for the higher Chow groups of pairs of quasi-projective varieties over a field, one of which is linear. Housing this argument in the language of Voevodsky's motivic cohomology simplifies the process somewhat. In a paper by Heller, Voineagu, and Østvær, the authors introduced a Bredon cohomology theory to serve as an equivariant generalisation of the theory of Voevodsky. We follow the approach of Joshua to produce a Künneth theorem for the Bredon motivic cohomology of quasi-projective C_2-varieties over a field, one of which is linear.

Supervisor(s): Mircea Voineagu, Jie Du

Keyword(s): algebraic topology; geometry

15:55
Hello Session

Density Estimation via Bernstein Polynomials

Peter Hanna

Exploring a (potentially) new way of performing Nonparametric Density Estimation using Bernstein Polynomials

Supervisor(s): Zdravko Botev

Keyword(s): statistics

The noncommutative space we live in

9:00
Theatre A

Eva-Maria Hekkelman

The strange but wonderful field of noncommutative geometry studies geometrical "spaces" which are unlike any space you come across in day-to-day maths. I will attempt to convince you that these spaces are indeed odd and that it is hard to imagine what they look like, but also that the universe we live in might be one. Skipping an outrageous number of steps, I will vaguely sketch how, taking this perspective, the physical laws of both the standard model of particle physics and general relativity can be derived from the same mathematical object, a functional called the spectral action, which is the current focal point of my research.

Supervisor(s): F. Sukochev (primary), D. Zanin and E. McDonald (Penn State)

Keyword(s): noncommutative geometry; mathematical physics; functional analysis

15:55
Hello Session

Semi-Definite Program Reformulation for Distributionally Robust Optimisation, with Applications in Portfolio Selection

Queenie Huang

Moment problems find the worst-case probability measure from a class of distributions governed by expectation inequality constraints. Unfortunately, evaluating a multi-dimensional integral for the expectations and searching through the infinite-dimensional space of probability distributions is computationally hard. Motivated by portfolio selection problem, we convert a class of linear moment problems into a computationally tractable semi-definite program using optimisation duality theory. This allows us to reformulate certain constrained distributionally robust optimisation problem as another tractable semi-definite program. Finally, we provide a tractable reformulation for the portfolio selection problem that can be readily applied in practice.

Supervisor(s): Jeya Jeyakumar, Guoyin Li

Keyword(s): optimisation; distributions; portfolio selection

Restricted Character sums in finite fields

15:55
Hello Session

Siddharth Iyer

Bounds for additive, multiplicative and mixed character sums are well known in literature when the domain of summation is restricted to large vector spaces in finite fields. In our paper we prove non-trivial bounds with summation restricted to "fixed digits".

Supervisor(s): Igor Shparlinski

Keyword(s): number theory

13:50
Theatre C

Symbolic data: small, efficient and accurate

Ahmad Hakiim Jamaluddin

The extraction and analysis of the full information contained in large data sets requires massive computational efforts. The computational burden can be significantly reduced by summarising or aggregating the data into objects that are easier to work with. The philosophy behind this approach aligns with the concepts developed in symbolic data analysis (SDA), a recently emerging field of statistics. In this presentation, we will introduce some statistical methodologies to aid in the design of the aggregation process of raw data into symbolic data. In particular, we will build on earlier work by Beranger et al. (2022) and develop a Bayesian framework to propose some optimal designs of symbolic data.

Supervisor(s): Scott Sisson and Boris Beranger

Keyword(s): uDASH; data science; Bayesian inference

Generalized Partial Least Square in Deep Neural Network

14:10
Theatre C

Qian Jin

While deep learning has shown exceptional performance in many applications, the model's mathematical understanding, model designing, and model interpretation are still new areas. Combining the two cultures of deep and statistical learning can provide insight into model interpretation and high-dimensional data applications. This work focuses on combing deep learning with generalized partial least square estimation. In particular, Bilodeau et al. (2015) proposed a generalized regression with orthogonal components (GROC) model, which is more flexible than the standard partial least square (PLS), because it may involve more complex structure of dependence and the use of generalized additive model (GAM) instead of linear regression. We propose a deep-GROC (DGROC) model, which allows for different measures of dependence (through their copula representation) to be used and shows a high prediction accuracy. Hyperparameter selection and transfer learning in the training loop are included to boost model performance. The superiority of the proposed method is demonstrated on simulations and real datasets, which show that our method achieves competitive performance compared to GROC, PLS and traditional Neural Networks.

