PhD Opportunities

A selection of some of the projects and supervisors currently available for new CSC applicants.

To explore more opportunities, visit Find a supervisor.

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Explore a selection of opportunities in the following areas:

Auckland Bioengineering Institute

Mapping the spread of breast cancer through the lymphatic system

Breast cancer is the most common cancer amongst women. The most important prognostic factor for patients is whether it has spread beyond the primary tumour in the breast and into the lymphatic vessels to form secondary tumours in lymph nodes. The exact location of these 'sentinel lymph nodes' (SLNs) varies considerably between women and therefore it is critical to identify where they are in each patient to optimise patient's treatment and chance for survival.

The goal of this project is to develop advanced computational and statistical models of the lymphatics draining the breast by using a large database of lymphoscintigraphy (LS) and 3D single-photon emission computed tomography (SPECT/CT), where individual breast cancer patient's SLNs have been accurately located. Outcomes of this project will: 1) quantify potential patterns of breast cancer spread with superior statistical power, 2) build decision support systems for clinicians to inform treatment planning and guide treatment follow-up, and 3) provide valuable resources for medical education. During the research we will be closely collaborating with clinicians and lymphatic anatomy experts in Sydney, Australia.

Desired skills: expertise in medical image processing, basic programming, data visualization, and statistical analysis.

Contact: Hayley Reynolds, hayley.reynolds@auckland.ac.nz

Heart rate variability and heart failure

In Chinese medicine, pulse diagnosis is a very helpful tool to assess overall health. The diagnostic information is based on the rhythm of the heart, where between one heartbeat and the next, there are naturally-occurring time differences. This time difference between beats is known as heart rate variability (HRV). Low HRV is associated with a higher risk of death in patients with heart disease. Monitoring HRV is also important in assessing healthy aging and life longevity, and COVID.

Despite its importance, HRV has not yet shown to have a therapeutic opportunity in treating heart failure. This project will test the therapeutic potential of re- instating HRV in diseased heart muscles. Experiments will include functional measurements (force and heat output) and molecular analysis (Western blots, qPCR). Experimental data will be used to aid the refinement of our mathematical model to provide insightful mechanistic interpretation.

Contact: June-Chiew Han, j.han@auckland.ac.nz

Investigation of brain structure, brain function, and brain age in people who are long-term exercisers

We will explore the relationship between brain structure, brain function and brain age in people who are long-term exercisers. The multimodal MRI and vestibular function tests will be compared for people who are expert Tai Chi (TC) practitioners and age matched controls. We are looking for highly motivated research students for this project within the field of neuroimaging data analysis.

The principal research aim is to explore the relationship between multimodal MRI measures (structural MRI, fMRI, diffusion MRI, ASL MRI), vestibular and balance function and cognitive function in people who are long-term TC practitioners compared to an age matched sedentary group. We hope that findings from this study will help us to develop science based interventions that have a long-term impact on brain health.

Preferred candidate: Experience in biomedical engineering, biomedical science, computer science, electronic engineering, computational neuroscience or related subject. Programming skills in Matlab, C++, or python. Experience in statistical analysis, machine/deep learning and/or (medical) image analysis. Excellent writing and communication skills (in English).

Contact: Alan Wang, alan.wang@auckland.ac.nz

Machine/Deep Learning in Neuroimaging Quantifications

We will develop innovative machine / deep learning algorithms for big data analytics, robust pooling and harmonization of neuroimaging data with varying acquisition protocols, and finding new representations from large cohort of neuroimaging data in order to classify diseases and predict disease progression and evaluate of future recovery in neurological and psychiatric diseases. The major focus will be on the MRI neuroimaging quantification in concussion, dementia, stroke, Parkinson's disease, and etc. We are looking for highly motivated research students for different kinds of research questions within the interdisciplinary field of machine / deep learning and neuroimaging data analysis.

Preferred candidate: Experience in computer science, biomedical engineering, electronic engineering, mathematics, physics, computational neuroscience or related subject. Good programming skills in Matlab, C++, or python Strong experience in machine/deep learning and/or (medical) image analysis. Excellent writing and communication skills (in English).

Contact: Alan Wang, alan.wang@auckland.ac.nz

Smooth muscle organ function: From data to model

Smooth muscle organs exhibit rhythmic electrical activity that helps to coordinate organ function. For example, bio-electrical waves in the stomach muscle wall coordinate the peristalsis responsible for digestion, in the uterus, labour and preparation for labour, while in the bladder, the detrusor muscle remains relaxed during filling, and contracts when emptying. These contractile patterns are coordinated by electrically active pacemaker cells. The patterns of electrical activity in the uterus and bladder are generally poorly understood, however, disordered electrical activity is believed to be associated with a number of clinical disorders such as overactive bladder and endometriosis, and premature labour. This project aims to:

1. Use multi-electrode electrical mapping data to assess the spatio-temporal electrical patterns in the bladder and uterus.
2. Develop new analytical techniques to quantify and visualise these results.
3. Develop mathematical models of the electrical activity in the uterus and bladder to aid in the interpretation of the experimental results.

Desired skills: bachelors or masters degree in engineering, physics or physiology. Strong background in computational modelling or signal processing. Some experience with experimentation, measuring bio-electrical signals (e.g., ECG, EMG), scientific analysis (e.g., MATLAB, Python) would be desirable.

Contact: **Leo Cheng**, **l.cheng@auckland.ac.nz** & **Alys Clark**, **alys.clark@auckland.ac.nz**

Strains on the fetal heart during development

When a baby does not reach its growth potential in its mother's womb, it can have life long health consequences, including an increased risk of cardiac disease. The condition, known as fetal growth restriction, has been shown to be associated with poor placental vascular development. As the placenta supplies oxygen to the developing fetus, it's form and function is critical for a healthy development. The interaction between the placenta and the fetal circulation is likely to play an important role, both in the short term growth of the baby, and in determining health in later life, however, the interactions between placental and fetal circulations are poorly understood.

We have developed computational models that suggest placental blood vessel structure typical of fetal growth restriction are sufficiently high resistance to impact on the function of the fetal heart. In this project you will take this concept further and develop a computational model of the fetal cardiovascular system that can predict if changes in placental resistance and oxygen delivery to the fetus could result in sustained alterations in fetal cardiac function during pregnancy. The project will suit students with a background in areas such as Biomedical Engineering, Engineering Science, Maths, or Physics with an interest in computational modelling and biological applications. Programming experience, particularly with python, is preferred.

Contact: **Alys Clark**, **alys.clark@auckland.ac.nz**

Faculty of Arts

Dr Jamie Gillen

Dr Jamie Gillen (Global Studies) is interested in supervising students with projects relating to China's political and cultural relationship to Southeast Asia, particularly Vietnam and mainland Southeast Asia.

Contact: **Dr Jamie Gillen**, **jamie.gillen@auckland.ac.nz**

Dr Karen Huang

Dr Karen Huang (Asian Studies/Chinese) is looking to supervise students in an area of Chinese linguistics.

Contact: **Dr Karen Huang**, **k.huang@auckland.ac.nz**

Dr Danping Wang

Dr Danping Wang (Asian Studies/Chinese) is interested to supervise on the following topics: teaching and learning Chinese in contentious geopolitical contexts; aspirations and well-being; and translanguaging perspectives on the family language policy of transnational Chinese migrants.

Contact: Dr Danping Wang, danping.wang@auckland.ac.nz

Dr Changzoo Song

Dr Changzoo Song (Asian Studies/Korean) has research interests in nationalism (particularly cyber-nationalism) in China and South Korea; and projects relating to integration and identity issues of Chinese (or Asian generally) migrants in New Zealand.

Contact: Dr Changzoo Song, ch.song@auckland.ac.nz

Dr Ellen Nakamura

Dr Ellen Nakamura (Asian Studies/Japanese) is interested in research topics that cover Japanese history, gender history, or family history.

Contact: Dr Ellen Nakamura, e.nakamura@auckland.ac.nz

Dr Mi Yung Park

Dr Mi Yung Park (Asian Studies/Korean) is interested in: Learning/teaching Korean as a foreign language in China; Korean language learning and identity among Chinese international students in Korea; Family language policy and heritage language maintenance among (mixed) Korean migrant families in China; Multilingualism and heritage language maintenance among (mixed) Asian migrant families in Korea (or in New Zealand).

Contact: Dr Mi Yung Park, my.park@auckland.ac.nz

Dr Bing Xiong

Dr Bing Xiong (Communication) is interested in: Social media in rural China; Chinese internet and politics; Chinese public discourse; Digital culture and communication;

intercultural communication/Asian communication theory.

Contact: **Dr Bing Xiong**, **bingjuan.xiong@auckland.ac.nz**

Dr Louisa Buckingham

Dr Louisa Buckingham (Applied Linguistics) is interested to supervise on the following topics: sociolinguistics, corpus-informed discourse analysis, language and technology.

Contact: **Dr Louisa Buckingham**, **l.buckingham@auckland.ac.nz**

Professor Yan Huang

Professor Yan Huang (Linguistics) is interested to supervise on the following topics: Pragmatics, semantics, pragmatics and syntax interface, anaphora, philosophy of language.

Contact: **Professor Yan Huang**, **yan.huang@auckland.ac.nz**

Dr Sunhee Koo

Dr Sunhee Koo (Anthropology) specialises in research on East Asia: China, Korea, and Japan. In her works, she examines the construction and negotiation of identities. Based on her ethnographic research on diasporic Koreans in China, Korea, and Japan, she has published a number of articles in prestigious journals. This year, Sunhee published her first monograph, Sound of the Border: Music and Identity of Korean Minority in China (Sept. 2021, University of Hawaii Press). She is keen to supervise PhD students who work on topics in East Asia (expressive cultures, popular/traditional music, and dances) and issues of identity, transnationalism, diaspora, migration, politics, and agency.

Contact: **Dr Sunhee Koo**, **s.koo@auckland.ac.nz**

Associate Professor Katherine Smits

Associate Professor Katherine Smits (Politics and International Relations) is interested in supervising these areas: Multiculturalism and policies towards ethno-cultural minorities; Nationalism, politics of national identity; Political participation, deliberation, practices of citizenship.

Contact: **Associate Professor Katherine Smits**, **k.smits@auckland.ac.nz**

Dr Stephen Noakes

Dr Stephen Noakes (Politics and International Relations) is interested in supervising these areas: Chinese political economy, civil society/NGOs, Chinese diaspora/transnational organisations, foreign development aid, or anything with a focus on PRC-relations with Pacific Island Countries or the 5 eyes security partners.

Contact: Dr Stephen Noakes, s.noakes@auckland.ac.nz

Associate Professor Neal Curtis

Associate Professor Neal Curtis from Media and Screen is interested to supervise students working on political or cultural aspects of Chinese social media. He is also a comics studies scholar and would welcome any students interested in developing a thesis on Chinese manhua, especially their history or role in either communication, propaganda or cultural change.

Contact: Associate Professor Neal Curtis, n.curtis@auckland.ac.nz

Associate Professor Nabeel Zuberi

Associate Professor Nabeel Zuberi (Media and Screen) is interested in the following supervision areas: Popular Music and Media Cultures, Technologies and Industries; Sound Studies; Nationalisms, Transnationalisms and Diasporas in Film, Media and Cultural Studies; Race, Racism, Racialisation and Media; Muslims and Media; South Asian Media; Black Media and Cultural Studies; Media, Film, Television, Communication.

Contact: Associate Professor Nabeel Zuberi, n.zuberi@auckland.ac.nz

Faculty of Business and Economics

Differentiating Services on Ride Sharing Platforms (PhD subject: Operations Management)

Ride hailing platforms are offering several options to differentiate their services with the ultimate objective of offering services that balance prices with the waiting time expectations. For example, with Uber Pool the rider can find a ride at discounted price but endures long wait time and loss of privacy. The goal of this project is to use mathematical models (in particular Markov decision processes) to evaluate different services from an efficiency perspective and to capture the implications of different services on driver and rider welfare.

Contact: Dr Aadhaar Chaturvedi, aadhaar.chaturvedi@auckland.ac.nz

Strategies in Drug Procurement (PhD subject: Supply Chain Management)

The objective of this project will be to look at how global health organisations can better tune their procurement policy for drugs in order to enable sustainable access to low-cost medicines without compromising on quality. In particular this project will look at strategies like limited volume discounts, competitive bidding and dual sourcing to leverage drug manufacturer’s scale economies as well sustain market competition. The scope of this project falls under United Nations Sustainable Goal 3 which aims to ensure healthy lives and promote well-being.

Contact: Dr Aadhaar Chaturvedi, aadhaar.chaturvedi@auckland.ac.nz

Operations and supply chain management using quantitative methodologies (PhD subjects: Supply Chain Management and Operations Management)

Professor Tava Olsen has a particular interest in agricultural supply chains, supply chain risk and resilience, supply chain sustainability, supply chain strategy, and emergency department operations.

