10th AUT Mathematical Modelling and Analytics Symposium

Auckland University of Technology
Auckland, New Zealand

24th – 25th November 2025

Published by:
Mathematical Modelling and Analytics Research Centre
School of Engineering, Computer and Mathematical Sciences
Auckland University of Technology
https://mmarc.aut.ac.nz/our-research

V: November 17, 2025

Contents

Welcome to the 10^{th} Mathematical Modelling and Analytics Symposium

On behalf of the Department of Mathematical Sciences, and the Mathematical Modelling and Analytics Research Centre (MMARC) within the School of Engineering, Computer and Mathematical Sciences at Auckland University of Technology, I have much pleasure in welcoming you to the 10th Mathematical Modelling and Analytics Summer Symposium.

This year's Symposium is a continuation of our efforts to develop and promote the research being undertaken in Mathematical Sciences at AUT. I am delighted to welcome a number of keynote speakers to the Symposium with the aim of exploring collaborative opportunities and potential new areas of research that can be established with our research active staff.

The concept of this Symposium was a joint effort of Professor Emeritus Jeffrey Hunter and me, starting in 2014. With interruptions due to covid, I am glad that we were able to resume this important series in 2023 and continue it since then. I appreciate the assistance of staff of the Department and the Centre, in particular Dr Nuttanan Wichitaksorn, Dr Victor Miranda, Dr Ryan Ip, Dr Catherine Hansell Sweatman, Dr Patricio Russel, Dr Wenjun Zhang and others, who have each been involved in a variety of activities to ensure the continued success of this series.

As New Zealand's youngest university, we run our undergraduate program in Mathematical Sciences with the offer of two majors: "Analytics" and "Mathematical Modelling and Computation", together with three relevant minors in BSc. As the only university of technology in the country, we value inter-disciplinary research engagement and collaboration with our industry partners. For these purposes, we are putting in place a number of opportunities that will support and assist our academic staff to extend and enhance their activities, with this meeting being one such effort.

Our growing postgraduate program in the Mathematical Sciences at Honours, Masters and Doctoral levels has been enhanced with our Master of Analytics (MAnalytics) degree, now in its 11th year. The success of this program is leading to increased project supervision demands on our staff as well as leading to growing links with business and industry. We have an established arrangement with the SAS Institute that sees students in our MAnalytics degree gaining SAS Certification on graduation.

The Mathematical Modelling and Analytics Research Centre focuses on five main themes – Financial modelling and computation, Industrial optimisation and operations research, Modelling in health, biology and the environment, Statistical data analytics, and Radio astronomy modelling and statistics. We are very much focused on "research-led teaching" and we have developed a small number of research clusters to strengthen and support those academic staff working in these themes. Ideally we would like to foster collaborative activities and we thank those of you who have joined us at this meeting and we hope that we can facilitate some future joint research efforts.

We have kept the focus narrow so as to make the meeting meaningful and rewarding for those who participate. I hope that you enjoy your time with us and that you find the exercise a useful adjunct to the mathematical and statistical scene within New Zealand.

On behalf of the Mathematical Sciences Department, and the Mathematical Modelling and Analytics Research Centre,

Jiling Cao
Professor of Mathematics
Chair of the 10th Mathematical Modelling and Analytics Summer Symposium

AUT CITY CAMPUS

55 Wellesley Street East, Auckland 1010

SCHOOLS

Art & Design – Level 3, WE building
Business & Economics – Level 1, WF building
Creative Technologies – Level 11, WG building
Communication Studies – Level 12, WG building
Engineering, Computer & Mathematical Sciences – Level 3, WZ building
Hospitality & Tourism – Level 3, WH building
Language & Culture – Level 8, WT building
Law – Level 6, WY building
Science – Level 5, WS building
Social Sciences & Public Policy – Level 14, WT building
Te Ara Poutama – Level 3, WB building

STUDENT HUB

Level 2, WA building

Phone: 0800 AUT AUT (0800 288 288)
Web: www.aut.ac.nz/studenthub

SERVICES AND FACILITIES

AUT International Centre – Ground Floor, WY building
AUTSA (Auckland University of Technology Student Association) – Level 2, WC building
Early Childhood Centre – Level 2, WA building via Gate 2
Estates Service Centre, Security – Corner St Paul & Wakefield St, WO building
Learning Lab – Level 3, WA building
Library – Level 4, WA building
PinkLime (print services) – Level 3, WA building
Student Counselling & Mental Health – WB204, WB building
Student Medical Centre – WB219, WB building
ubiq (formerly University Bookshop) – WC122, WC building

- Student Hub
- Student lounge & study space
- Cafés
- Library
- Early Childhood Centre
- Gym
- Conference facility
- Intercampus shuttle bus stop
- Breast feeding and baby change room
- Mobility parks

Symposium Information

Location

The 10th AUT Mathematical Modelling and Analytics Symposium will be held in the **WS and WZ Buildings**, located in the corner of St Paul Street and Symonds Street, Auckland Central. All plenary talks will be held in WS114, and parallel sessions in WZ502 and WZ503.

Registration

Registration will take place on level 1 of the WS building, from 9:00am, on 24 November.

Presentations

Invited talks will be 40 minutes with 5 minutes for questions and contributed talks will be 20 minutes with 5 minutes for questions. There is a 5-minute break after each invited talk to allow delegates to move between rooms.