Supervisor(s): Pierre Lafaye De Micheaux; Clara Grazian

Keyword(s): dependence measurement; machine learning; deep learning

15:55
Hello Session
Poster

A deep learning hybridization approach for process-based hydrological modelling

Arpit Kapoor

Nonlinear Spatio-temporal problems are a common occurrence in earth and environmental science including hydrology. Traditionally, process-based approaches inspired by our understanding of the underlying physical processes are employed for such problems. The observed data, however, is noisy and process-based methods fail to capture data patterns and uncertainty, leading to poor prediction performance. Machine learning provides an excellent set of computational and mathematical tools, such as Deep neural networks (DNN), for data-driven learning of such processes. DNNs have long been considered excellent for extracting latent features from extensive environmental data that challenge traditional modelling approaches. Despite the considerable success of deep learning in environmental modelling using a range of architectures, these models are physics agnostic and suffer from a variety of issues such as overfitting, local optima and lack of interpretability. Albeit recent, hybrid modelling and physics-informed learning approaches have shown a lot of promise in capturing the underlying physics from data by combining data-driven learning and physics/process-based modelling. We propose a sub-model hybridization for GR4J conceptual rainfall-runoff model using convolutional neural networks (CNNs) and long short-term memory (LSTM) networks for data-driven optimization. The results show that hybrid models outperform the base conceptual model as well as the base DNN architectures in terms of mean test Nash-Sutcliffe Efficiency (NSE) performance across 223 catchments in Australia. We show that the proposed hybridization approach provides a significant improvement in the predictive performance in arid catchments. These results motivate further study of hybrid modelling approaches to gain a deeper understanding of methods in constraint machine learning literature such as physics-informed neural networks while focusing on generalizability and convergence issues within the context of environmental process modelling problems.

Supervisor(s): Dr Rohitash Chandra, Dr Sahani Pathiraja

Keyword(s): environment; machine learning; neural networks; uDASH

A new algorithm for computing zeta functions of algebraic curves

13:50
Theatre B

Madeleine Kyng

The zeta function of an algebraic curve over a finite field is a rational function which encodes algebraic and geometric information about the curve. An important problem in computational number theory is to give efficient algorithms to compute zeta functions of curves. We have developed a new algorithm for this problem based on Harvey's trace formula and we have analysed the complexity of this new algorithm.

Supervisor(s): David Harvey

Keyword(s): number theory; point counting

12:10
Theatre A

Mixed Integer Linear Programming and Game Theoretic Techniques in Closed-Loop Supply Chain Network Designing

Samudra Lamahewage

Session info here

Mixed Integer Linear Programming and Game Theoretic Techniques in Closed-Loop Supply Chain Network Designing

Samudra Madushani

Game theoretic models allow us to consider the strategic interactions among decision-makers. In contrast, mixed integer linear programming (MILP) modeling focuses on a single decision problem from the perspective of a particular decision-maker. Hence, the investigation of these modeling techniques is crucial in CLSC network designing. In this study, MILP modeling obtains optimal quantity transformation decisions between supply chain entities with the objective of profit maximization of the hybrid plant. Stackelberg's game theoretic modeling is considered to account for the leader and multi-followers' decision-making, and then the bilevel optimization approach is applied to obtain Stackelberg equilibria. However, the Stackelberg model doesn't capture the dependency between followers. Hence, this study further develops the Cournot game theoretic modeling in order to deal with this limitation as well as to consider the simultaneous movement of supply chain members, and then the Linear Generalized Nash Equilibrium Problem (LGNEP) is solved to obtain Nash equilibria based on Karush Kuhn Tucker(KKT) Conditions. Finally, these modeling approaches are applied to illustrate the results of the tire CLSC network in the region of Greater Toronto Area in Ontario, Canada. The results indicate that optimal solutions of MILP modeling are equivalent to the optimal strategies of Stackelberg game theoretic modeling. The Cournot model demonstrates that there is a non-unique Nash equilibrium due to the existence of a singular matrix. Hence, imposing further constraints is required to investigate the unique Nash Equilibrium.