Contact: Professor Tava Olsen, t.olsen@auckland.ac.nz

Understanding Touristification in the Sharing Economy: Airbnb and the Housing Market (PhD subject: Property)

Tourism development is widely recognised as an impetus for economic growth. In many cities worldwide, the income generated from domestic and international tourism contributes to socio-economic and cultural development. However, tourism growth simultaneously poses significant challenges to resource allocations and changes cities' socio-economic structures. "Touristification" is a novel concept that has been recently applied to understanding the process through which relatively spontaneous and unplanned tourism development transforms a designated space into a tourism commodity.

Contact: Dr William Cheung, william.cheung@auckland.ac.nz

Faculty of Creative Arts and Industries

Opportunities within the School of Dance

Supervisor: Professor Nicholas Rowe, School of Dance

Professor Rowe’s expertise includes Dance, Social Inclusion, Wellbeing, Critical Theory. Professor Rowe is available, willing and has capacity to take on new CSC students in 2022.

Contact: Professor Nicholas Rowe, n.rowe@auckland.ac.nz

Associate Prof Ralph Buck and **Dr Becca Webber** might also consider new applicants.

Opportunities within the School of Architecture and Planning

Supervisor: Associate Professor Julia Gatley

Dr Gatley’s expertise includes general areas of Architectural History and Heritage Conservation.

Dr Gatley is available, willing and have capacity to take on 1 new CSC students in 2022. Applicants should have a good GPA and good writing skills.

Contact: Associate Professor Julia Gatley, julia.gatley@auckland.ac.nz

Supervisor: Dr Lee Beattie

Lee is a practicing urban designer and urban planner with over 26 years' professional experience. He specialises in urban design, policy implementation and evaluation, liveability, growth management and housing issues. He is currently supervising four PhD students. Research interests include urban design policy development, implementation and evaluation, urban resilience, liveability and growth management issues. He is currently involved in a number of research projects considering the role that master-planning, transit orientated developments, and role urban design panels play in ensuring urban design quality and built form outcomes in practice.

Dr Beattie is available, willing and have capacity to take on new CSC students in 2022. Applicants should have a background in urban design.

Contact: Dr Lee Beattie, l.beattie@auckland.ac.nz (Students are required to email Dr Beattie before application for admission).

Supervisor: Dr Emilio Garcia

Dr Garcia's expertise includes resilience, collapse and sustainability. His current project is the impact of wealth in the built environment.

Dr Garcia is available, willing and have capacity to take on new CSC students in 2022. Candidates with basic knowledge of statistics and GIS are preferable. Candidates must be aware of Dr Garcia's publications to know in which ways he can help them. Research proposals must align with his current research interest, to extend it and complement it.

Contact: Dr Garcia, e.garcia@auckland.ac.nz (Students are required to email Dr Garcia before application for admission).

Supervisor: Associate Professor Kai Gu

Dr Gu's expertise includes urban planning and urban design.

Dr Gu is only available to take on new CSC students from December 2022.

Contact: Dr Gu, k.gu@auckland.ac.nz (Students are required to email Dr Gu before application for admission).

Associate Professor Paola Boarin

Dr Boarin's expertise includes regenerative design, adaptive reuse and heritage conservation, post-occupancy evaluation. Topics could also align broadly with those of the Future Cities Research Hub.

Dr Boarin is available, willing and has capacity to take on one new CSC student as main supervisor in 2022, who will commence no earlier than April 2022.

Preliminary knowledge on the topics above is required. Depending on their research topics, students may be asked to join the Future Cities Research Hub and may contribute to their activities.

Contact: Dr Boarin, p.boarin@auckland.ac.nz (Students should email Dr Boarin before application for admission. She would like to see the research statement before it is submitted).

Opportunities within the ELAM School of Fine Arts

Dr Lucille Holmes may consider new applicants.

Contact: Dr Lucille Holmes, la.holmes@auckland.ac.nz

Opportunities within the School of Music

Supervisors: Associate Professor Allan Badley and Professor Dean Sutcliffe

Associate Professor Allan Badley and Professor Dean Sutcliffe may consider new applicants.

Contacts: Associate Professor Allan Badley, a.badley@auckland.ac.nz, and Professor Dean Sutcliffe, wd.sutcliffe@auckland.ac.nz

Faculty of Education and Social Work

Women’s sport

Opportunities are available for those interested in women’s sport, especially media coverage, fan experiences or journalist perspectives.

Contact: Professor Toni Bruce, t.bruce@auckland.ac.nz

Analyses of education

Opportunities are available for those interested in anything related to philosophical and theoretical analyses of education in any context and sector, or anything to do with gender and feminist studies in the area of education.

Contact: Dr Kirsten Locke, k.locke@auckland.ac.nz

Educational assessment processes

Opportunities are available for those interested in educational assessment processes including design of tests, administration, scoring, feedback and psychological responses of teachers, students, and related stakeholders.

Contact: Professor Gavin T. L. Brown, gt.brown@auckland.ac.nz

Designing interventions to improve valued teaching and learning outcomes

Opportunities are available for those interested in designing interventions to improve valued teaching and learning outcomes. Mei has co-designed an intervention model that has been used for over 16 years, in five countries and across different contexts (e.g., rural and urban). This work has raised achievement primarily in literacy, and was awarded the University of Auckland's Research Excellence Award for work of demonstrable quality and impact. Mei's methodological focus is in design-based research and mixed methods. Her expertise is in design-based research interventions, and the use of data and teacher inquiry in professional learning communities to improve teaching and learning. There are several exciting opportunities to work with Mei to extend research in these areas and to improve teaching and learning in China. These include: the opportunity to co-design an intervention (digital, hybrid or non-digital) to improve teaching and learning in an Asian context and to examine the role of culture and context in designing successful interventions.

Contact: Associate Professor Mei Kuin Lai, mei.lai@auckland.ac.nz

Faculty of Engineering

Auckland Space Institute/Astrodynamics

Dynamics study about small-body missions

Design and operate missions to small bodies are challenging tasks due to the limited Î”v budget, highly perturbed and uncertain dynamics, and constraints coming from orbit determination and contact with the ground. A primary objective for these missions is to design operational orbits that meet mission requirements, require low Î”v for their maintenance and transfers, and that are robust to uncertain parameters and unmodeled dynamics. Within this context, mathematical tools for a better understanding of the behavior of the dynamics can prove useful to support the mission design process. In this research we aim to define new nonlinearity indicators that can assist the selection of operative orbits for missions to small bodies. We will exploit the automatic computation of Taylor expansions enabled by differential algebra to extend classical first-order approaches to high-order. We will perform this research in collaboration with Surrey Space Centre.
Main Supervisor: Roberto Armellin, roberto.armellin@auckland.ac.nz

Spacecraft Autonomous Guidance with Reinforcement Learning

Spacecraft autonomy is the next challenge to reduce space mission costs and enable more intense use of space. We propose a project to develop spacecraft with self-driving capabilities in complex Earth-based and deep-space missions. We aim to develop reinforcement learning (RL)-enhanced Lyapunov-based guidance laws where RL is used to improve optimality while retaining stability. Devising Lyapunov control laws is an art; there is no automatic way to establish a Lyapunov function that guarantees stability while ensuring optimality. Recently, significant advances have been made in discovering the governing equations for dynamical systems from data using machine learning. Building on these results, we will investigate ways to determine the formal expression of a Lyapunov function that produces a control history as close as possible to optimal control theory-based ones.

Main Supervisor: Roberto Armellin, roberto.armellin@auckland.ac.nz

High order continuation techniques for astrodynamics

The solution of astrodynamics problems often requires numerical continuation procedures. The computation of families of periodic orbits or the solution of optimal control problems are two relevant examples. Standard approaches based on Newtonâ€™s method typically provide discrete representations of the solutions with the risk of missing some important features. In this research, we aim to develop novel continuation procedures based on the differential algebra of Taylor polynomials. Our algorithms aim at generating dense family branches as an atlas of polynomial charts that are locally valid for a range of system and continuation parameters. We aim to apply the tool to problems in dynamical systems (e.g., automatic computation of solution families and bifurcations in n-body dynamics) and the optimization of multi-impulsive transfers in dynamics of increasing fidelity. We will perform this research in collaboration with Surrey Space Centre.

Main Supervisor: Roberto Armellin, roberto.armellin@auckland.ac.nz

Cislunar Space Situational Awareness

There is a renewed interest in missions in cislunar space, the American Artemis programme and the Chinese Chang'e project are two examples. As a result, the space around the Moon will be populated with spacecraft, some of which will be manned. To guarantee the safety of these missions, it will be necessary to extend space domain awareness to cislunar space. This new need will bring many challenges. The difficulty to track these far space objects and the non-Keplerian, possibly chaotic, dynamics are two relevant ones This research project aims to develop new initial orbit determination algorithms tailored for non-Keplerian dynamics and the use of both ground- and space-based optical observations, an essential capability for space safety in cislunar space.

Main Supervisor: Roberto Armellin, roberto.armellin@auckland.ac.nz

Department of Chemical and Materials Engineering

Addressing energy and environmental challenges with membrane technology

Membrane-based separation technology is gaining popularity due to it is considered as a clean technology, energy-efficient, small footprint, and its ability to produce superior product quality. Various projects are available in the area of membrane filtration technology for water and wastewater treatment, desalination, resource recovery, and food processing applications. These include the development of non-invasive membrane fouling monitoring techniques, novel membrane fouling mitigation strategies, emerging membrane separation processes, hybrid membrane system (membrane-based separation system integrated with a bioreactor, 3D printing, renewable energy source).

Main Supervisor: Filicia Wicaksana, f.wicaksana@auckland.ac.nz

Biotransformation and remediation of per- and polyfluoroalkyl substances

Dr Shan Yi's research group is seeking a motivated candidate passionate about solving environmental problems to join a research project on per- and polyfluoroalkyl substances (PFAS). PFAS are ubiquitous and persistent environmental contaminants with adverse effects on biota. In this research project, we aim to use advanced analytical chemistry tools to investigate the occurrence of PFAS in the NZ coastal environment and biota. A Master's degree in Chemical Engineering, Environmental Engineering, Analytical Chemistry, Environmental Microbiology, or closely related fields is required. The candidate is expected to have excellent verbal and written communication skills and strong motivation and dedication to academic excellence. Experience with microbiological techniques, mass spectrometry, or other analytical techniques is highly desired. Programming skills in R/Python and statistical analysis are also advantageous.

Main Supervisor: Shan Yi, shan.yi@auckland.ac.nz

Solid-State Magnesium Battery

Rechargeable batteries are very efficient and reliable electrical energy storage devices. Their plays a critical role in transmitting and distributing electrical energy, especially, with the introduction of electrical vehicles in last a few decades. Compared to lithium-ion and other commercial batteries, magnesium rechargeable batteries show low cost and high volumetric capacity advantages. However, Magnesium battery charge and discharge performance is significantly affected by the electrolyte. This research project aims to develop novel inorganic solid-state electrolyte to boost the magnesium batteries performance.

Main Supervisor: Shanghai Wei, s.wei@auckland.ac.nz

Department of Civil and Environmental Engineering

Success of Integrated Stormwater Management as Best Practice

The Best Practice Option for managing effects from development under the Network Discharge Consent is centred around the need of integrated stormwater management. While numerous overseas studies have shown this is a best practice method, limited studies have been completed for Auckland. Given the wider range of urban development that has occurred, is occurring or will occur, bringing in integrated stormwater management, there are plenty of opportunities for research at varying timeframes.

Providing answers to some of the key implementation questions, including:

- Are devices being installed as required?
- Are devices being decommissioned or maintained once building consents have been issued?
- Have devices resulted in stabilisation of flows to streams (reduce peak, maintain baseline)?
- Have devices resulted in reduced sediment, flooding, and heavy metals?
- Do they improve ecological values.
- Are rules effective in ecological values.

Main Supervisor: Dr Kilisimasi Latu, kilisimasi.latu@auckland.ac.nz

Pest fish impacts and effectiveness in management techniques

Pest fish like Koi are the possums of waterways. They predate and out compete native fish as well as reduce water quality by disturbing sediment. Work is being undertaken across New Zealand on managing pest fish but is not well funded and none with an Auckland context. Health Water has significant issues relating to pest fish its stormwater ponds, as well as lakes across parks (Western Springs and Lake Pupuke most notable). Watercare also has issues in its reservoirs. Pest fish provide great source of fish meal.

Further research is required on:

- Collection of data â€“ fish survey, identification of pest fish species and relative abundance (focus in urban lakes such as Lake Pupuke and Western Springs, and stormwater ponds in Auckland)

- Identification of environmental impacts caused by pest fish (such as the increased release of sediments and nutrients) (e.g., koi carp resuspend sediments in the water column due to their feeding nature; farmers in Waikato claim this is substantial)

- Pest fish management and control techniques and effectiveness (monitoring pre and post-work).