Morning and Afternoon Tea

Morning tea (for both days) and afternoon tea (for Day 1) are provided, and will be served on Level 5 of the WZ Building, in front of WZ502/503.

Lunch

Lunch is **not** provided. There are a large number of choices around the WZ building, and within a short walking distance of the campus.

Dinner

The symposium dinner will begin at 6pm on 24 November at the Puen Eatery & Bar Restaurant, located at 3 Mount Eden Road, Grafton, Auckland. This Thai restaurant is approximately 20 minutes walking distance away from the WZ Building. A map is provided on the next page.

The cost of dinner will be covered by Mathematical Modelling and Analytics Research Centre for participants who have registered.

Guest WiFi Access

If needed, please use the following login details to access WiFi on campus:
Network: AUTwifi
Username: di11049-guest@guest
Password: 31350549

Further Queries

If you have any queries please do not hesitate to contact a member of the organising committee: Jiling Cao, Nuttanan Wichitaksorn, Patricio Maturana-Russel, Wenjun Zhang, Shu Su, and Ryan Ip.

Direction to the Dinner Venue

Symposium Schedule

	Monday 24 November			Tuesday 25 November	
9:00 - 9:30	**Registration** WS Level 1				
9:30 - 9:45	**Welcome** WS114		9:30-10:15	**Jae Kyung Woo** WS114	
9:45-10:30	**Zhi Liu** WS114				
10:20-10:50			10:20-10:50	Morning Tea	
10:30-11:00	Morning Tea		10:50-11:15	**Hammed Fatoyinbo** WZ502	**Rebecca Evans** WZ503
11:00-11:25	**Binyamin Oz** WZ502	**David Wilson** WZ503	11:15-11:40	**Malavika Smitha** WZ502	**Tong Zhang** WZ503
11:25-11:50	**Iain Sweatman** WZ502	**Rardchawadee Silapunt** WZ503	11:40-12:05	**Samuel Kofie** WZ502	**Davide Papapicco** WZ503
11:55-13:00	Lunch		12:05-13:10	Lunch	
13:00-13:45	**Benchawan Wiwatanapataphee** WS114		13:10-13:35	**Catherine Sweatman** WZ502	**Arman Zili** WZ503
13:50-14:15	**Yajun Shi** WZ502	**Stephen Thorpe** WZ503	13:35-13:50	**Peter Olanipekun** WZ502	**James Bristow** WZ503
14:20-14:45	**Yuanyuan Li** WZ502	**Avi Vajpeyi** WZ503	13:55-14:40	**Cuong Nguyen** WS114	
14:45-15:15	Afternoon Tea		14:40-15:00	**Farewell** WS114	
15:15-15:40	**Jose Da Fonseca** WZ502	**Tu Quach** WZ503			
15:40-16:05	**Karalaini Verebasaga** WZ502	**Jiling Cao** WZ503			
16:05-16:30	**Wenqiang Liu** WZ502	**Ha Truong** WZ503			
18:00	**Dinner** Puen Eatery & Bar Restaurant				

List of Authors and Titles

Realized copula of volatility

Zhi Liu, Kim Christensen, Wenjing Liu, Yoann Potiron
Department of Mathematics, University of Macau
liuzhi@um.edu.mo

Asset empirical volatility is random. The statistical inference on the volatility itself, conditional on the volatility path, has been well established. However, the inference on the distribution of the stochastic volatility is yet to be well studied, particularly for the multivariate case. In the work, we study the copula of the distributions of bivariate stochastic volatility. We propose realized copula based on estimators of the spot volatility, and establish both infill and long-span asymptotics. Simulation studies based on two well-known stocahstic volatility models, Heston model and OU process, demonstate good performance of our realized copula in capturing the joint distributional pattern of the bivariate stochastic volatility. We also implement our realized copula to a real high-frequency data including two futures contracts, the E-mini S&P 500 (ES) and the 10-Year Treasury Notes (TY). The results suggest a Gumbel copula with a parameter around 1.6 for two stochastic volatilities.

Fractional Network Thermo-Fluid Dynamics for Controlled Drug Transport in Cerebral Microcirculation

Benchawan Wiwatanapataphee, Parul Tiwari
Statistics and Industrial Optimisation, Curtin University
b.wiwatanapataphee@curtin.edu.au

Fractional-order models provide a powerful framework for capturing anomalous transport, memory, and nonlocal interactions in biological microvascular networks. This study presents a hybrid 1D–3D model of cerebral drug transport under mild hyperthermia, coupling fractional intravascular dynamics with non-Fourier tissue bioheat. The vascular network is represented as a directed 1D graph, where advection, diffusion, and reactive exchange obey Caputo–Fabrizio time-fractional and Riesz space-fractional laws, linked through Robin-type mass and heat transfer to surrounding 3D tissue governed by a Cattaneo–Vernotte bioheat equation. Thermal feedback modifies permeability and perfusion, yielding a two-way thermo-chemical coupling. The explicit fractional scheme employs exponential-memory updates for Caputo–Fabrizio derivatives and symmetric Grönwald–Letnikov sums for nonlocal spatial fluxes while preserving global conservation. Simulations on an arteriole–capillary–venule network show that increasing fractional order α sharpens pulse dispersion and delays washout; higher temperature enhances vascular–tissue exchange and accelerates equilibration; and dual-phase-lag relaxation mitigates nonphysical heat spikes near vessel walls. The framework unifies anomalous vascular transport, temperature-sensitive physiology, and network geometry into a scalable model suitable for hyperthermia-optimized brain drug delivery and parameter calibration from imaging data.