Supervisor(s): Dr. Sahani Pathiraja, Prof. Scott A. Scission, Assoc. Prof. Edward Cripps, Prof. Lucy Marshall

Keyword(s): Samudra Madushani is a PhD candidate in the School of Mathematics and Statistics, UNSW, and the ARC-funded Industrial Transformation Training Centre in Data Analytics for Resources and Environments (DARE). She completed the MSc degree in Industrial Mathematics at the University of Sri Jayewardenepura and the BSc degree in Statistics and Operations Research at the University of Peradeniya, Sri Lanka.

Supervisor(s): Dr. Sahani Pathiraja, Prof. Scott A. Scission, Assoc. Prof. Edward Cripps, Prof. Lucy Marshall

Keyword(s): optimisation

Douglas-Rachford method is the best!

9:35
Theatre A

Hongzhi Liao

We prove that the Douglas–Rachford method applied to two closed convex cones in $\mathbb{R}^2$ converges in finitely many steps if and only if the set of fixed points of the Douglas–Rachford operator is nontrivial. We reduce the analysis of this special case to studying the dynamics of a circle map.

We also construct explicit examples for a broad family of projection methods for which the set of fixed points of the relevant projection method operator is nontrivial, but the convergence is not finite. This three-parametric family is well-known in the projection methods literature and includes both the Douglas–Rachford method and the classical method of alternating projections.

Supervisor(s): Vera Roshchina and Mareike Dressler

Keyword(s): optimisation

9:35
Theatre C

Estimating effect size in multivariate analysis using bootstrap inversion

Michelle Lim

Multivariate analysis is widely used to study ecological communities, using abundance data collected simultaneously across many taxa. Effect size measures are widely used in statistics - for example to report on the size of a treatment effect, for meta-analysis, power simulation or equivalence testing - but measuring effect size in an intuitive way is challenging in the multivariate setting, where many parameters are used to capture the multivariate effect (β_j for taxon j). Here we explore an approach which reduces effect size to a single parameter (ρ) by using domain knowledge to classify taxa as "increasers" ($\beta_j = \rho$), "decreasers" ($\beta_j = -\rho$) and "no-effect" ($\beta_j = 0$) taxa. We have previously used this parameterisation to develop procedures for power analysis and equivalence testing of multivariate abundance data (implemented in R package `ecopower`), and in this study, we address the question of how to estimate and make inferences about ρ from a given multivariate dataset. We apply bootstrap inversion, a simulation-based approach which uses the duality between hypothesis testing and confidence intervals, and explore different stochastic optimisation tools to construct a confidence interval for ρ in an efficient and stable fashion.

Supervisor(s): David Warton

Keyword(s): ecology

A comparison study of likelihood-free inference algorithms

11:30
Theatre C

Yiyi Ma

Physical process-based state-space models and stochastic processes are two main categories of models to describe an environmental system. They are applied to model spatial or temporal events. Although vanilla cases like modelling spatial data with Gaussian processes exist, it is more general to encounter an intractable or censored likelihood when applying such models. The inference task will then be computationally expensive for high-dimensional situations. On the contrary, the likelihood-free inference (LFI) methods show the potential for tackling the problem. We have reviewed the mainstream LFI algorithm for parameter inference, including the traditional Markov Chain Monte Carlo (MCMC) based methods, generative adversarial networks (GANs) based and neural estimation-based methods. A simple comparison test shows that the last category performs better than the GANs-based algorithm in terms of recovering the posterior distribution of the parameters. The popular neural estimation-based methods consider designing a neural network with a proper loss function as an estimator of the parameters of interest. The network is trained to the implicit structure of the likelihood space. Literature shows that they have achieved promising estimations in inference for spatial extremal dependence models such as max-stable and r-Pareto processes. However, as our ultimate target is the posterior of the parameters given observations, the likelihood estimation technique can use additional MCMC sampling, which is somewhat inefficient. The last type of neural estimation-based method is designed based on normal flows and diffusion models, which provide us with a way of learning the posterior through a network directedly and lack of exploiting. We are currently trying to conduct careful experiments to compare the performances of the neural estimation-based models on a) spatial models like the Brown-Resnick processes and b) temporal models like the Hawkes processes. We will start from there to explore if adopting a posterior learning scheme is more robust and efficient to speed up the high-dimensional inference task and is worthwhile to apply to real environmental data.