- Innovative studies (e.g., managing pest fish through hormonal work or release of Koi herpes (limited study occurring in Northland, no lab testing)).

- Other work aligned with that being undertaken by Michelle Archer in Waikato which may need further evaluation, particularly in Auckland context â€" she is working on report that should be available later this year.

- Analysis of possible uses for captured pest fish (e.g., caught koi fish can be reutilized for other uses/environmental projects â€" refer to CarpN Neutral project).

Main Supervisor: Dr Kilisimasi Latu, kilisimasi.latu@auckland.ac.nz

Develop a hydroinformatics system for the Pacific Island Countries

Hydrologic modelling can inform decision-makers on responding to extreme hydrologic events (Alcantara et al., 2019; Swain et al., 2015). The Pacific Island Countries (PICs) are experiencing the adverse effects of these events that are further worsened by climate change. While hydrological modelling has been well studied and used in many parts of the world, the same cannot be said to the Pacific Island Countries.

Communicating model results to different groups have been a recurring challenge due to the evolving nature of hydrologic models and the distinct needs of different groups (Alcantara et al., 2017; Swain et al., 2015). The insufficient infrastructure to house developed models and not making modelling results available to a broader audience on a real-time basis with advanced forecasting ability can cause delays and ineffective responses during critical events.

In this project, we will advance the tool developed at a study at Brigham Young University (Alcantara et al., 2017; Alcantara et al., 2019) and apply it to the Pacific Region. Programming skills required.

Main Supervisor: Dr Kilisimasi Latu, kilisimasi.latu@auckland.ac.nz

Investigation of long-term performance of modified bentonites against aggressive solutions

Geosynthetic clay liners (GCLs) are widely used as barriers which are safe and low cost alternative to Compact Clay Liners (CCLs) or Concrete barriers. Many research has been conducted to evaluate GCLsâ€™ performance in different conditions. The function of these materials strongly depends on bentonite performance which be impaired by being exposure to electrolytic liquids, especially in long-term. Also, structural type of bentonite, being pre-hydrated or not, wet and dry cycle, temperature, pH and so on are other factors which affect bentonite. So, new methods for improving bentonite properties and decreasing the impacts of these factors on performance are suggested such as, polymer-treated bentonite technology.

This study focuses on improving linerâ€™s performance by modifying bentonite with novel adsorbents. Not only this subject can promote bentoniteâ€™s hydraulic conductivity properties, but also will adsorption capacity increase significantly. Adsorption capacity plays a crucial role in preventing entry of pollutants to soil and groundwater in case of unpredictable matters such as earthquake, barrier’s installation damage and so on.

Although primarily research has been done on modified bentonite with different adsorbents, there are not satisfactory data related to long-term behaviors and sustainability of these compounds. The lack of sufficient knowledge is the main motivation for this research.

Main Supervisor: Dr Lokesh Padhye, l.padhye@auckland.ac.nz

Department of Electrical, Computer and Software Engineering

Towards Effective Testing of Machine Learning Models

ML is powering an increasing number of technologies that touch many aspects of our society. This raises genuine concerns about the correctness, efficiency, and fairness of ML systems. Testing ML systems is a new and exciting research topic as techniques to expose faults in ML systems would be extremely valuable. Recently, researchers applied Sofware Testing approaches for testing ML systems, showing promising results. However, there are many open problems and research opportunities to investigate. This PhD project aims to propose new techniques for generating test inputs and oracles for ML systems, inspired by Software Testing methods.

Main Supervisor: Dr Valerio Terragni, v.terragni@auckland.ac.nz

Autism AI: Detection of Autism Spectrum Disorder based on Artificial Intelligence Techniques

Autistic spectrum disorder (ASD) is a neurodevelopment condition normally linked with substantial healthcare costs and time consuming assessments where early detection of ASD traits can help limit the development of the condition but the mean age of diagnosis in NZ is 6-7 years - usually 2-3 years after families/carers had expressed concerns. The optimal window for delivering treatment to children with ASD is at 2-3 years, which necessitates identification before two. In addition to be time consuming, clinical diagnosis has accessibility issues and rely on clinical judgment. Screening tools have been proposed but they are not being used often because of concerns about accuracy.

In this project we aim to design an automated system based on Artificial Intelligence technologies to enable early, accessible, and accurate identification of children on autism spectrum.

Main Supervisor: Reza Shahamiri, reza.shahamiri@auckland.ac.nz

Automated Objective Intelligibility Assessments of Dysarthric Individuals

Dysarthria is a neurological disability that damages the control of motor speech articulators. An effective treatment plan requires a good understanding of the disability and its severity. The severity of dysarthria is usually identified by a subjective speech intelligibility assessment, which is based on the identification of how well normal speakers can comprehend the subject's speech. In this project we would like to design a mobile based solution that uses Deep Learning algorithms to conduct an objective assessment of dysarthria by listening to individual's speech and conducting an automated assessment.

The objectives of this project are:

1. Understating dysarthric speech intelligibility assessments

2. Proposing a deep learning-based software solution to conduct automated and intelligent assessments

3. Implementation and verification of the proposed system

Main Supervisor: Reza Shahamiri, reza.shahamiri@auckland.ac.nz

Impaired Speech Recognition

Automatic speech recognition (ASR) can be very helpful for speakers who suffer from dysarthria, a neurological disability that damages the control of motor speech articulators. ASR can act as a medium to not only understand the impaired speech but also to talk on their behalf and enable them to have a better social and digital life. Nevertheless, normal speech recognition systems have not been able to understand dysarthric speech, leaving speech impaired individuals not being able to utilize ASR technologies that could be life changing for them.

In this project our ultimate aim is to enable computers to understand dysarthric speech, as accurately as possible, using deep and machine learning technologies.

Main Supervisor: Reza Shahamiri, reza.shahamiri@auckland.ac.nz

Deep Learning-based Automated Software Test Oracles for Complex Systems

Test oracle is a mechanism to determine whether an application is executed correctly. It is a reliable source of how the SUT (Software Under Test) must operate. It is also expected to provide correct results for any inputs that are specified by the software specifications, and a comparator to verify the actual behaviour. Automated test oracles are helpful in providing an adequate automated testing framework.

After test cases are executed and results of the testing are generated, it is necessary to decide whether the results are valid in order to determine the correctness of the software behaviour. To verify the behaviour of the SUT, correct results are compared with the results generated by the software. The results produced by the SUT that need to be verified are called actual outputs, and the correct results that are used to evaluate actual outputs are called expected outputs. Test oracles are used as a reliable source of how the SUT must behave and a tool to verify actual outputs correctness. Usually, the verifier makes a comparison between actual and expected outputs.

Deep Learning (DL) is an umbrella term used for a collection on advanced machine learning algorithms capable of learning complex patterns from big data. In this project we would like to explore how DL based supervised, unsupervised, or reinforcement learning algorithms can be used to facilitate the design and implementation of complex software test oracles to help reduce the difficulties and complexities of testing difficult-to-test software systems.

Main Supervisor: Reza Shahamiri, reza.shahamiri@auckland.ac.nz

Safe Autonomy by formal methods enabled machine learning

Autonomous vehicles require high assurance safety and timing guarantees. They rely heavily on machine learning algorithms in their decision making. These algorithms, while being very smart and efficient, lack formal semantics, especially when several algorithms are composed into â€‹a single overall system. Moreover, the timing of the system may be non-deterministic, which is counterproductive for safety critical systems.

In this project we seek to combine machine learning with formal methods to address these shortcomings. We expect to use machine learning to determine a set of suitable policies / properties, which will aid the formal analysis of the system. Both static and run-time verification techniques will be considered.

Main Supervisor: Partha Roop, p.roop@auckland.ac.nz

Security of Implantable Medical Devices (IMD)

Attacks on IoT devices and implantable medical devices may have catastrophic consequences. This project seeks to employ formal techniques for mitigating the situation. We seek to develop a formal language for expressing security policies and will develop an approach for automatic synthesis of run-time monitors which will enforce these policies. We will explore issues related to compositionality and incrementality. We will explore efficient implementations that maximise battery life.

Main Supervisor: Partha Roop, p.roop@auckland.ac.nz

High performance computing for Radio Astronomy

The telescopes used for Radio Astronomy generate enormous amounts of data. Processing this data is a very challenging computational problem. For extremely large telescopes like the Square Kilometer Array (SKA), the generated data rate will be so high that storing the data is not possible. This means data needs to be processed in real time. One of the challenging science problems in radio astronomy is the search and timing of pulsars and Fast Radio Bursts (FSBs). Proposed methods to search for unknown pulsars and FSBs are based on brute force approaches, where the telescope data is processed assuming wide ranges of possible parameters. Research in this area focuses on developing fast methods to detect and observe these objects and to develop high performance implementations for the computational needs of these methods.

Main Supervisor: Oliver Sinnen, o.sinnen@auckland.ac.nz

Artificial Intelligence Approaches to Task Scheduling for Parallel Systems

Project Description: Crucial for the efficiency of a parallel program is how the (sub)tasks of the program are mapped and ordered on the processors of the system. In task scheduling, the program is represented by a graph, where the nodes represent the tasks and the edges the communication between the tasks. The objective is then to find the best scheduling of this graph on the processors that allows the fastest execution of the program. Unfortunately, this is a very difficult optimisation problem (NP-hard). The research in this area deals with algorithm design, graph theory, complexity theory, multi-criteria optimisation, experimental evaluations on real parallel systems and system modelling. Artificial Intelligence approaches are very promising to solve these problems optimally, for example using A* from the robotics domain.

Main Supervisor: Oliver Sinnen, o.sinnen@auckland.ac.nz

Department of Engineering Science

Computational Fluid Dynamics for river bioremediation

Improving river water quality is a major priority in New Zealand, with the main source of contaminants being nitrates and e-Coli from farming. While there has been much work conducted to-date on designing bioremediation technologies in slow moving bodies of water, such as lakes and ponds, their application in faster moving environments such as rivers is much less explored. This project will build upon a preliminary study, using computational fluid dynamics to design in-river bioremediation technologies that are optimised to maximise removal of contaminants.

Main Supervisor: Richard Clarke, rj.clarke@auckland.ac.nz

Modelling the lymphatic system

The overarching goal of the programme, which is in collaboration with researchers in the Auckland Bioengineering Institute and Faculty of Medical and Health Sciences, is to reduce the incidence and severity of organ failure due to dysfunction of the lymphatic system (the network of vessels that clear fluid and toxins from tissues around the body). It is currently estimated that over 6m people each year are admitted to intensive care units with organ failure, with a mortality rate of more than 30%.

This PhD project will contribute to these overall goals by better understanding the mechanics of fluid clearance in the lymphatic system through computational modelling. In particular, how fluid is returned from the lymphatic system to the blood circulation, and how the lymphatic system pumps fluid around the body through vessel contractions (there is no equivalent of the heart in the lymphatic system).

The project will involve computational modelling of fluid-structure interactions, using anatomical geometries obtained from clinical data that will be collected by researchers working on the clinical side of the programme study.

Main Supervisor: Richard Clarke, rj.clarke@auckland.ac.nz

Computational Neuroscience

Department: Engineering Science/Computational Modelling

We are looking for a motivated graduates who are keen to contribute to the rapidly expanding field of Neural Engineering in the area of computational neuroscience.

In this project, you will develop novel mathematical and computational models to model human neurons and astrocytes and combine them in networks and simulate their cellular communication.

Main Supervisor: Associate Prof. Charles Unsworth, c.unsworth@auckland.ac.nz

Lab on a chip

Department: Engineering Science/Electronics & Microelectronics

We are looking for highly motivated graduates in Engineering or Science who are keen to contribute to the field of Neural Engineering by developing the next generation of neural chip platforms, in the form of Multi-Electrode Arrays (MEAs), to help us better understand the communication that occurs in human brain cells and brain cancer cells.

The experience that we seek is ranked but not limited to: electronics, microelectronics, nanotechnology, multi-electrode arrays, signal processing and cell culture.

Their main focus will be to extend the electronics of our current system to develop novel MEA neural platforms to accommodate large organised grid networks of brain cells on chip such they can be both stimulated and recorded from before, during and after drug therapeutics. Such a platform will lead to the gain of new knowledge that will feed directly into building new phase I trials in order to rapidly translate drug therapeutics into the clinic.

Main Supervisor: Associate Prof. Charles Unsworth, c.unsworth@auckland.ac.nz

Microfluidic Platforms for Brain Cancer

Department: Engineering Science/Microfluidics

We are looking for a motivated graduate who is keen to contribute to the rapidly expanding field of Neural Engineering with skills in microfluidics and/or electronics

The project will be to develop microfluidic platforms that can be used to capture and measure extra-cellular vesicles that are released when cancer cells die.