Actuarial modelling under dependence in life and nonlife Insurance: Applications to joint life equity-linked Products and bonus-malus systems

Jae Kyung Woo, Kelvin Tang, Eric Cheung
Risk and Actuarial Studies, UNSW Sydney
j.k.woo@unsw.edu.au

This talk addresses the role of dependence structures in the design and valuation of insurance products. In the life insurance setting, we introduce new equity-linked products for couples whose benefits depend on both lifetimes. Recognizing the empirical dependence between spouses' mortality, valuation is conducted via the discounted density function approach, yielding closed-form expressions for various benefit types including income, death, and withdrawal guarantees. In the nonlife context, we explore dependence between claim frequency and severity in Bonus-Malus Systems (BMS). A bivariate random effects model is proposed, incorporating symmetric and asymmetric absolute error objective functions to derive optimal relativities. The resulting framework provides new insights into the performance and fairness of BMS designs. Overall, the analysis highlights how incorporating dependence enhances actuarial modeling accuracy in both life and nonlife domains.

Portfolio Optimization through Regular Vine Copula Model and Computational Intelligence Method

Rewat Khanthaporn, Nuttanan Wichitaksorn, Cuong Nguyen
Department of Financial and Business Systems, Lincoln University
cuong.nguyen@lincoln.ac.nz

This talk explores the use of artificial immune systems and genetic algorithms in computational intelligence to enhance investment portfolio strategies, incorporating sentiment analysis. The proposed forecasting model is a multivariate regular vine copula framework that considers 13 parametric bivariate copula functions. The univariate marginal model combines the intertemporal capital asset pricing model (ICAPM) with the asymmetric exponential GARCH (EGARCH) model. The innovation component follows a mixture distribution comprising a Gaussian and two generalized Pareto distributions, forming what is referred to as the R-vine-ICAPM-EGARCH-Mixture model. Empirical analysis is divided into two main scenarios. Scenario 1 addresses the "new normal" economic environment shaped by the COVID-19 crisis, focusing on risk-reward portfolio performance. Scenario 2 evaluates diversity and convergence in portfolio performance using pre-COVID-19 data, highlighting shifts in financial market dependence structures. We also integrate cryptocurrency with traditional stock portfolios. Performance evaluations demonstrate that the proposed model outperforms benchmark models in terms of both risk-adjusted returns and portfolio diversity. Parallel computing techniques are employed to accelerate the convergence of the evolutionary algorithms used in optimization. Backtesting across multiple strategies confirms the model's effectiveness, especially in stock selection for improved investment efficiency. Importantly, the study reveals a significant transformation in financial market dependence structures, largely influenced by the COVID-19 pandemic, indicating the emergence of a new market regime.

Mistaking Confidence for Preference: When Mixture Models Mislead Paired Comparison Estimation

Binyamin Oz, Naomi Kaplan-Damary, Hal S. Stern
Information Systems and Operations Management, University of Auckland
b.oz@auckland.ac.nz

Paired comparison models are a natural way to study how people choose between pairs of items. Each item receives a strength parameter, and differences between these parameters determine choice probabilities. The parameters carry two kinds of information. Their order encodes ordinal preferences, and their magnitude reflects the confidence or consistency with which those preferences are expressed. When analyzing data from many judges, a common strategy is to relax the single-population assumption using a mixture model with a fixed number of subgroups, each with its own parameter set. However, if individual variation in confidence is not modeled, estimation under a fixed number of groups may allocate the limited subgroups to capture magnitude differences in the parameters rather than differences in order. In that case, the estimated subgroups mainly reflect varying confidence, which is often less informative than uncovering genuinely distinct preference structures. We present a framework that combines mixture models with random effects, allowing subgroup-level differences and individual-level confidence variation to be estimated simultaneously. By giving the model a way to absorb within-group confidence variation, the available subgroups are freed to capture meaningful differences in preference order. A simulation study shows improved estimation and interpretability, and we further illustrate the approach with data on juror assessments of forensic evidence.

TSGBiNet: An End-to-End Spatio-Temporal Graph Neural Network for Multi-Site PV Power Forecasting with Missing Values

Tong Zhang, Nuttanan Wichitaksorn
Department of Mathematical Sciences, Auckland University of Technology
tongzhang_1998@cumt.edu.cn

Accurate spatio-temporal forecasting of photovoltaic (PV) power is critical for the effective management of multi-site PV systems. However, existing approaches often exhibit limitations in accurately modeling spatial dependencies in the absence of explicit graph structures, and typically presume fully observed datasets, an assumption that is frequently violated in practical applications due to sensor malfunctions or the high cost of data acquisition. To address these challenges, we propose a novel end-to-end and scalable framework for multi-site PV power forecasting, capable of effectively handling spatio-temporal data incompleteness. The proposed model, termed TSGBiNet, adopts a hierarchical architecture integrating the Multi-Scale Missing-Aware Temporal Attention Network (MS-MTAN) module and the Graph Bias-injected Network (GBiN) module. In particular, MS-MTAN is designed to capture multi-scale temporal dependencies that are often disrupted by missing values within each individual PV site. Meanwhile, GBiN learns hidden spatial correlations across sites while explicitly modeling missing data patterns through an adaptive bias-injection mechanism. Ablation studies validate the framework's effectiveness in uncovering intricate spatio-temporal relationships, even under severe data incompleteness. Extensive experiments on real world datasets demonstrate that TSGBiNet consistently improves forecasting accuracy and robustness.