Supervisor(s): Sahani Pathiraja, Scott Sisson, Lucy Marshall

Keyword(s): likelihood-free inference (LFI); simulation-based inference (SBI)

12:10
Theatre C

Hybrid kernel Stein variational gradient descent

Anson MacDonald

Stein variational gradient descent (SVGD) is a particle-based approximate inference method that utilises the score function of the target distribution. The SVGD algorithm has many theoretical properties including mean field results, non-asymptotic guarantees, and a gradient flow interpretation. Many variants of SVGD have been proposed in recent years, but the hybrid kernel variant (h-SVGD) does not inherit those results. This work fills that theoretical gap by establishing analogous results for the h-SVGD variant and defining a hybrid kernelised Stein discrepancy (h-KSD). Empirical results show that h-SVGD outperforms vanilla SVGD and other variants on standard machine learning tasks.

Supervisor(s): Scott Sisson, Sahani Pathiraja

Keyword(s): approximate inference; variational inference; KL-divergence

Spatio-temporal Species Distribution Models

10:35
Theatre A

Sam Mason

To date, the temporal aspects of Species Distribution Models (SDMs) have been less explored and common practice in Ecology is to fit point-in-time spatial models with temporally static predictors obtained from 30 year averaged data products derived from satellite observations.

This approach masks the accelerating effects of climate change and the resulting impact on species richness and distribution due to environmental stressors. Failing to account for species responses to climatic extremes leads to a loss of statistical power, biased predictions and wider prediction intervals when forecasting, all of which reduces the utility of such models in informing effective policy.

Until recently, this approach was largely due to difficulties in obtaining suitable covariates at the relevant spatial and temporal scales and at sufficiently high resolution. However recent advances in online services and toolkits provide opportunities for a new class of spatio-temporal SDMs for large datasets over arbitrary spatial scales and temporal windows.

Ecology also lacks a standard modelling approach allowing for uncertainties in predictors and observations (measurement, location, time or species identification) in SDMs. A far larger issue is the lack of a comprehensive visualisation solution bringing together observations, covariates and their respective uncertainties in both time and space.

In this talk we discuss these issues, cover progress to date and focus on the milestones for the next stages of this research.

Supervisor(s): David Warton, Mitchell Lyons, Andrew Zammit Mangion

Keyword(s):

10:15
Theatre C

New Methods for Grouped Variable Selection

Anant Mathur

Grouped variable selection in linear regression is the process of selecting important predictors that have a natural group structure to them. In this talk we will detail popular frameworks for grouped variable selection, in particular, the Group ℓ_0 and ℓ_1 penalized problems. We will then briefly outline two novel contributions in this area. The first is a fast algorithm for computing the solution to the ℓ_1 penalized problem (also referred to as Group Lasso) that can outperform existing algorithms on large datasets. The second contribution is a continuous optimization algorithm that can approximate the solution of the discrete Group ℓ_0 problem.

Supervisor(s): Zdravko Botev, Sarat Moka

Keyword(s): feature selection; computational statistics

Compactness in quasi-Banach spaces associated with a non-commutative torus

14:10
Theatre B

Yerlan Nessipbayev

We discuss compactness criteria in non-commutative quasi-Banach symmetric spaces associated to a finite von Neumann algebra, with focus on the non-commutative torus. In particular, we discuss new compactness criterion in the commutative setting; and the generalization of the Kolmogorov–Riesz compactness theorem.

Supervisor(s): Fedor Sukochev, Dmitriy Zanin

Keyword(s): (Frechet)-Kolmogorov-Riesz theorem; quasi-banach space; non-commutative torus

13:30
Theatre C

Statistical Analysis of Sampled Network Data

Kevin Pan

We consider incomplete observation of large networks – the size of these networks, combined with data collection constraints, may make it infeasible to observe all the relations. We discuss some special cases in the problem of estimating a random graph model from an observed subgraph.

Supervisor(s): Pavel Krivitsky, Feng Chen

Keyword(s): statistics

Simplicity of forest-skein groups

11:50
Theatre B

Ryan Seelig

In 1965 Richard Thompson discovered three fascinating groups: F, T, and V, which are groups of homeomorphisms of the Cantor space. Thompson's groups exhibit many rare properties, notably, T and V were the first examples of finitely presented infinite simple groups. Since then, Thompson-like groups have been a fruitful source of groups with these properties.