Main Supervisor: Associate Prof. Charles Unsworth, c.unsworth@auckland.ac.nz

Cancer on a Chip

Department: Engineering Science/Neural Engineering

We are looking for a motivated graduate in: Cancer Cell Biology, Cell Biology, Biology, Neuroscience or Bioengineering who is keen to contribute to the field of Neural Engineering. The experience that we seek is ranked but not limited to: in vitro cell culture, in vitro cancer cell culture, ion channels, cell patterning and live cell microscopy.

Their main focus will be to perform in vitro experiments on how well different adult & childhood brain cancer cells organise and pattern on silicon chips, to perform ion channel blocking, drug therapeutic delivery, laser stimulation of cells and the live fluorescent cell recording of calcium to help us better understand the communication that occurs in brain cancer. Such cell biology will lead to the gain of new knowledge that will feed directly into building new phase I trials in order to rapidly translate drug therapeutics into the clinic.

Main Supervisor: Associate Prof. Charles Unsworth, c.unsworth@auckland.ac.nz

Bioprinting on a Chip

Department: Engineering Science/Bioprinting

We are looking for a motivated graduate in: in vitro Cell Biology, Biology, Neuroscience or Bioengineering who is keen to contribute to the field of Neural Engineering who is interested to contribute to the field of Bioprinting. The experience that we seek is ranked but not limited to: in vitro cell culture, ion channels, cell patterning and live cell microscopy.

Their main focus will be to perform in vitro experiments on bioprinted networks of human brain cells on a chip to understand the fundamentals of communication in networks.

Main Supervisor: Associate Prof. Charles Unsworth, c.unsworth@auckland.ac.nz

Identifying Cancer with Image Processing and Machine Learning

Department: Engineering Science/Image Processing & Machine Learning

We are looking for motivated graduates who are keen to contribute to the rapidly expanding field of Neural Engineering and who have skills in the following areas:

Signal & Image processing, Artificial Neural Networks & Machine Learning.

This project will be to develop novel advanced signal & image processing techniques and combine them Artificial Neural Networks & Machine Learning to identify different grades of brain cancer automatically.

Main Supervisor: Associate Prof. Charles Unsworth,
c.unsworth@auckland.ac.nz

Signal Processing & Prediction of signals from networks of brain cells

Department: Engineering Science/Signal processing & Artificial Neural Networks/Machine Learning

We are looking for a motivated graduate who is keen to contribute to the rapidly expanding field of Neural Engineering with skills in the area of signal processing and/or artificial neural networks/machine learning

The project will be involved with the signal processing and signal analysis of multi-channel signals that come from networks of brain cells on a silicon chip to understand the communication that goes on in networks of cells.

Main Supervisor: Associate Prof. Charles Unsworth,
c.unsworth@auckland.ac.nz

Department of Mechanical Engineering

Modelling, Analysis and Development of Adaptive Robotic and Prosthetic Hands

This project will focus on modelling, analysis and development of a new class of simple, adaptive robot hands for robust grasping and dexterous, in-hand manipulation. The designs will demonstrate the adaptive behaviour of compliant, under-actuated grippers and their superior grasping capabilities under uncertainties. In this project, we will also explore alternative uses of structural compliance for the development of grasping mechanisms. The devices will be fabricated using rapid prototyping techniques.

This project will be done in collaboration with the OpenBionics Initiative and will result in the creation of an open-source repository for the New Dexterity research group robot hand designs.

Main Supervisor: Dr Minas Liarokapis, minas.liarokapis@auckland.ac.nz

Design, Analysis, Modelling, and Development of Soft, Wearable Exoskeleton Gloves

Robotic exoskeletons have become a popular technological solution for assisting people that suffer from neurological conditions and for enhancing the capabilities of healthy individuals. This class of devices ranges from rigid and complex structures to soft, lightweight, wearable gloves. Despite the progress in the field, most existing devices do not provide the same dexterity as the healthy human hand. This project focuses on a new class of affordable, lightweight, robust, easy-to-operate exoskeleton gloves that can be developed with off-the-shelf materials and rapid prototyping techniques.

Main Supervisor: Dr Minas Liarokapis, minas.liarokapis@auckland.ac.nz

Blind Robot Grasping and Haptic Object Identification with Adaptive Hands

This project will focus on blind grasping and haptic object identification with adaptive hands. These goals will be achieved by formulating hybrid schemes that will leverage the benefits of simple, adaptive robot grippers (that can grasp successfully without prior knowledge of the hand or the object model), with simple sensors and advanced machine learning techniques.

The applications of this project will be in the fields of industrial and warehouse automation, object quality and environment inspection. This project will take advantage of the robotic devices developed by the New Dexterity research group.

Main Supervisor: Dr Minas Liarokapis, minas.liarokapis@auckland.ac.nz

Quantification of the effect of air entrapment in free-surface water impacts

Free-surface fluid-structure impacts, such as waves battering marine vessels or coastal infrastructure, can be extremely damaging. Our aim is to understand the fundamentals of these impacts, with a particular focus on air trapped between the structure and the fluid. Extensive research has been undertaken looking at fluid-structure interactions, but these have typically neglected the influence of any entrapped air. This work will experimentally characterise the two-phase water/airflow in the contact region and develop predictive models to enable maximum impact loads to be accurately determined.

Main Supervisor: Dr Tom Allen, tom.allen@auckland.ac.nz

Constitutive models and failure criteria, incorporating large deformation and rate effects, for sandwich composite polymer foam cores

The aim of this PhD to use advanced experimental and numerical modelling techniques to understand what underpins the deformation and failure behaviour of polymeric foams, and then develop and validate new constitutive models that can predict the behaviour. This will include high-speed imaging and digital image correlation-based deformation measurement during high-rate testing in the CACM drop-tower test facilities, development of multi-axal loading methods for cores and structural panel testing for hard-object and water impact. Constitutive models will be developed, refined and validated, and implemented in explicit finite element models.

Main Supervisor: Dr Tom Allen, tom.allen@auckland.ac.nz

Smart Factory Communications for Industry 4.0

Smart factories in the Industry 4.0 era need to be agile and reconfigurable to need changing customer needs. This project aims to develop a smart factory that is elastic enough to cope with dynamic changes. Industrial standards such as IPC UA and MQTT will be used.

Main Supervisor: Xun Xu, xun.xu@auckland.ac.nz

Expansion power recovery in a refrigeration system

Department: Mechanical Engineering/Thermal Engineering

In a conventional vapour compression refrigeration system, a significant amount of exergy is lost in the throttling valve. An expander can be used to overcome this issue. However, expander performance in such application is currently still not optimized yet. In addition, the refrigeration system itself has not been optimised properly to reap the full benefit of expanders. In this project, the main sources of losses in refrigeration systems with expanders will be looked at. Novel solutions will be proposed and tested (experimentally and numerically).

Main Supervisor: Alison Subiantoro, a.subiantoro@auckland.ac.nz

Shape-based Object Classification using Underactuated Hands with Stretch Sensors

Department: Mechatronics

Project Description: Robotic hands capable of identifying objects can be applied in various situations, including assisting the disabled or assembling components in factories. This research proposed and successfully developed a system focusing on object shape identification using an underactuated robotic hand equipped with soft sensors with only one single grasp. Soft sensors, using piezoresistive and capacitive transductions, were fabricated and tested to provide information on the grasping postures. Tests results show that the capacitive pressure sensors, whose dielectric was made of Ecoflex with copper electrodes, are sensitive to surroundings. The stretchable piezoresistive sensors were made from carbon black/Ecoflex composite encapsulated within the Ecoflex elastomer, where the resistance of the sensors is related to their stretched lengths. Two methods, data fitting and superquadrics, are presented in this research to identify the shapes of objects. Four general shapes were used to classify objects, and simulations and tests demonstrated that the methods are valid.

Main Supervisor: Kean Aw. C., k.aw@auckland.ac.nz

Faculty of Law

History/Private Law

Professor Warren Swain is one of the world's leading historians of private law. He is currently Deputy Dean. He was educated at Hertford College, the University of Oxford, where he was awarded a BA, MA, BCL and D.Phil. He has previously taught at Oxford, Birmingham and Durham universities in the UK and the University of Queensland in Australia. He was elected a life member of Clare Hall, University of Cambridge. He is secretary for the Selden Society in New Zealand.

Professor Swain is interested in the history of contract, tort and unjust enrichment as well as intellectual history more broadly especially in so far as it applies to the law. He also undertakes research in comparative legal history, the history of English law in a colonial context and Roman law.

Contact: Professor Warren Swain, w.swain@auckland.ac.nz

Healthcare Law

Professor Jaime King is an expert in healthcare reform, specializing in some of the most complex challenges facing domestic healthcare systems, especially within the United States. Her current research focuses on reform efforts using combination of regulatory and competition-based tools to reduce costs and promote equitable access to healthcare. Her past scholarship has also addressed questions related to the balance of individual autonomy and state power, including but not limited to medical decision making and constitutional and regulatory questions regarding genetic testing.

Contact: Professor Jaime King, jaime.king@auckland.ac.nz

Criminal and Indigenous Law

Dr Fleur Te Aho is a senior lecturer in the University of Auckland's Faculty of Law where she researches and teaches on Indigenous peoples and the law and criminal law. Fleur has an especial interest in understanding how international law norms regarding Indigenous peoples influence domestic law, Indigenous peoples' rights, and Māori and criminal justice.

Contact: Dr Fleur Te Aho, f.teaho@auckland.ac.nz

Legal Philosophy Theory of Private Law

Dr Arie Rosen teaches legal philosophy, contract law, and private law theory at the University of Auckland Faculty of Law. He is a co-director of the New Zealand Centre for Legal Theory and the Secretary of the Australasian Society of Legal Philosophy. Arie holds a BA/LLB from Tel Aviv University, and an LLM and a JSD from New York University. Arie researches in the fields of general jurisprudence, political theory, and theory of private law. His published work covers questions relating to the concept and the nature of law, the theory of authority, statutory interpretation, economic liberty, and the relations between democracy and private law.

Contact: Dr Arie Rosen, a.rosen@auckland.ac.nz

Family Law

Professor Mark Henaghan is the Co Director of the PhD program at the Auckland University Law Faculty. Professor Henaghan is a Fellow of the Royal Society of New Zealand for the excellence of his research in the humanities. He is a Fellow of the International Academy of Family Lawyers which connects the leading Family Lawyers from around the world.

Professor Henaghan specialises in all aspects of Family Law including children's rights, parents, grandparents and wider family rights and duties, divorce, family violence, financial and property family disputes, adoption and surrogacy, child abuse, international child abduction, international adoption. Professor Henaghan also has research interests in the legal and ethical implications of the discovery of the Human Genome as well as how Judges should play their roles as decision-makers. Professor Henaghan is an experienced PhD supervisor who has supervised a number of PhDs from around the world.

Contact: Professor Mark Henaghan, mark.henaghan@auckland.ac.nz

Tax Law

Professor Craig Elliffe specialises in taxation law. Craig was appointed to a chair after 14 years as a tax partner at KPMG and nine years as a tax partner at Chapman Tripp. Craig's research areas are in the field of international tax, corporate tax and tax avoidance. He is the author of International and Cross-Border Taxation in New Zealand (Thomson Reuters), which was awarded the JF Northey best law book award in 2015, and Dividend Imputation: Practice and Procedure (Lexis). His latest book, Taxation of the Digital Economy: Theory, Policy and Practice, was published by Cambridge University Press in 2021. He was a member of the Permanent Scientific Committee of the International Fiscal Association (2011-2018) and a member of the New Zealand Government's Tax Working Group (2018/19). Craig is an experienced PhD supervisor, who has supervised local and overseas candidates.

Contact: Professor Craig Elliffe, c.elliffe@auckland.ac.nz

International/Economic Law

Dr An Hertogen is a senior lecturer at the University of Auckland Faculty of Law, where she completed her PhD in 2012. She also holds an undergraduate law degree from the KU Leuven in Belgium, and an LLM from Columbia University.

Her research interests are in international law and international economic law. She is particularly interested in questions on the allocation of domestic jurisdiction in relation to the regulation of economic issues.

Contact: Dr An Hertogen, an.hertogen@auckland.ac.nz

Faculty of Medical and Health Sciences

Research in plasticity in the brain and peripheral nervous system

The Montgomery Lab at The University of Auckland is focused on examining how plasticity can underpin different neurological and cardiovascular disorders, and also how it can be applied to develop treatments for these disorders. We are part of the Department of Physiology and the Centre for Brain Research.

PhD projects available in 2022 will utilise electrophysiology, imaging, and behavioural techniques to examine plasticity in the brain or in the innervation of the heart. Projects include:

1. Examining dietary zinc treatment in Autism in human stem cells
2. Examining neuron physiology in the heart and how they cause arrhythmia

Contact: Associate Professor Johanna Montgomery, jm.montgomery@auckland.ac.nz

Development of vaccines against gonococcus using the PilVax platform

Neisseria gonorrhoeae (gonococcus) is a Gram-negative bacterium that causes gonorrhoea in humans after colonising genital, rectal and oral mucosa. Gonorrhoea is the second most common sexually transmitted infection (STI) and generally manifests as urethritis or cervicitis. *N. gonorrhoeae* has evolved many different resistance determinants to prevent the activity of all major classes of antibiotics 1 and The World Health Organisation (WHO) has declared the development of effective treatments against this bacterium a global priority 2, 3. One of the remaining strategies to tackle antibiotic-resistant *N. gonorrhoeae* is the development of an effective vaccine.