Calisim: A Toolbox for the Calibration and Evaluation of Simulation Models with Applications in Evolutionary Biology

James Bristow, Ting-Hsuan Chen, Matthieu Vignes, David Hayman
School of Mathematical and Computational Sciences, Massey University
j.bristow2@massey.ac.nz

Computer simulation models allow scientists to study complex systems, identify outcomes, and test hypotheses in silico within various scientific domains such as agriculture, ecology, epidemiology, and horticulture. The precise calibration and evaluation of models is critical for producing accurate predictions and robust parameter estimates, which are necessary to support informed decision making and policy recommendations. Here, we introduce calisim, a toolbox for the calibration and evaluation of simulation models. Our open-source Python library provides a standardised interface and streamlined workflow for a suite of model calibration procedures, including Bayesian parameter estimation, black-box optimisation, sensitivity analysis, uncertainty analysis, optimal experimental design, and surrogate modelling. We present the use of calisim to two complex computer simulation models: TEgenomeSimulator, which simulates mutation accumulation in transposable element (TE) sequences and their genomic insertions for tool benchmarking and genome evolution research; and treesimulator, a simulation model for generating rooted phylogenetic trees under several supported Multi-Type Birth–Death phylodynamic models. We provide several examples of calibration procedures and their applications to both TEgenomeSimulator and treesimulator, and further discuss how these procedures may be used to iteratively validate and analyse these complex simulation models. Readily available documentation and tutorials are available online for access.

How big is a clam and what sort is it?

David Wilson
Data Science & AI, Auckland University of Technology
diwilson@aut.ac.nz

The responsible management of marine fisheries requires that one undertakes a survey every year throughout the marine environment. This is time consuming and expensive, and in the case of harvesting marine clams, one must both measure all the clams, note their species, and then immediately return those clams to the seabed. This means that the marine survey must be done in situ on the vessel. This project demonstrated that one could use image processing and machine learning too adequately measure the size of the claims, but a straight forward classification of species between very similarly looking claims proved problematic. Consequently, it was decided to use an algorithm that measured the striations on the clam body in order to differentiate and therefore classify between similarly looking clamps. The striations and direction were obtained using the gradient of the colour variations, which means it is to some degree immune to variations in background lighting, something that is crucial when undertaking on an actual marine vessel in varying lighting conditions. Due to the way the clams grow, these arcs will be centred along the hinge, which we can reconstruct by solving a large, sparse, system of linear equations. The uncertainty of the intersection point given by the variance-co-variance matrix also can give hints to what species the shell is.

Time series analysis of coupled slow–fast neuron models: From Hurst exponent to Granger causality

Indranil Ghosh, Hammed Olawale Fatoyinbo, Sishu Shankar Muni
Department of Mathematical Sciences, Auckland University of Technology
Hammed.fatoyinbo@aut.ac.nz

This presentation explores the time series dynamics of small neuronal networks where each node is modelled as a slow–fast version of the denatured Morris–Lecar neuron proposed by Schaeffer and Cain. Using several well-known coupling strategies, we examine how varying coupling strength shapes network behavior. Through quantitative time series analyses including measures of persistence, irregularity, chaos, quasi-periodicity, and synchronisation we identify distinct dynamical regimes. Chaotic behavior arises under inhibitory coupling and at elevated temperatures when coupling is thermally sensitive. Weak coupling produces quasi-periodic oscillations, while strong excitatory coupling leads to synchronised bursting. In certain parameter ranges, decay oscillations also emerge. Finally, causality testing reveals directional influence between neurons, highlighting how one neuron's activity can drive another within the coupled system.

Beyond Universal Superiority: Model Performance Across Five Developed Countries

Arman Zili, Nuttanan Wichitaksorn
Department of Mathematical Sciences, Auckland University of Technology
arman.zili@autuni.ac.nz

Accurate mortality forecasting is essential for actuarial planning, pension design, and demographic policy. This study compares the performance of advanced forecasting models across five developed countries (USA, Japan, France, New Zealand, and Sweden) and both genders. We evaluate two modern approaches: the Gradient Boosted Lee-Carter (GBLC), which integrates demographic structure with machine learning, and the non-parametric LightGBM (LGBM) model. Using the Mean Absolute Scaled Error (MASE) over 1- to 10-year horizons, we find distinct cross-country performance patterns. GBLC achieves superior accuracy in populations with volatile or structurally complex mortality trends (USA, Japan, France), while LGBM performs best in stable and predictable populations (Sweden, New Zealand). Notably, the traditional Hyndman-Ullah (HU) model surpasses both advanced methods for female mortality in Japan and France, reflecting its robustness in exceptionally smooth data environments. The results reveal that model superiority is not universal but shaped by each population's demographic stability and structural complexity. This study underscores the need to move beyond the pursuit of a single "best" model toward adaptive, data-driven selection for robust mortality forecasting.