In 2022 Arnaud Brothier introduced *forest-skein* (FS) groups. These are similar to Thompson's original groups, though they are augmented with *skein*-relations, reminiscent of Vaughan Jones' subfactor theory. FS groups come in three flavours: G^F, G^T, and G^V, which share many of the same properties as F, T, and V.

Surprisingly however, not all FS groups enjoy analogous simplicity properties to F, T, and V. In this talk we will discuss necessary and sufficient conditions under which a triple G^F, G^T, G^V of FS groups admits nice simplicity properties, give an infinite class of concrete examples, and mention some open questions.

Supervisor(s): Arnaud Brothier and Pinhas Grossman

Keyword(s): simple groups; Jones' technology; infinite discrete groups; finitely presented groups; Thompson's groups

13:50
Theatre A

Constraining Stochastic Models Using Multiple Data Sets: An Algorithmic Approach

Brock Sherlock

Mean-field models are often used to identify describe physical processes. However, mean-field models do not take into account the stochasticity and variance usually found in real world systems and don't always provide explanatory mechanisms for the processes. Our work is motivated by identifying explanatory mechanisms for protein translocation in mammalian cell metabolism in response to insulin. Mean-field models have previously identified dominant processes at the macroscopic scale but do not explain the mechanisms of action (J. Biol. Chem., 289(25): 17280-17298). We have developed a candidate stochastic queuing network model that may provide further insight into mechanisms at the molecular scale for glucose transporter translocation in insulin regulated metabolism.

To test the efficacy of the model as an explanation of the biological mechanisms, an assessment of the ability of the model to represent all the different experimental observations needs to be quantified. For each experimental protocol, a value is measured at discrete time points of the system under that experimental condition. These data sets often consist of small sample sizes from repeated experiments. The stochastic model then aims to describe all the different time evolving distributions corresponding to the different experimental protocols.

Methods exist to quantify the difference between two distributions. However, a comparison needs to be made across time as each of the distributions evolve, not just between the distributions at each time point. Additionally, the correspondence of the stochastic model and observations across the different experimental protocols needs to be quantified. Given the sparsity of data, inference can be made more robust if data from independent data sets can be combined to constrain the mode, given that the model parameters constrained by the different protocols overlap.

In this investigation, different comparators evolving distributions are explored for the candidate model of glucose transporter translocation. Pseudometrics suitable for use in a practical algorithm for inference of stochastic models with multiple stochastic data sets from different experimental protocols are identified. The efficacy and implications of different approaches and for the candidate model is discussed.

Supervisor(s): Adelle Coster, Michael Watson

Keyword(s): mathematical biology; model fitting; queuing networks

Global well-posedness and numerical approximation of the Landau–Lifshitz–Baryakhtar equation

15:55
Hello Session
Poster

Agus Soenjaya

Landau–Lifshitz–Baryakhtar (LLBar) equation is a nonlinear time-dependent fourth order PDE which describes the evolution of magnetic spin field in a ferromagnet at an elevated temperature, taking into account contributions from long-range interactions. We prove that the LLBar equation is globally well-posed in the appropriate function spaces for dimensions 1, 2, and 3. To solve this equation numerically, we propose a conforming finite element method using the Hsieh–Clough–Tocher element. This numerical scheme is rigorously shown to converge to the actual solution at an optimal rate, provided the solution is sufficiently smooth. This is a joint work with Thanh Tran.

Supervisor(s): Thanh Tran

Keyword(s): partial differential equation; numerical analysis; finite element method

15:20
Theatre A

Multilevel quasi-Monte Carlo methods for kernel-based interpolation

Abi Srikumar

As high-dimensional problems become increasingly prevalent in many applications, such as finance and risk management, quantum physics and biology, the effective evaluation of these problems within the limits of our current technology poses a great hurdle - the exponential increase in computational cost as dimensionality of the problem increases. One class of strategies for evaluating such problems efficiently are quasi-Monte Carlo (QMC) methods.