PilVax is a novel peptide delivery platform utilising the pilus structure from serotype M1 (PilM1) Group A Streptococcus (GAS) to stabilise and amplify peptides, and present them on the surface of the food-grade bacterium *Lactococcus lactis* 4,5, a common surrogate for the generation of live mucosal vaccines 6.

The ultimate goal of this project is to investigate the potential application of the novel PilVax platform to develop vaccines against gonorrhoea. As *N. gonorrhoeae* colonises the genital, rectal and oral mucosa, we believe that a mucosal vaccine might be able to interfere with the early steps in gonococcal pathogenesis. We will focus on several newly identified and promising vaccine targets that are suitable candidates for integration into the PilVax platform.

Contact: Professor Thomas Proft, t.proft@auckland.ac.nz & Dr Catherine Tsai, j.tsai@auckland.ac.nz

Artificial Intelligence Enabled IVF

Applications are invited for a PhD scholarship opportunity on exploring ways to improve in-vitro fertilization (IVF) through a combination of computer vision based and machine learning techniques. This scholarship is part of a research project–Improving IVF success rates through machine learning–supported by the MBIE smart ideas grant.

The primary purpose of the position is to undertake research activities as required to advance understanding of what factors influence successful IVF procedures. The project will leverage millions of embryo images along with a deep clinical information plus next-gen sequencing data to arrive at potential solutions. This inter-disciplinary project has scope to incorporate bioinformatics, computer vision, machine learning and clinical diagnostic development. Successful applicants will have a strong programming base and be motivated to help improve fertility rates.

Essential knowledge and skills include:

• Expertise in computer science, ideally CV models based on single shot detectors or Feature Pyramid Networks (FPN)

• Expertise in quantitative and qualitative data analysis

• Excellent written and verbal communication skills across a range of technical and non-technical personnel.

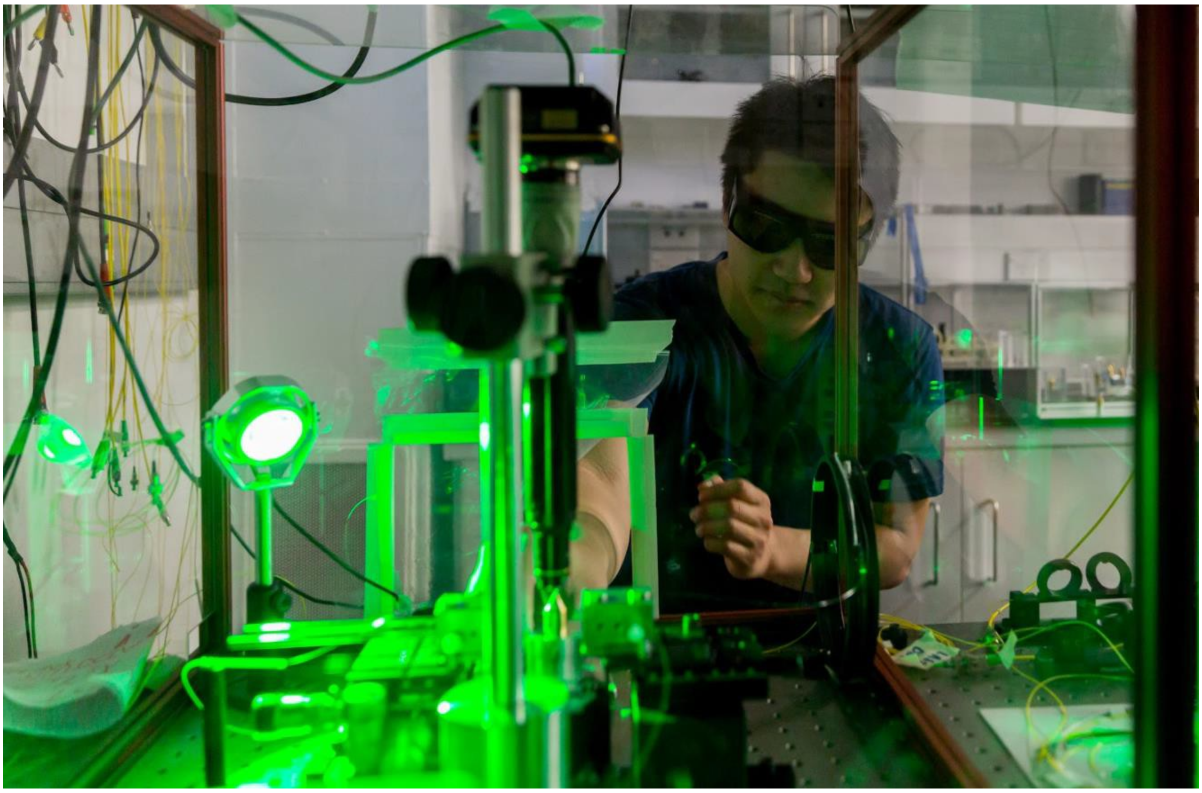
• A qualification in computer science or related computational discipline such as information systems, statistics, or computer engineering to meet the eligibility criteria for entry into the PhD programme for the University of Auckland.

• Strong interest in health and using computer science to enhance health outcomes, in particular sub-fertile couples.

Application documents required: CV, transcripts of previous degrees, two references of character

Contact: Dr Nicholas Knowlton, n.knowlton@auckland.ac.nz

Faculty of Science



School of Chemical Sciences

Peptide Stapling to Selectively Target Biomolecules to Improve Therapeutic Performance

Stapled peptides are an emerging class of therapeutics that bridge the gap between small molecule drugs and biologicals (e.g. monoclonal antibodies - Herceptin), allowing one to target protein-protein interactions (PPIs) once considered “undruggable”. Stapled α-helical peptides can mimic and block these crucial interactions occurring both within and on the surface of cells, covering larger binding surface areas than is typically possible with conventional small molecule drugs. As such, stapled peptides are expected to provide medicinal chemists access to countless new therapeutic targets in treatment of cancers, metabolic disorders (e.g. diabetes) and infectious disease (e.g. SARS-CoV-2). Using modern organic synthesis techniques, linear peptides can be “stapled” to improve their α-helical secondary structure and biological

activity properties. Stapled peptides benefit from enhanced receptor affinity and selectivity, improved membrane permeability (accessing intracellular targets) and increased half-lives in body.
The successful candidate will apply modern synthetic organic chemistry, developing new and improved stapling methodology to apply this towards medicinal targets which may include cancer treatments, combatting antibiotic resistance or anti-viral drugs.
(Not suitable for an off-shore start).
Supervisors:
Distinguished Professor Dame Margaret Brimble, m.brimble@auckland.ac.nz
Assoc. Prof. Paul Harris, paul.harris@auckland.ac.nz Dr Alan Cameron, alan.cameron@auckland.ac.nz
Dr Freda Li, freda.li@auckland.ac.nz

Synthesis of New Generation Lipopeptide-based Antibiotics

Antibiotic resistance has been recognised by the WHO as one of the greatest threats to humanity and infectious diseases rank as the second most common cause of death worldwide. New antibiotics are desperately needed!
Cyclic lipopeptides are an emerging subset of peptide-based antibiotics (e.g. daptomycin and polymyxin) containing a lipid or fatty acid. They have been shown to possess clinical efficacy and are used as the "last line of defence" against otherwise untreatable bacterial infections. Despite their promise, undesired toxicity is often a significant drawback of these antibiotics.
Our lab is developing novel, non-toxic derivatives of naturally occurring lipopeptide antibiotics by modifying the chemistry of the lipid tail and hydrophobic groups. The challenge remains, however, to efficiently produce new antibiotics based on a cyclic peptide scaffold incorporating the crucial lipid motif. Using our "in-house" methods to install lipids onto peptides this project aims conduct an SAR study by generating a synthetic chemical library of analogues of natural lipopeptide antibiotics. Novel antibiotic analogues will

undergo biological testing against multi-drug resistant (MRD) strains of bacteria and evaluation of potential toxicity to probe the SAR and establish their therapeutic potential.
Successful candidates will use organic synthesis techniques and modern methods of solid phase peptide synthesis. Candidates will also have the opportunity to undertake and learn biological assays if they desire.
(Not suitable for an off-shore start)

Supervisors:
Distinguished Professor Dame Margaret Brimble,
m.brimble@auckland.ac.nz
Assoc. Prof. Paul Harris, paul.harris@auckland.ac.nz Dr
Alan Cameron, alan.cameron@auckland.ac.nz

Natural Product Cytotoxic Payloads for Antibody–Drug Conjugates

Antibody-drug conjugates (ADCs) are a clinically proven class of medicines used in the treatment of various cancers. Utilisation of the exquisite selectivity of antibody targeting to cancer epitopes coupled to delivery of highly potent small molecules is revolutionising modern oncology. Given the modular nature of the ADC design concept, the future potential of this field is truly vast, and will rely on the discovery of i) new antibody-antigen couples, ii) novel linker chemistries and iii) the discovery of highly potent cytotoxins for conjugation.
Critically, the availability of suitably potent, stable cytotoxic agents is considered rate-limiting for progress in this field. Cytotoxic peptide natural products provide a rich source of anticancer agents that can be readily appended to antibodies using amino acid-based conjugation technology.
This research project provides a unique opportunity to develop a novel class of cytotoxin with optimal properties for use in ADCs. The student undertaking this project will be involved in modern solid-phase peptide synthesis, HPLC purification and compound characterisation using related spectroscopic techniques.
(Not suitable for an off-shore start)

Supervisors:
Distinguished Professor Dame Margaret Brimble, m.brimble@auckland.ac.nz
Assoc. Prof. Paul Harris, paul.harris@auckland.ac.nz Dr Iman Kavianinia, i.kavianinia@auckland.ac.nz

Linker Design for Antibody-Drug Conjugates

Antibody-drug conjugates (ADCs) are a clinically proven class of medicines used in the treatment of various cancers. The ADCs utilise monoclonal antibodies (mAbs) to specifically bind to the corresponding antigens present on the surface of cancer cells. This selective binding minimises the systemic toxicity associated with the anti-cancer treatment and significantly increases the pharmacological activity of the conjugated cytotoxin. The three main components of ADCs are the desirable monoclonal antibody, an appropriate linker and an active cytotoxic drug. Linkers designed to be cleaved under specific cellular conditions include acid-labile hydrazone linkers sensitive to the low-pH conditions in the endosome and lysosome, disulfide-based linkers that can be reduced by the high (millimolar) levels of reduced glutathione in the cell cytosol compared to serum, or dipeptide linkers cleaved by specific lysosomal proteases. Despite considerable effort undertaken to design a stable linker between the antibody and cytotoxic agent, systemic toxicity is observed in several ADCs in clinical development. Therefore, interest in designing a suitable chemical linker that helps the antibody to deliver the cytotoxic agent specifically to cancer cell has become an important target for scientists involved in the development of novel antibody-drug conjugates.

The proposed research aims to generate a new class cleavable linkers that can facilitate efficient release of the cytotoxic agent at a targeted tumor site.

(Not suitable for an off-shore start)

Supervisors:
Distinguished Professor Dame Margaret Brimble, m.brimble@auckland.ac.nz
Assoc. Prof. Paul Harris, paul.harris@auckland.ac.nz Dr Iman Kavianinia, i.kavianinia@auckland.ac.nz

Virus Activated Cancer Prodrugs

Oncolytic viruses are an emerging class of therapeutics for cancer treatment. Importantly, these viruses selectively infect and lyse cancerous cells and their genomes do not integrate with the host's genetic material. Furthermore, viral infection of the tumour can reactivate the patient's immune response to the tumour, transforming it from 'cold' to 'warm'. However, these therapies still suffer from certain limitations, perhaps the greatest of which is antiviral immunity, e.g. patient immune system clearance of the virus prior to complete tumour destruction. To elicit maximal efficacy, these viruses can be used in combination with chemotherapeutics or radiotherapy. The presence of viral infection on the tumour microenvironment not only stimulates the patient immune response to the tumour, but further differentiates the cancerous tissues from healthy tissue, providing novel opportunities for selectively targeted chemotherapeutics. Common amongst antibody targeted, or prodrug chemotherapeutics, is the concept of exploiting enzymes (e.g. cathepsins), that are upregulated in the cancerous tissue, to release the active cytotoxic payload. However, infection with an oncolytic virus offers opportunities for greater selectivity through entirely unique features of the virus not found elsewhere in the body (e.g. viral proteases). This project seeks to develop a novel Virus-Directed Enzyme Prodrug Therapy (VDEPT). Novel cytotoxic payloads will be developed and conjugated to an inactivating peptide sequence that is selectively cleaved by the protease of a promising oncolytic virus to release the active cytotoxin selectively in the tumour microenvironment. Thus, the project seeks to develop a novel prodrug and combination therapy. A key aspect of the research will be optimising the self-immolating cleavable linker system for a favourable rate of payload release. The successful candidate will develop skills in modern organic chemical synthesis, Solid Phase Peptide Synthesis (SPPS), reverse phase-HPLC and may also have the opportunity to conduct enzymatic assays and tissue culture experiments. (Not suitable for an off-shore start)

Supervisors:

Distinguished Professor Dame Margaret Brimble, m.brimble@auckland.ac.nz
Assoc. Prof. Paul Harris, paul.harris@auckland.ac.nz **Dr Alan Cameron,** alan.cameron@auckland.ac.nz
Dr Iman Kavianinia, i.kavianinia@auckland.ac.nz

Total Chemical Synthesis of Novel Antimicrobial Peptides

Despite being somewhat overshadowed recently by the global COVID-19 pandemic, antimicrobial resistance (AMR) remains another ongoing global health crisis. The World Health Organization (WHO) reported that AMR infections result in more than 35,000 deaths annually in the US alone.