Decomposing heterogeneous treatment effects in event studies

Tu Quach
Department of Mathematical Sciences, Auckland University of Technology
tuduong.quach@autuni.ac.nz

We propose a new design for the difference-in-differences estimator to estimate heterogeneous treatment effects. Our analysis demonstrates that the parameters of interest in the two-way fixed effects estimator are equivalent to the random intercept terms in multilevel regression. This approach enables the decomposition of heterogeneous treatment effects, allowing us to test and capture potential heterogeneity in the models. Furthermore, our method aggregates the average treatment effects on the treated (ATT) by using the parameters from the post-treatment period, rather than averaging all estimated ATT, which could introduce potential bias. We will revisit two studies to illustrate our method.

An infinite-server queue driven by a Cox-BESQ process

Jose Da Fonseca, Wenjun Zhang, Yajun Shi
School of Computing and Mathematical Sciences, Auckland University of Technology
pjs2823@autuni.ac.nz

This paper introduces an infinite-server queueing model driven by a Cox–BESQ process. Exploiting the affine structure of the underlying dynamics, we derive a closed-form expression for the joint moment generating function (MGF) of the queue length and its time-integrated process. The availability of this explicit MGF enables the application of the large deviation principle, yielding asymptotic characterizations for the integrated queue, and facilitates the derivation of a functional central limit theorem as well as the analysis of the queue's behavior in the heavy-traffic regime. Moreover, the closed-form MGF allows for the efficient computation of risk measures such as Value at Risk (VaR) and Expected Shortfall (ES), which provide insight into the tail behavior and potential losses associated with the integrated queue. These results enhance the model's applicability to contexts involving stochastic resource demand and performance evaluation under uncertainty. Numerical experiments are included to illustrate the implementation and relevance of the theoretical findings.

Enabling Practical Acceptance Sampling for Proportion Data: An Optimization Framework and R Implementation

Ha Truong, Victor Miranda, Roger Kissling
Department of Mathematical Sciences, Auckland University of Technology
ha.truong@aut.ac.nz

Acceptance sampling is a fundamental tool in quality control, but conventional methods are typically developed under the assumption of normally distributed measurement data. This limits their applicability when dealing with proportion-type quality characteristics, which are common in food compositional analysis and other settings where variables are naturally bounded between 0 and 1. Although previous studies have proposed models based on the Beta and truncated Normal distributions to better capture these characteristics, their industrial use remains limited due to the absence of standardized software and the computational burden of simulation-based plan construction. This work introduces an optimization-based framework for designing acceptance sampling plans under the Beta distribution, offering a practical and computationally efficient alternative to simulation methods. Implemented in the R package AccSamplingDesign, the proposed approach derives a closed-form expression for the probability of acceptance and employs non-linear programming to efficiently optimize sampling parameters. This framework substantially improves computational efficiency and usability, facilitating broader adoption of statistically principled acceptance sampling for proportion data in industrial quality control.

Multivariate Spectral Density Estimation using Variational and Hamiltonian Methods

Avi Vajpeyi, Renate Meyer, Patricio Maturana-Russel
Department of Statistics, University of Auckland
avi.vajpeyi@gmail.com

We present a Bayesian framework for modelling multivariate time-series spectra using penalised B-splines and probabilistic inference. This approach represents the logarithm of the multivariate power spectral density (PSD) through smooth spline bases with adaptive roughness penalties, enabling flexible yet stable estimation of both auto- and cross-spectral structure. Posterior inference is performed using stochastic variational inference for scalability and NUTS sampling for accurate uncertainty calibration. Applied to gravitational-wave detector data, the method captures evolving noise correlations across instruments and improves spectral resolution compared to classical estimators. We further demonstrate its versatility on wind-sensor and EEG datasets, illustrating its ability to recover interpretable, time-varying coupling patterns. This framework provides a unified and efficient tool for spectral modelling of complex, correlated signals across physics, earth sciences, and neuroscience.

Belief-Behavior Feedback, Cascade, and Optimal Platform Intervention

Yuanyuan (Lydia) Li, Simona Fabrizi, Steffen Lippert
Department of Economics, University of Auckland
yuanyuan.li@auckland.az.nz

Digital platforms face a persistent challenge in managing behavior-driven content diffusion and curbing misinformation. This paper develops a dynamic theoretical framework in which individuals choose to support, reject, or ignore content based on a Logit utility shaped by evolving private beliefs and platform incentives. Through local social learning, beliefs update via neighbors' observable actions, creating a feedback loop that links micro behavior and collective belief dynamics. We show that this mechanism endogenously generates self-reinforcing behavioral cascades, where weak incentives or early random actions can lock the network into a dominant behavioral state—supportive, neutral, or rejecting—regardless of factual accuracy. To address this structural fragility, we formulate the platform's challenge as a dynamic optimal control problem and characterize the optimal incentive path as an "early push, gradual fade" strategy: interventions should be strongest when beliefs are most volatile and taper as the system stabilizes. To better capture real-world interactions, we extend the analysis to specific network topologies to assess how structure mediates cascade dynamics and intervention effectiveness.