QMC methods have been studied thoroughly for many different applications, but one field has been gaining momentum over recent years - uncertainty quantification of partial differential equations with random coefficients. Uncertainty quantification is the field of quantifying the behaviour of models and their solutions where there exists some randomness inherent to the model (e.g. uncertainty in parameters or inputs). Such random models appear frequently in the real-world in areas such as structural mechanics in engineering, modelling groundwater flow in hydrology and model calibration in weather forecasting and epidemiology.

In this talk, we begin with an overview to QMC and the trade-offs between computational cost and accuracy leading to a discussion on multilevel methods. We then explore the effectiveness of multilevel QMC methods for approximating solutions to elliptic partial differential equations with stochastic coefficients that depend periodically on the stochastic parameters. In particular, we are interested in fast approximation using kernel-based lattice point interpolation to reduce the cost of computation. We present some theoretical results regarding the error convergence of such approximations and the results of numerical experiments.

Supervisor(s): Frances Kuo, Ian Sloan, Alec Gilbert

Keyword(s): quasi-Monte Carlo; uncertainty quantification; multilevel methods; kernel interpolation

Joint Model for Longitudinal and Multi-state Responses with Functional Predictors

9:55
Theatre C

Rianti Siswi Utami

Joint modeling is increasingly used to analyse the association between longitudinal and time-to-event data. This approach can be applied when the event process for a subject may be affected by a covariate measured longitudinally on the same subject. This leads to reverse dependency because the existence of the covariate depends on the subject's survival. In the joint model, both the longitudinal and the time-to-event data are considered as responses that are modelled in separate submodels and then linked together through an association parameter. A recent development on joint models includes multi-state processes which allows for analysing multiple events. Another recent development is taking into account the influence of functional data in both submodels. Here we combine these two developments to create a functional joint multi-state model. We demonstrate the empirical performance of our approach through a simulation study. Using this model it becomes possible to analyse a complex dataset with longitudinal, multi-state, and functional components altogether.

Supervisor(s): Prof. Jake Olivier, A/Prof. Pierre Lafaye de Micheaux, A/Prof. Maarit Laaksonen

Keyword(s): joint model; longitudinal data; survival data; functional data

15:55
Hello Session

Analytic and Numerical Solutions to the Non-Homogeneous Landau-Lifshitz Equation with Applications to Spin-Torque Problems in Micromagnetics

Noah Vinod

We show the existence and uniqueness of regular solutions to the non-homogeneous Landau-Lifshitz equation given certain assumptions on the non-homogeneous term and develop a numerical algorithm to compute the approximate solution. This non-homogeneous Landau-Lifshitz equation is analogous to the spin-torque-type Landau-Lifshitz equation and thus can be used to study spin-torque phenomena in micromagnetics.

Supervisor(s): Thanh Tran

Keyword(s): partial differential equations; numerical methods; computational mathematics

Pedestrian Trajectory Prediction Using Dynamics-based Deep Learning

10:35
Theatre C

Honghui Wang

Pedestrian trajectory prediction plays an important role in the modern intelligent system and has been applied in the field of autonomous driving and robotics. Recent popular deep learning algorithms for pedestrian motion prediction gain good performance but make a limited priori assumption about human movements, resulting in insufficient explainability required for autonomous entities. To address this issue, the dynamics-based deep learning algorithm is proposed. Our new model proposes a novel asymptotically stable dynamical system to model human motion and therefore provides human movements with a strong priori. In addition, deep learning with strong data-fitting abilities is used to learn some features of human motion such as collision avoidance, for our proposed dynamical system. The experimental results show that our proposed algorithm performs better than the recent deep learning algorithms in pedestrian trajectory prediction on five commonly used real-world human motion datasets.

Supervisor(s): Rohitash Chandra, Gustavo Batista

Keyword(s): pedestrian trajectory prediction; asymptotically stable dynamical system; deep learning

15:55
Hello Session

The Influence of Weekly Mobius Lessons on Mathematics Students' Achievement and the Achievement Gap

Mian Wang

This research probes the effects of Weekly Mobius Lessons (WML) on student achievement, contrasting these effects with those observed in the Traditional Learning Methods (TLM) in an Australian university setting. The study also explores the role of WML in narrowing the achievement gap amongst high-, medium-, and low-achieving students. Through comparative analysis, this study investigates the disparities in student achievement across these groups under both the TLM and WML. The objective is to discern the potential of WML to not only enhance overall student achievement but also to promote educational equity among diverse learners. Quantitative metrics are utilized to categorize student achievement, and the differential impacts of TLM and WML on these categories are thoroughly assessed.