The existing clinical pipeline has thus far failed to effectively address increasing rates of AMR infections. Accordingly, developing novel antimicrobial agents into potential drug candidates is of paramount importance. This research aims to undertake the total chemical synthesis of promising and novel antimicrobial peptides (AMPs), that are isolated as secondary metabolites from microorganisms, similar to malacidin A, isolated from a soil bacterium. These exciting new AMPs often possess cyclic scaffolds rich in non-proteinogenic amino acids and bear unsaturated lipid moieties or ester linkages. This combination of factors makes these molecules complex and challenging targets for total chemical synthesis, an essential step in both verifying their chemical structure and establishing a synthetic route; critical for further development of these important molecules towards combatting AMR infections. The prospective student will undertake a variety of modern peptide synthesis techniques, including solid-phase peptide synthesis (SPPS), learn a variety of instrument skills, including but not limited to; use of automated peptide synthesizers, RP-HPLC, ESI-MS and NMR. The project may also include asymmetric synthesis of appropriately protected non-proteinogenic amino acids.

(Not suitable for an off-shore start)

Supervisors:

Distinguished Professor Dame Margaret Brimble, m.brimble@auckland.ac.nz

Assoc. Prof. Paul Harris, paul.harris@auckland.ac.nz

Dr Alan Cameron, alan.cameron@auckland.ac.nz

Dr Freda Li, freda.li@auckland.ac.nz

Investigating the surface chemistry and wettability/drop impact properties of NZ flora – are these native plants unique and what can they tell us?

The study of native NZ plant leaves to understand the features that result in the hydrophobicity of leaves could lead to understanding of critical features of water-repellent surfaces and therefore aid in the design of these surfaces and materials. One of the key ways to identify these critical features is to relate surface chemistry and surface wettability/drop impact properties of leaves by measuring these attributes, defining models that represent these relationships for use in the development of leaf-inspired water repellent surfaces. Furthermore, investigating native NZ plants provides an excellent opportunity to study and compare natural leaf surfaces that have evolved separately and in a geographically-isolated region compared to other non-native plant species such as distinctive plants of Chinese origin.

(Suitable for an off-shore start for the first couple of months for literature search, experimental design, etc. but afterwards lab work would require the student to be on-site at UoA).

Supervisors:
Dr Lisa Pilkington, lisa.pilkington@auckland.ac.nz
Assoc. Prof. Geoff Wilmott, g.willmott@auckland.ac.nz

Analysis of plant-based "milks"

Alternative products to mammalian milks are currently on the rise in popularity and consumption. Furthermore, there is the belief that plant-based "milks" could offer a more sustainable source of nutrition in the future. This project will be based upon the investigation of a range of plant-based "milks" to analyse their chemical composition using a range of analytical methods, particularly FTIR, NMR and HPLC. This analysis and the research in this project will ultimately provide valuable information and insight into the chemistry behind this ever-increasing consumable sector.
(Suitable for an off-shore start for the first couple of months for literature search, experimental design, etc. but afterwards lab work would require the student to be on-site at UoA).
Supervisor: Dr Lisa Pilkington, lisa.pilkington@auckland.ac.nz

Development of smart wound-healing devices

Chronic wounds that remain unhealed for months or even years are extremely burdensome on the individual and their families, affecting quality of life, and the healthcare system. Recently, we have developed the basis of a technology that can release wound-healing agents in a controlled manner, allowing promotion of growth and healing of the wound. This project will be based upon the further development and optimisation of these materials. This will involve the synthesis and characterisation of these materials, followed by testing of their performance and subsequent research to improve their capabilities. The research in this project is targeted toward the generation of a technology that could be revolutionary in wound-healing platforms.
(Suitable for an off-shore start for the first couple of months for literature search, experimental design, etc. but afterwards lab work would require the student to be

on-site at UoA).
Supervisors:
Dr Lisa Pilkington, lisa.pilkington@auckland.ac.nz
Professor Jadranka Travas-Sejdic, j.travas-sejdic@auckland.ac.nz
Dr Ali Akbarinejad, aakb405@aucklanduni.ac.nz

Development of QSAR-Software for Drug Development and Design

One of the most important goals in drug development is to establish a quantitative structure-activity relationship (QSAR) between the structure of a compound and its biological activity. Current strategies to generate QSARs are often simple and fail to adequately account for the complex interaction between structural features. This project aims to create an R-based lead-optimisation QSAR-development statistical software package that will be the definitive tool for medicinal chemistry lead-optimisation projects, thereby having far-reaching usage and applicability. This package will involve the use of a range of machine learning techniques to best model the QSAR of a class of bioactive compounds in order to direct future analogues in the process of drug development and class optimisation. Students wishing to undertake this project should have an understanding of how to use and operate the statistical software, R.
(Suitable for an off-shore start)
Supervisor: Dr Lisa Pilkington, lisa.pilkington@auckland.ac.nz

Narrowing the gap between calculations and experiments in the electrochemical CO2 reduction reaction

Rational catalyst design is arguably the ultimate goal in heterogeneous catalysis research. In the last few decades, new computational methods have been developed to further our understanding of the catalytic performance of heterogeneous catalysts, which makes it possible to do a priori catalyst design using high-performance computing resources. However, there is still a large disagreement between theoretical prediction and experimental performance to truly revolutionise the chemical industry. The disagreement is mainly caused by the differences between the predicted catalyst structures from computational chemistry and the synthesised catalyst in the actual experiment. Understanding these false-positive predictions by collaborating with experiment scientist is necessary to refine the current computational chemistry framework and improvement the prediction accuracy.

In this project, the student will learn how to develop a high-throughput catalyst design method using the descriptor-based design framework and machine learning algorithm under the supervision of Dr Ziyun Wang. The adsorption energy of intermediate states will be used as the descriptor, and the catalyst structure with the optimal adsorption energy will be chosen as potential candidates for experimental screening, carried out by the experiment collaborators. The student will analyse the catalytic performance and theoretical calculation to deduce any structure-to-properties relationship. Further iterations will be performed to design a final catalyst with superior performance. The CO2 electrochemical reduction reaction (CO2RR) will be used as a model reaction in this project due to its significant technological importance.

(The project is a pure computational chemistry project and suitable for an off-shore start. 1. The student can access the supercomputer in China to carry out the calculations and coding. 2. Dr Wang will arrange weekly meetings via ZOOM or VooV to ensure the progress of the project. 3. The experiment collaborators in this project are likely to be Prof. Yadong Li and Prof. Dingsheng Wang at Tsinghua University. Dr Ziyun Wang have been actively collaborated with Prof. Li and Prof. Wang (Chem, 2020, 6, 725; JACS, 2018, 140, 11161; Angew. Chem. Int. Ed., 2018, 57, 11262) and the student will have the opportunity to visit Tsinghua University while waiting for the border rule change.)

Supervisor: Dr Ziyun Wang, ziyun.wang@auckland.ac.nz

Metal-based Anticancer Agents: Design, Preparation and Analysis of the Modes of Action of Bioorganometallic Chemotherapeutics

More than 50% of cancer patients receive platinum-based chemotherapeutics, and many more inorganic compounds are widely used in the diagnosis and treatment of other diseases. This is owed to their specific properties such as tunable ligand exchange reactions, redox activity, unpaired electrons, and/or radioactivity. Bioorganometallic chemistry, i.e. the chemistry of compounds featuring at least one metal-carbon bond, is a thriving field of research and in particular the development of anticancer drugs based on organometallic moieties has received a lot of attention in recent years. While the modes of action of anticancer metallodrugs are crucially dependent on their interactions with biological molecules, we often lack an understanding of the targets and how the complexes are metabolized in biological environment.

My group designs, synthesizes and studies new anticancer agents, often with bioactive co-ligands, and we develop analysis methods using high-end instrumentation to investigate their modes of action. We have several projects available in this area for students with interest in synthetic and/or analytical chemistry and who have an interest in the drug development process in general.

Hartinger et al., Angew. Chem. 2020, 59(34), 14609

(Suitable for an off-shore start for the first couple of months for literature search, compound design, etc. but afterwards lab work would require the student to be in Auckland).

Supervisor: Professor Christian Hartinger: c.hartinger@auckland.ac.nz

School of Chemical Sciences and Department of Physics

Nanoaspiration: Using Pipettes for Nanomechanical Measurements

Scientists from many disciplines are currently striving to understand the vast biological (and technological) importance of subcellular-sized particles: from protein complexes to exosomes, from food emulsions to cancer drug delivery particles. There is a particular opportunity for a project focussing on nanoaspiration, in which a pipette is used to probe the mechanical and interfacial properties of soft colloidal nanoparticles. Microaspiration is used to probe the mechanical properties of cells; we are extending this technique to smaller length scales, with ionic currents as a key data source. The project could focus either on experimental aspects, including surface modification of the pipettes, or theory and modelling of the deformations and ionic currents. The work aligns with the MacDiarmid Institute for Advanced Materials and Nanotechnology, which is developing a range of nanomechanics capability. Applicants will require a strong background in a physical sciences discipline and good command of English. Experience with electrochemistry or fluidics (for experiments), or with physics modelling (e.g. COMSOL) would be an advantage but is not necessary. The student will be trained in relevant research techniques.

International travel for conferences and to work with collaborators in Australia and the UK will be available as appropriate.

(Suitable for an off-shore start) **Supervisor:**
Assoc. Prof. Geoff Willmott,
g.willmott@auckland.ac.nz

Collective Dynamics of Janus Spheres

This project will use experiments and/or theory to study the dynamics of two or more interacting Janus spheres, and especially to study how they come together to form interesting out-of-equilibrium phases. Janus spheres are micro- and nanoscale colloids which have some asymmetry in their physical and/or chemical properties. Commonly, the sphere's two hemispheres have different surface chemistries, e.g. hydrophilic and hydrophobic. Asymmetric particles (such as Janus spheres) are increasingly of interest because of their bioinspired possible uses as building blocks for new self-assembled and even reconfigurable materials.

In experimental work, we are interested in observing Janus colloids as they are brought together in a microfluidic system. In theoretical work, we hope to model such processes and explain the resulting phases. The work is affiliated with the MacDiarmid Institute for Advanced Materials and Nanotechnology. Applicants will require a strong background in a physical sciences discipline and good command of English. Experience with microfabrication or fluidics (for experiments), or in relevant physical research (e.g. statistical mechanics, molecular dynamics) would be an advantage but is not necessary. The student will be trained in relevant research techniques. International travel for conferences and to work with collaborators will be available as appropriate.
(Suitable for an off-shore start)
Supervisor: Assoc. Prof. Geoff Willmott, Email:
g.willmott@auckland.ac.nz

Dynamic Microfluidics

The beautiful and complex drop impact phenomenon has fascinated scientists for over 100 years. Its importance is instantly familiar to us from raindrops, sprinklers, sprays, ink-jets, painting, and so on. However, it is only due to recent advances in microfabrication and high-speed imaging that we can understand drop impacts on the rough and structured solid surfaces commonly encountered in everyday life. This project will use high-speed imaging to study drops falling on to interesting surfaces, such as extremely water-repellent ('superhydrophobic') surfaces, which generate particularly rich and complex bouncing and splashing phenomena. Water is always of interest, but the group is also studying non-Newtonian fluids (such as milk) and ferrofluids which generate instabilities in magnetic fields. The project is based in the Dynamic Microfluidics Laboratory at Auckland and affiliated with the MacDiarmid Institute for Advanced Materials and Nanotechnology.
Applicants will require a strong background in a physical sciences discipline and good command of English. Experimental experience with fluidics and/or microfabrication would be an advantage (but is not necessary). The student will be trained in research techniques which enable them to make and characterise surfaces, design and execute experiments and analyse and interpret their data. International travel for conferences and collaborations will be available as appropriate.
(Not suitable for an off-shore start)
Supervisor: Assoc. Prof. Geoff Willmott,
g.willmott@auckland.ac.nz

School of Computer Science

Data-quality driven database design

Database design aims at organizing data and its relationships in order to process data efficiently. Traditional database design only addresses the integrity of data. The goal of this project is to develop a mathematically rigorous and robust framework to incorporate other data quality dimensions into the design of databases. If successful, data will be fit for purpose by design and therefore form the foundation for deriving meaningful insight from higher quality data that is trusted. Candidates should have a strong background in discrete mathematics, in particular logic and complexity theory, but also a drive to apply this background to data and develop tools that bring new theories to life. It is expected that this research will lead to outputs in the leading database conferences and journals, such as ICDE, VLDB, SIGMOD, ACM Transactions on Database Systems, IEEE Transactions on Knowledge and Data Engineering, and The VLDB Journal.