Inferring critical transitions from time series

Davide Papapicco, Graham Donovan, Lauren Smith
Department of Mathematics, University of Auckland
dpap666@aucklanduni.ac.nz

Critical transitions (or tipping points) are sudden, abrupt and often unforeseen departures of states of a dynamical system from a regime of stable equilibrium. In the past 20 years, tipping points have been an ever increasing studied subject in climate science and ecosystems given how disruptive these events can be. Mathematical characterisation of tipping points happened more recently with an tentative classification into three different mechanisms being proposed in 2012 by Ashwin et al.: bifurcation (B-tipping), noise (N-tipping) and rate (R-tipping) induced. Lately, more and more efforts from the community have shifted towards the robust and reliable prediction of these transitions in the form of early-warning signals (EWS). In this talk we will discuss one recent statistical method to derive an EWS from a large deviation principle using only timeseries data prior to a saddle-node type bifurcation.

Optimal Control of the Heat Equation

Iain Sweatman, Steve Taylor
Department of Mathematics, University of Auckland
iswe866@aucklanduni.ac.nz

The theory of optimal control was well-established for ordinary differential equations with the developments from calculus of variations and Pontryagin's Principle. Here we'll discuss an approach for applying the theory to a partial differential equation, and some resulting difficulties.

Investigating the etiology and stability of metabolic phenotypes via a mathematical model of glucose and lipid metabolism

Catherine Hassell Sweatman
Department of Mathematical Sciences, Auckland University of Technology
catherine.sweatman@aut.ac.nz

Metabolic phenotypes have been divided into four groups, based on the absence or presence of two conditions, metabolic syndrome and obesity. These groups are the metabolically healthy non-obese (MHN), metabolically healthy obese (MHO), metabolically unhealthy non-obese (MUN) and the metabolically unhealthy obese (MUO). The etiology of the MHO and MUN phenotypes is not well understood, and many questions have been asked. For example, is the MHO state healthy and is it stable? Should the MUO be encouraged to transition to MHO? Why are some people metabolically unhealthy, yet normal weight? A mathematical model of glucose and lipid metabolism is applied to investigate transitions between phenotypes by studying contributions to lipid balances in different organs due to diet and rates of lipolysis, lipogenesis, lipid secretion and lipid oxidation. Factors affecting these rates are discussed. Modelling predictions may help formulate medical advice.

Valuation of variable annuities in a general stochastic environment

Jose Da Fonseca, Patrick Wong
Department of Economics and Finance, Auckland University of Technology
jose.dafonseca@aut.ac.nz

This paper develops an advanced analytical framework for pricing variable annuity products, specifically Guaranteed Minimum Maturity Benefits (GMMB), Guaranteed Minimum Death Benefits (GMDB), and Guaranteed Minimum Income Benefits (GMIB), within a stochastic environment featuring general dependencies. The model assumes stochastic dynamics for jump intensity, interest rates, and volatility, explicitly incorporating interdependencies among these risks. A significant contribution of this research is the derivation of analytical, closed-form solutions, facilitating efficient and accurate pricing. We demonstrate that dependencies between various risks substantially influence product prices, particularly for longer-dated options. In particular, our framework generalizes and enhances the recent approximation approaches of Zhong et al. (2023) [Scandinavian Actuarial Journal] which necessitates an approximation due to model limitation. To obtain our result, we extend the methodology of Kirkby and Nguyen (2021) [Insurance: Mathematics and Economics] to multidimensional densities. Despite the highly flexible model, our method allows us to efficiently price and manage risk for these products.

Using humongous datasets to provide insights into social, cultural, and economic factors that shape wellbeing in Aotearoa

Rebecca Evans, Josie Tait, Victor Miranda
Te Ipukarea Research Institute, Auckland University of Technology
rebecca.evans@aut.ac.nz

The Growing Up in New Zealand (GUiNZ) study offers an unparalleled opportunity to understand the social, cultural, and economic influences shaping wellbeing across the lifecourse. As Aotearoa New Zealand's largest contemporary longitudinal study of child development, GUiNZ follows over 6,000 children born in 2009–2010 and their whānau, generating a rich dataset that reflects the diversity and complexity of modern childhoods. This presentation explores how humongous, population-level datasets such as GUiNZ can illuminate patterns of participation, connection, and inequality in Aotearoa. Drawing on recent analyses of children's engagement in music, arts, and recreation, I demonstrate how longitudinal approaches reveal developmental and socioecological factors that contribute to wellbeing outcomes. I also discuss emerging directions for this research, including the application of Māori models of health—such as Ngārururoro—to reframe wellbeing as a holistic, relational process grounded in Indigenous knowledge systems. By integrating big data methods with culturally responsive frameworks, this work highlights both the potential and responsibility of large-scale research to advance equity, inclusion, and flourishing across Aotearoa's diverse communities.