Supervisor(s): Pierre Lafaye de Micheaux Jonathan Michael Kress Laure Nicole Helme-Guizon

Keyword(s): statistics

Irreducible Pythagorean representations of Thompson's groups and the Cuntz algebra

11:30
Theatre B

Dilshan Wijesena

Richard Thompson's groups F, T and V are one of the most fascinating discrete infinite groups for their several unusual properties and their analytical properties have been challenging experts for many decades. One reason for this is because very little is known about its representation theory. Luckily, thanks to the novel technology of Jones, a rich family of so-called Pythagorean unitary representation of Thompson's groups can be constructed by simply specifying a pair of finite-dimensional operators satisfying a certain equality. These representations can even be extended to the celebrated Cuntz algebra and carry a powerful diagrammatic calculus which we use to develop techniques to study their properties. This permits to reduce very difficult questions concerning irreducibility and equivalence of infinite-dimensional representations into problems in finite-dimensional linear algebra. This provides a new rich class of irreducible representations of F. Moreover, we introduce the Pythagorean dimension which is a new invariant for all representations of the Cuntz algebra and Pythagorean representations of F, T, V. For each dimension d, the irreducible classes form a moduli space of a real manifold of dimension $2d^2 + 1$.

Supervisor(s): Arnaud Brothier

Keyword(s): group theory; operator algebra; representation theory

11:50
Theatre C

Stochastic and Sequentail Variational Bayes for GARCH Models

Hanwen Xuan

Stochastic variational inference algorithms are derived for fitting various heteroskedastic time series models. We examine Gaussian, t, and skew-t response GARCH models and fit these using Gaussian variational approximating densities. We implement efficient stochastic gradient ascent procedures based on the use of control variates or the reparameterization trick and demonstrate that the proposed implementations provide a fast and accurate alternative to Markov chain Monte Carlo sampling. Additionally, we present sequential updating versions of our variational algorithms, which are suitable for efficient portfolio construction and dynamic asset allocation.

Supervisor(s): Feng Chen, Clara Grazian, Luca Maestrini

Keyword(s): Bayesian inference; financial time series; skew-t innovation; stochastic gradient descent; variational Bayes

Graph Denoising Diffusion for Inverse Protein Folding

14:45
Theatre A

Kai Yi

Proteins, in terms of both structure and function, are of crucial importance in all biological organisms. Recent advancements in machine learning, exemplified by systems like AlphaFold2, are revolutionizing medicine, bioengineering, environmental science, and so on.

Inverse protein folding - the prediction of amino acid sequences based on known protein geometric structures - presents a significant computational challenge due to its inherent one-to-many mapping characteristic. A multitude of viable amino acid sequences can fold into an identical protein backbone, which complicates not only the identification of valid sequences but also the representation of the extensive diversity of potential solutions. Current machine learning methods, such as transformer-based auto-regressive models, encounter difficulties when attempting to capture the broad spectrum of plausible solutions. However, diffusion probabilistic generative models, a emerging field in Bayesian-based generative models, hold the potential to sample the mode of high-dimensional joint distributions, thereby offering various possible sequences folding into a given structure.

This paper introduces a novel graph denoising diffusion model for inverse protein folding, where a given protein backbone guides the diffusion process on the corresponding amino acid residue types. The model infers the joint distribution of amino acids, conditioned on the nodes' physiochemical properties and local environment. Compared to several established baseline methods, our model delivers superior performance in sequence recovery, showcasing its potential for wide-ranging applications in protein sequence design.

Supervisor(s): Scott Sisson

Keyword(s): uDASH; biology

10:35
Theatre B

Perturbation theory, spectral theory of commuting self-adjoint operators and related topics

Hongyin Zhao

In this talk, firstly we give an overview of the perturbation theory of commuting self-adjoint operators and related topics, which started from the classical Weyl-von Neumann theorem and then the significant result of Voiculescu. These results provide profound insights into the spectral theory of operators and the behaviour of self-adjoint operators on Hilbert spaces. We then talk about how far we can go in the extension of results in $B(H)$ to von Neumann algebras or factors.

Supervisor(s): Fedor Sukochev

Keyword(s): operator algebra; wave operators