Previous work of the supervisor on this subject includes:

Ziheng Wei, Sebastian Link: Embedded Functional Dependencies and Data-completeness Tailored Database Design. ACM Trans. Database Syst. 46(2): 7:1-7:46 (2021)

Sebastian Link, Ziheng Wei: Logical Schema Design that Quantifies Update Inefficiency and Join Efficiency. SIGMOD Conference 2021: 1169- 1181

Henning Köhler, Sebastian Link: SQL Schema Design: Foundations, Normal Forms, and Normalization. SIGMOD Conference 2016: 267-279 (Suitable for an off-shore start)

Supervisor: Professor Sebastian Link, s.link@auckland.ac.nz

Data profiling and sampling

Data profiling refers to activities that derive meta-data from given data sets. In this project, we are interested in developing efficient algorithms for the discovery of advanced classes of database constraints from given data sets. The application of the discovered constraints in data cleaning, integration, and schema design will also be investigated. Sampling approaches that help with the identification of constraints that are meaningful for underlying application domains will be combined with the discovery process. If successful, sound foundations for automating important tasks in data preparation will be established. This can save considerable resources in any data science projects. Candidates should have a strong background in discrete mathematics, in particular logic and complexity theory, but also a drive to apply this background to data and develop tools that bring new theories to life. It is expected that this research will lead to outputs in the leading database conferences and journals, such as ICDE, VLDB, SIGMOD, ACM Transactions on Database Systems, IEEE Transactions on Knowledge and Data Engineering, and The VLDB Journal.

Ziheng Wei, Sven Hartmann, Sebastian Link: Algorithms for the Discovery of Embedded Functional Dependencies, The VLDB Journal, https://doi.org/10.1007/s00778-021-00684-3, 2021.

Henning Koehler and Sebastian Link: Possibilistic Data Cleaning, IEEE Transactions on Knowledge and Data Engineering, http://doi.org/10.1109/TKDE.2021.3062318, 2021

Ziheng Wei, Uwe Leck, Sebastian Link: Discovery and Ranking of Embedded Uniqueness Constraints. Proc. VLDB Endow. 12(13): 2339- 2352 (2019)

(Suitable for an off-shore start)

Supervisor: Professor Sebastian Link, s.link@auckland.ac.nz

Investigation of Computational Architecture for Edge AI

Edge Artificial Intelligence is a system that uses Machine Learning algorithms to process data generated by a hardware device without the connection of the Internet. A complete processing toolkit that allows on- device inference is highly desirable. It allows us to build products that are efficient, private, fast and offline. Computer architecture for Edge Artificial Intelligence has become a popular research topic.

In this project, we explore the solution to the computer architecture for Edge Artificial Intelligence. The proposed solution can be categorized into three methodologies. First, we will apply Processing-in-Memory (PIM) techniques as it has been explored as a promising solution to tackle the data movement challenge in various applications. Second, we will apply a well-designed Non-blocking Network switch to connect the PIM blocks to reduce the latency and logic complexity for data movement. Third, we will design a compiler to capture the characteristics of the neural network model. The compiler can produce a sequence of micro-instructions to control the data movement and operations of PIM blocks.

Recently, the popular machine learning frameworks heavily rely on a variety of dedicated hardware implementations for their neural network operations. In contrast to conventional computing applications, the computational and memory resources of these neural network applications are mixed. The mixing

of the computational and memory resources results in a significant amount of data movement. A well-designed Processing-in-Memory (PIM) architecture can prevent this memory bottleneck by providing fast near-data processing. By studying the characteristics of neural network models, we can determine the most appropriate size of memory for each PIM block. To provide an energy-efficient computation, the processing unit will employ fixed-point arithmetic. The batch normalization will be applied to reduce the loss of accuracy.
We can apply a non-blocking network switch to connect the PIM blocks. A non-blocking network switch is a design of crossbar switch to allow the connection between N inputs and N outputs in any permutations at various moments. By applying a non-blocking network such as the Benes network, we can achieve the maximum flexibility of data movement between the PIM blocks. However, only a subset of complete permutations is required for most popular neural networking models. A sub-optimal non-blocking network will be explored. By applying a simplified non-blocking network, the PIM architecture can still accommodate the data movement for most neural network models and this can reduce the reduce latency and logic complexity of the crossbar switch for the non-blocking network. (Suitable for an off-shore start)

Supervisor: Dr Chiu-Wing Sham, b.sham@auckland.ac.nz

Accelerating Chip Design with Machine Learning

Chip floorplanning plays an important role in the physical design of very large scale integration circuits. It plans the shapes and locations of the modules on a chip. It generates the physical layout of a computer chip, the result of which will greatly affect the overall performance of the final circuit. Chip floorplanning is a very time-consuming task and it takes a very long time (up-to a few months) to produce a produce manufacturable layouts.
In this project, the student is going devise a reinforcement learning model to carry out the chip floorplanning process including place-and-route and timing and physical signoff analysis. The proposed method is believed to be used to design the next generation of artificial intelligence (AI) accelerators. The more powerful AI-designed hardware will fuel advances in AI. This creates symbiotic relationship between the two fields. (Suitable for an off-shore start)

Supervisor: Dr Chiu-Wing Sham, Email: b.sham@auckland.ac.nz

Mathematical and algorithmic challenges in phylogenetics

How did HIV evolve? Which vaccine will best protect against next season's flu? To answer these and other questions in the study of evolution, phylogenetic trees and networks play a crucial role. Phylogenetic networks are leaf-labelled rooted acyclic digraphs that are used to represent the evolutionary history of a set of present-day species. To accurately reconstruct phylogenetic networks, a deep understanding of their underlying mathematical structure is necessary. The goal of this project is to develop new theory and algorithms to unravel complex ancestral relationships between species without compromising accuracy.
Of particular interest is the development of new parameterized and approximation algorithms to tackle some unanswered questions in the reconstruction and comparison of phylogenetic networks. Candidates are expected to have a strong background in graph theory or theoretical computer science.
(off-shore start is feasible, but needs to be discussed with the potential student)
Supervisor: Dr Simone Linz, s.linz@auckland.ac.nz

Applications of quantum annealing in computational biology

Phylogenetic (evolutionary) trees are widely used by biologists to represent ancestral relationships between species. Due to non-treelike events such as hybridization and horizontal gene transfer that cannot be captured by a single phylogenetic tree, the representation of evolution is now being generalized to phylogenetic networks which are leaf-labeled directed acyclic graphs. However, in contrast to algorithms for phylogenetic trees, many of the algorithms that are currently being used to reconstruct and analyse phylogenetic networks do not scale up well to large data sets. The purpose of this project is to develop new algorithms to reconstruct phylogenetic networks by using quantum annealing (implemented by the Advantage D-Wave machine). This model of quantum computing can solve native optimization problems and is well suited for this project. The project combines the development of the model, the proof of correctness and experimental testing on Advantage
D-Wave. Candidates are expected to have a strong background in discrete mathematics and/or theoretical computer science. Knowledge in biology is not required.

(An off-shore start is feasible, but needs to be discussed with the potential student)
Supervisors:
Professor Cristian S. Calude, Email: cristian@cs.auckland.ac.nz Dr Michael J. Dinneen, Email: mjd@cs.auckland.ac.nz
Dr Simone Linz, Email: s.linz@auckland.ac.nz

Early Screening for Dementia Disorders using Virtual Reality

Early and frequent screening for dementia disorders such as Parkinson's and Alzheimer's is important, but standard testing methods are impractical for this. Digital methods offer several advantages such as being more engaging, nonobtrusive, and more enjoyable. Virtual Reality allows testing to be done in scenarios that better mimic the real world, improving ecological validity. This project will involve designing non- obtrusive digital versions of standard cognitive tests, implementing them, and testing their validity in a Virtual Reality environment. The focus will be on immersive virtual reality using technologies such as the Oculus Rift or HTC Vive head-mounted-displays.
(Suitable for an off-shore start)
Supervisors:
Dr Burkhard Wuensche, Email: burkhard@cs.auckland.ac.nz
Dr Alex Shaw, Email: l.shaw@auckland.ac.nz

A Gamified Virtual Reality Tutor for Training Spatial Reasoning Skills

Spatial skills are a significant predictor of achievement in STEM subjects (Science, Technology, Engineering, and Mathematics). In contrast to many other cognitive abilities, spatial skills can be trained. However, it is unclear how to make training effective and enjoyable for a wide range of users. In this research, we will develop and evaluate a VR training tool for spatial skills, which will be based on recent research in pedagogy and neuroscience. In order to make the application engaging, it will contain gamification elements.
(Suitable for an off-shore start)
Supervisors:
Dr Burkhard Wuensche, burkhard@cs.auckland.ac.nz Dr Paul Denny, paul@cs.auckland.ac.nz

AR/VR Embodied Spatial Training

Spatial skills are a significant predictor of achievement in STEM subjects (Science, Technology, Engineering, and Mathematics). In contrast to many other cognitive abilities, spatial skills can be trained. In this project we will investigate how spatial reasoning skills can be trained in AR/VR by physically interacting with virtual or augmented objects, and whether training effects are improved when using physical motions (e.g. hand gestures) rather than mouse interactions. In addition, we also want to investigate the role of haptic feedback on spatial training in an AV/AR environment.

(Suitable for an off-shore start)

Supervisors:

Dr Burkhard Wuensche, burkhard@cs.auckland.ac.nz Dr Danielle Lottridge, d.lottridge@auckland.ac.nz

Automatic Generation of Formative Feedback for Computer Graphics Programming Assignments

Teaching and learning computer graphics is often considered challenging due to it requiring a diverse range of skills such as mathematics, programming, problem solving, and art and design. Assignments are a popular tool to support learning and to assess students' understanding. The value of such assignments depends on the ability to give fast (and ideally formative) feedback, and enabling students to interactively explore the solution space. This is often a problem, in particular for large classes, where assignment marking can take many days or even weeks. By the time feedback is received students often don't remember details, and there is usually no opportunity to resubmit and hence little motivation to reflect on and correct mistakes.

In previous research we developed CodeRunnerGL, a tool for automatic assessment of OpenGL programming questions. The tool has been used in a class of about 300 students for several years now and students perceive the tool as having significantly improved their learning.

In the proposed research we will extend CodeRunnerGL to automatically produce formative feedback. This means, if a student solution is incorrect the tool should provide feedback where the error is and it should give hints how the error could be resolved (without displaying the correct solution).

(Suitable for an off-shore start)

Supervisor: Dr Burkhard Wuensche, burkhard@cs.auckland.ac.nz

Scalable machine learning with locality sensitive hashing

Locality-sensitive hashing (LSH) is a primary algorithmic tool for many computer science applications in high dimensions. It has been shown that LSH can significantly reduce the complexity of many machine learning models, including Support Vector Machine, Nearest Neighbor Search, Deep Learning… The project will exploit recent development of LSH to further advance well-known machine learning algorithms on large-scale data sets.
Prerequisites: Experience with high-performance programming in C/C++, Python, Matlab (Suitable for an off-shore start)
Supervisor: Dr Ninh Pham, ninh.pham@auckland.ac.nz

Exploring Embodiment in Immersive XR

How can audio-visual effects in virtual and mixed-reality change our sensory perception and physical activity? "Dancing in/Dancing With the Digital" is an interdisciplinary project exploring the alternative sense of embodiment produced by real-time, immersive technologies. Working with partners from the School of Computer Science, the Auckland Bioengineering Institute, and the Dance Studies department, you will have the opportunity to design and co-create immersive experiences that seek to increase creative movement potential and engage multisensory awareness in their audiences, with an aim to better understand human movement and perception in XR realms. Outputs include practical and creative VR/AR prototypes allowing for virtual sensing and moving together.