Integrating Statistical, Machine Learning, and On-Chain Valuation Signals for Optimal Bitcoin Entry Timing

Karalaini Verebasaga
Department of Mathematical Sciences, Auckland University of Technology
tqw3220@autuni.ac.nz

This research explores a hybrid approach to timing Bitcoin entry points by combining statistics, computing, and finance. It uses trend filters like SMA, machine learning classifiers like logistic regression, and on-chain metrics such as the NVT ratio, with application to historical Bitcoin data from 2018 to 2025 (with 15-minute bars aggregated daily). Results show that technical signals like the SMA crossover improve risk-adjusted returns and lower drawdowns compared to buy-and-hold strategies. Logistic regression enhances entry timing when its probability threshold is between 0.5 and 0.52. While the NVT Z-score alone performs poorly, it serves as a valuable long-term valuation filter when combined with trend signals. Over different test windows, this combined method achieves higher Sharpe ratios and lower maximum drawdowns with manageable turnover. Overall, these findings highlight that integrating these disciplines offers more reliable, risk-aware Bitcoin entry strategies.

Pricing American options with the hybrid SABR and Heston model of volatility

Jiling Cao, Jeong-Hoon Kim, Wenjun Zhang
Department of Mathematical Sciences, Auckland University of Technology
jiling.cao@aut.ac.nz

In this paper, we study the valuation of American put options under a multi-factor hybrid model that blends the SABR volatility and Heston's volatility in a rescaled version. The option price problem is transformed into a partial differential equation (PDE) problem with free boundary. Applying the averaging principle approach developed by Fouque et al. (2011), we turn the PDE problem into a few terms of asymptotic expansions of the option price and free boundary. Then we derive an approximate formula for the price of an American put option as the sum of the corresponding European put price and an early exercise premium, which makes the of computation of the prices of American put options easier. We check the accuracy of the resultant approximate option price and free boundary by using the least squares Monte Carlo simulation method and we compare the results under our hybrid SABR-Heston model with the results under those reduced CEV, Heston and SABR models, respectively.

Contrasting Big Data Techniques in Exploring New Zealand Road Crash Data

Stephen Thorpe, Baosen Hu
Department of Computer and Information Sciences, Auckland University of Technology
sthorpe@aut.ac.nz

Motor vehicle crashes result in high social and economic costs globally and in New Zealand. Therefore, accurate analysis of crash events is critical for evidence-based prevention and policy. This study explored the application of Big Data techniques, specifically Hadoop and MapReduce, to improve the analysis of the impact of weather and speed on motor vehicle crashes in New Zealand. Contemporary Big Data approaches were applied to address the limitations inherent in traditional methods of crash analysis. We used Hadoop's distributed storage and MapReduce's processing capabilities on the New Zealand Transport Agency's Crash Analysis System (CAS) dataset to identify and visualize environmental and spatial trends to a higher degree of understanding. The project involved Elasticsearch and Kibana to make sense of unstructured data in geographic views, while Hue, Hive, and Power BI represented structured data with charts and dashboards. Results show that non-injury crashes, followed by minor crashes, are the most frequent, with over half happening at speed limits between 40–60 km/h. Geographically, Auckland represents crashes five times greater than in the other locations. Strong and extreme weather conditions appear to be a factor in the majority of reported fatal road accidents.

Valuation of American put options under a modified 4/2 stochastic volatility model

Wenqiang Liu, Jiling Cao, Wenjun Zhang, Jeong-Hoon Kim
Department of Mathematical Sciences, Auckland University of Technology
twj7486@autuni.ac.nz

In this talk, I will present our study on the valuation of American put options based on the 4/2 stochastic volatility model that incorporates multiscale double mean-reverting (DMR) volatility. The option price problem is transformed into a partial differential equation (PDE) problem with free boundary, which in turn leads to PDE problems for a few terms of asymptotic expansions of the option price and free boundary. The approximate American put price is decomposed into the sum of the corresponding European put price and the early exercise premium. The chosen modification of the 4/2 stochastic volatility allows for a step-by-step approach to the option price starting from the Black–Scholes price of the corresponding European option, making it easier to approximate the price of an American put option. We check the accuracy of the resultant approximate option price and free boundary by using the least squares Monte Carlo simulation method and investigate the impact of the Heston and 3/2 factors of the volatility on the option price and free boundary. We calibrate our model to real market data and benchmark it against the widely used Heston model and the 3/2 model. We also conduct a sensitivity analysis to show how small changes in model parameters influence the American put option premium and early exercise boundary, and discuss limiting scenarios when the 3/2 term vanishes or volatility becomes deterministic. In addition, two specific results are provided. We derive a semi-analytic solution for the approximate option price and free boundary when an American put option is near expiration. We also study the pricing of an American put option without an expiration date and obtain a closed-form analytic formula for the approximate option price and free boundary.

Mathematical Modelling in Avian Influenza

Malavika Smitha, Hammed Fatoyinbo, Parul Tiwari
Department of Mathematical Sciences, Auckland University of Technology
malavikashari@gmail.com

Highly pathogenic avian influenza (HPAI) H5N1 has expanded its host range with recent detections in dairy cattle, raising concerns about within-herd persistence and cross-species spillover. We develop a deterministic compartmental model (SEIR) that couples direct cow to cow transmission with an environmental reservoir representing contaminated milking systems, surfaces, and milk. The model separates symptomatic (IS) and asymptomatic (IA) infections, allows both classes to shed into the environment, and represents environmental force of infection with a saturating term. Using the next-generation matrix, we derive a closed form basic reproduction number R0 that decomposes additively into direct and environmental components, clarifying how contact rates, infectious periods, shedding, and environmental decay combine to determine invasion potential. We estimate parameters by fitting simulated trajectories to outbreak-consistent patterns and then quantify drivers of transmission via global sensitivity analysis (Latin Hypercube Sampling with Partial Rank Correlation Coefficients). Environmental transmission parameters, the environmental infection coefficient (βB), environmental decay (ε), the half-saturation constant (K), and shedding rates (ωs, ωa) exert the strongest influence on R0, with herd size (S*) also important. Simulations un- der fitted values yield subcritical dynamics ($R0 < 1$), producing short-lived, event-like outbreaks with rapid decline of IS , IA, and the environmental burden B, while sus- ceptible numbers gradually recover through recruitment. Scenario analysis shows that combinations that reduce shedding, accelerate environmental decay (hygiene, disinfec- tion), and increase removal/isolation of infectious animals decrease R0 synergistically and can ensure $R0 < 1$. These results highlight the central role of environmental path- ways in cattle HPAI control and provide actionable levers for on-farm biosecurity and early-response protocols.

Hybrid PLS-KNN Model for Reliable Prediction of Forage Quality Traits Using Near-Infrared Spectroscopy

Samuel Kofie, Ryan Ip, Parul Tiwari, Hammed Fatoyinbo
Department of Mathematical Sciences, Auckland University of Technology
tsc0052@autuni.ac.nz

Near-infrared spectroscopy (NIRS) is widely recognised as a rapid, non-destructive tool for forage quality evaluation, yet the complexity of fresh forage spectra continues to challenge conventional chemometric models. Linear approaches such as partial least squares regression (PLSR) capture global trends but are limited in addressing the non-linear interactions common in heterogeneous, high-moisture forages. Non-linear and hybrid models offer alternatives, but their computational demands often restrict scalability. This study investigates a partial least squares-k-nearest neighbours (PLS-KNN) framework that integrates PLS for spectral dimensionality reduction with KNN for modelling local non-linear structures in the transformed latent space. Using a dataset of 7,215 fresh forage samples, we benchmarked PLS-KNN against KNN-PLS, PLSR, ridge regression, and least angle regression (LARS) for predicting dry matter (DM, g kg^{-1}), crude protein (CP, g kg^{-1} DM), and neutral detergent fibre (NDF, g kg^{-1} DM). Various spectral pretreatments were evaluated, with the optimal selected through PLS cross-validation. Model predictive performance was assessed using the coefficient of determination (R^2), RMSE, and ratio of performance to deviation (RPD). Across all three traits (DM, CP, and NDF), PLS-KNN achieved the highest predictive accuracy. The model reached R^2 values of 0.989 (DM), 0.890 (CP), and 0.773 (NDF), with corresponding RMSE values of 17.876 g kg^{-1} (DM), 14.911 g kg^{-1} DM (CP), and 35.956 g kg^{-1} DM (NDF); and RPD values of 9.554 (DM), 3.010 (CP), and 2.099 (NDF) respectively. Overall, the results show that PLS-KNN is both scalable and accurate for modelling fresh forage spectra. This makes it a useful tool for improving real-time, on-farm decision support in precision livestock management.

From Connectivity to Capacity: Enhancing Spreading Factor Allocation in LoRaWAN for Massive IoT

Rardchawadee Silapunt, Phanupong Tempiem
Department of Electronics and Telecommunication Engineering, King Mongkut's University of Technology Thonburi
rardchawadee.sil@kmutt.ac.th

The Adaptive Data Rate (ADR) scheme in LoRaWAN plays a central role in assigning spreading factors (SFs), which directly influence data rate, coverage, and time on air. Nevertheless, ADR frequently suffers from the problem of SF clustering in dense network environments, where a great number of devices are assigned the same SF, leading to increased packet collisions and reduced efficiency. This limitation constrains the scalability of LoRaWAN in massive IoT scenarios and motivates the exploration of alternative allocation strategies to improve reliability and network performance. This study investigates several algorithms for SF assignment, including Quantile Classification of Variance from the Mean (QCVM), Standard Deviation (SD), and Geometric Distribution. These approaches classify or probabilistically distributed devices based on Received Signal Strength Indicator (RSSI) values and traffic characteristics to mitigate clustering and balance network load. Simulations were conducted under variations in node density, coverage distance, and payload size, with test samples derived from actual farm locations and herd sizes in Ratchaburi province, Thailand. The results demonstrate that the proposed algorithms consistently improve the Data Extraction Rate (DER) compared to the standard ADR scheme, underscoring their potential for enhancing LoRaWAN efficiency in large-scale IoT applications such as smart livestock monitoring.

Modelling and Analysis of HPAI Transmission

Peter Olanipekun
Department of Mathematics, University of Auckland
rardchawadee.sil@kmutt.ac.th

Highly pathogenic avian influenza continues to pose major risks to livestock and public health, motivating the need to understand transmission at the cattle-wild bird-environment interface. We present and analyse a deterministic compartmental model that integrates SEIR cattle dynamics, SIR bird dynamics, and environmental transmission to characterise outbreak thresholds, stability conditions, and the drivers of disease persistence. Numerical simulations and sensitivity analyses highlight key parameters shaping epidemic outcomes and provide guidance for interventions aimed at reducing spillover and controlling HPAI in livestock population.