(Not suitable for offshore start)

Supervisors:

Dr Danielle Lottridge, d.lottridge@auckland.ac.nz

Dr Becca Weber, b.weber@auckland.ac.nz

Department of Exercise Sciences

Biomechanical Simulation for Children with Cerebral Palsy

Cerebral palsy (CP) is a well-recognized neurodevelopmental condition resulting from brain injury, beginning at early childhood and lasting the lifespan. It can lead to progressive and permanent musculoskeletal disorders with the growth in most affected children. Ankle and foot equines is one of the most common deformities among patients with CP and receives a lot of attention from therapists and surgeons. The main purposes of this project include: 1. Using biomechanical principles and methods to improve clinical gait analysis; 2. Using medical images to create patient-specific musculoskeletal models and conduct finite element modelling for surgical outcome prediction.

The applicant(s) must have a masters degree in biomedical engineering, mechanical engineering, sports science, or a related area.

(Suitable for an off-shore start)

Supervisor: Dr Yanxin Zhang, yanxin.zhang@auckland.ac.nz

Development of an intelligent system for automated motor impairment assessment and risk prediction

Clinical assessment is important not only to quantify the severity of motor impairment, but to support the timely adjustment of appropriate clinical interventions. Advances in technology have allowed for valid and reliable measurement of biological signals, which can provide quantitative data that can be used by clinicians for objective decision-making. The project aims to develop an intelligent system for automated motor impairment assessment, which will include a portable motion capture sensor, a biomechanical model, and an expert system based on machining learning algorithms for risk prediction.

The applicant(s) must have a masters degree in biomedical engineering, mechanical engineering, computer science, epidemiology, or a related area.

(Suitable for an off-shore start)

Supervisor: Dr Yanxin Zhang, Email: yanxin.zhang@auckland.ac.nz

Department of Mathematics

Making sense of the complexity of university- level mathematics education and bettering its teaching and learning

University courses in mathematics gained a reputation for being intense and difficult for many students. Large classes, dense curricula, mathematical content that is conveyed in a way that is substantially different from the one that students are familiar with from high school – these and many other factors contribute to the complexity of students' learning of mathematics. This is a large-scale project with multiple components aiming to: understand the complexity of the processes students go through when studying university-level mathematics and explore the impact of innovative learning-and-teaching environments on these processes. PhD students who join this project might be interested in exploring teaching and learning processes that unfold in undergraduate courses in analysis, abstract algebra, combinatorics, graph
theory, game theory, number theory, or topology, possibly with a focus on how undergraduates work with definitions, generate examples, prove, solve and pose problems.

(Suitable for an off-shore start)

Supervisor: Dr Igor' Kontorovich, i.kontorovich@auckland.ac.nz

School and university mathematics education: Students' usage of online forums for mathematics learning

On the one hand, there is multiple evidence of a decline in students' interest in mathematics. On the other hand, there are infinitely many online mathematical forums with rich and insightful discussions, many posts in which are contributed by the school and university students. Some of these discussions are tightly linked to homework assignments that students get in a classroom. Other discussions reflect students' genuine interests in mathematics and a thrive to make sense of it.

Surprisingly, the widespread phenomenon of student (and teachers') usage of open online mathematical forums has not been explored yet. PhD students who join this project might be interested to explore the topics that are discussed in open online mathematical forums while attending to their communicational patterns. It is also important to understand how students make use of such

forums in respect to their school and university studies, and how teachers should account for these usages in their teaching, for instance, when designing homework assignments.
(Suitable for an off-shore start)
Supervisor: Dr Igor' Kontorovich, Email: i.kontorovich@auckland.ac.nz

Various projects in mathematical physiology and dynamical systems

Oscillations and waves in the concentration of free cytosolic calcium are one of the most important intracellular signalling mechanisms, controlling a wide range of cellular functions, including gene expression, cell differentiation, secretion and water transport. However, although they are physiologically important, these periodic phenomena are difficult to study using experimental techniques alone; their complexity is so great that only limited understanding can be gained in the absence of quantitative approaches. Thus, over the past few decades the study of calcium dynamics has developed into an important area of interdisciplinary research.
In collaboration with major international experimental groups in the USA, Japan and Europe, our research group is interested in constructing new mathematical models for calcium oscillations. These models allow us to make predictions that inform and guide further experiments, ultimately leading to a better understanding of the underlying physiology. Members of our research group also work on developing new mathematical ideas useful for the analysis of a wide class of physical and biological models, including our calcium models.
We welcome queries from students with a strong background in mathematics and an interest in cell physiology, although no prior background in physiology is required.
(Suitable for an off-shore start)
Supervisors:
Professor James Sneyd, j.sneyd@auckland.ac.nz
Assoc. Prof. Vivien Kirk, v.kirk@auckland.ac.nz

Post-quantum public-key cryptography

Post-quantum public-key cryptography is one of the hottest topics in mathematical cryptography and Professor Galbraith is a leading researcher in the field. The research group in Auckland is studying the security of post-

quantum cryptosystems, especially those based on isogenies and lattices. We are also designing cryptographic protocols, such as signature schemes, and evaluating the security of systems built from these components. Students can get publications at top rank conferences and journals, and are able to meet other leading experts in the field. There are several PhD projects in this subject for students with a strong background in algebra and number theory. Students will preferably also have some computer programming skills. (Suitable for an off-shore start) **Supervisor:**
Professor Steven Galbraith,
s.galbraith@auckland.ac.nz

Projects on moduli spaces, topological K-theory and geometric correspondences

Mathematics and physics are historically two intimately related fields and they currently share a highly active interface, which extends into completely new areas of both disciplines. Ideas from physics are being channelled into entirely new mathematical identities and structures. Examples include topological recursion, branes in moduli spaces, and invariants in low-dimensional topology obtained from Seiberg-Witten theory.

Dr Hekmati is a leading researcher with an expertise in algebraic topology and differential geometry. There are interesting PhD research problems in these areas, such as enumerative invariants associated to moduli spaces, K-theoretic calculations and geometric correspondences such as T-duality, well-suited for students with a strong background in algebra and geometry. (Suitable for an off-shore start)
Supervisor: Dr Pedram Hekmati, p.hekmati@auckland.ac.nz

Quantum Chaos

Classical chaos theory tells us that there are systems whose long term behaviour is extremely sensitive to initial conditions. However quantum theory tells us that we may never completely determine initial conditions such as position and momentum. One may then ask how can we reconcile these two ideas? What is the quantum analogue of a chaotic system and how does it behave?

Numerical simulations suggest that in some cases “scars” of classical behaviour are visible in such high energy stationary states.

However it is conjectured that in suitably chaotic system such scars never occur and stationary states behave more like random waves. These basic questions give rise to a number of projects at all levels.
(Suitable for an off-shore start)
Supervisor: Dr Melissa Tacy, melissa.tacy@auckland.ac.nz

Semiclassical and harmonic analysis

Harmonic analysis is a general set of tools for analysing functions by decomposing them into “basic functions”. For example functions on the torus can be written as

$$f(x) = \sum_{k=-\infty}^{\infty} c_k e^{ikx}$$

where the ck are the Fourier coefficients of f (x). Typical questions in this area involve the convergence of such infinite sums (and similar integrals) and analysing the behaviour of the composite function. For example quantifying its growth or regularity properties. Semiclassical analysis was developed to study high energy eigenstates (such as appear in quantum chaos) but can be used to approach other parameter problems. We build the parameter into the operators themselves. For example if

$$\Delta u = \lambda^2 u$$

then

$$(\lambda^{-2}\Delta - 1)u = 0.$$

If we set $h = \lambda^{-1}$ then as $\lambda \to \infty$, $h \to 0$. So we need to look at solutions of

$$(h^2\Delta - 1)u = 0.$$

We can then generalise to a full pseudodifferential calculus and study solutions to semiclassical problems. There is usually a strong overlap between semiclassical and harmonic analysis as techniques from harmonic analysis are commonly used to understand the solutions to semiclassical problems.

(Suitable for an off-shore start)

Supervisor: Dr Melissa Tacy, melissa.tacy@auckland.ac.nz

Random waves

It is generally believed that the eigenfunctions of chaotic systems behave as if there were a random wave. That is:

$$u = \sum_j c_j e^{\frac{i}{h} x \cdot \xi_j}$$

where ξ_j are a set of h separated directions in S^{n-1} and the c_j are randomly chosen such that

$$\sum_j c_j^2 = 1.$$

These random waves are known to have a number of nice properties such as slow L^∞ growth but there is still much unknown about their behaviour. Some questions about random waves are

- Random waves are spread out on an order 1 scale. That is if X is a set of fixed size
$$\mathbb{E}(\|u\|^2_{L^2(X)}) = (\mathrm{Vol}(X))$$
where $\mathbb{E}$ is the expectation value. What can we say about small scale spread of random waves? That is if X_h is a set $\mathrm{X}_h \to 0$ as $h \to 0$ what can we say about
$$\mathbb{E}(\|u\|_{L^2(X_h)})$$
as $h \to 0$
- Particularly in the small scale regime what can we say about join probability? That is the probability of concentration in sets X_h^1 and X_h^2 at the same time.
- There have been recently a number of works looking at random combinations of eigenfunctions. That is
$$\sum_j c_j u_j$$
where $\Delta u_j = \lambda_j^2 u_j$ and the c_j are randomly chosen. What can we say about random combinations of approximate eigenfunctions? These have the advantage that the can be strongly localised (which is not necessarily true for eigenfunctions) so they can be used to see information about fine scale structures.

(Suitable for an off-shore start)

Supervisor: Dr Melissa Tacy, melissa.tacy@auckland.ac.nz

Department of Physics

Bacteria detection using quantitative fluorescence

Bacteria are everywhere and are involved in many processes relevant to our everyday life, yet it is hard to monitor accurately and in real-time bacterial concentration. We have been utilising fluorescence and microfluidics to develop optofluidic methods for near-real time enumeration of low concentrations of bacteria. The next challenge is to be able to identify the specific types of bacteria using these optofluidic methods. This research will be carried out in collaboration with microbiologists who will provide samples and knowledge of microorganisms and bacterial processes.
(Not suitable for an off-shore start)

Supervisors:
Assoc. Prof. Frederique Vanholsbeeck,
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Dr Cushla McGoverin, c.mcgoverin@auckland.ac.nz

Multimodal optical imaging

Better understanding of the interplay between structure and chemistry is crucial to deepen our understanding of biological tissues, especially their mechanical properties. This project will involve the design and construction of an instrument for the simultaneous collection of optical coherence tomography (OCT), Raman and near-infrared spectroscopy data. OCT, the light-based analogue of ultrasound, imparts information about the structure of a sample. Raman and near-infrared spectroscopies are complementary vibrational spectroscopic methods which impart chemical information. Using these three techniques simultaneously will enable interrogation of both the structure and chemistry of a sample. (Not suitable for an off-shore start)

Supervisors:
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f.vanholsbeeck@auckland.ac.nz
Dr Cushla McGoverin, c.mcgoverin@auckland.ac.nz

Microresonator frequency combs

Optical frequency combs are laser light sources whose spectrum is composed of

numerous equidistant lines. They have had a transformative impact in the field of spectroscopy, enabling experimental measurements with astonishing precision. In 2007, a remarkable new method of frequency comb generation was demonstrated: low-power continuous wave laser light could spontaneously transform into a broadband frequency comb when coupled into an ultra-high-quality microresonator.
Because of their unique characteristics, such “microresonator frequency combs” have the potential to revolutionize a number of applications ranging from telecommunications to biomedical imaging, and they have accordingly attracted considerable research interest over the last decade. We run an extensive experimental research program on microresonator frequency combs. Details of individual projects can be found at our website.
(Suitable for an off-shore start)
Supervisors: Assoc. Prof. Stuart Murdoch, s.murdoch@auckland.ac.nz

School of Psychology

Investigating vocabulary development in Chinese -English bilingual children in NZ

Research indicates that the number and type of words bilingual children have in their two languages differ to that of their monolingual peers in either language. Little research has been undertaken to investigate this question with the pairing of Chinese (Putonghua) and English speaking children. This study will be a first of its kind in investigating bilingual children's knowledge of words in Chinese and English. The study will investigate this question with either preschool (3-5 year olds) or early primary school (5-6 years) children.
(Suitable for an off-shore start)
Supervisor: Dr Elaine Ballard, e.ballard@auckland.ac.nz

Investigating any aspect of grammatical development in Chinese-English bilingual children in NZ

There is very little research into the syntactic development of Chinese and English in bilingual children. This will be a landmark study investigating an aspect of grammatical structure (e.g. tense/aspect marking, pronouns) in children's language development in their two languages. The study will investigate this question with either preschool (3-5 year olds) or early primary school (5-6 years) children.
(Suitable for an off-shore start)
Supervisor: Dr Elaine Ballard, e.ballard@auckland.ac.nz

Performance of Chinese (Putonghua and/or any other varieties of Chinese) speaking adults on the

Chinese and English versions of the Boston Naming Test

The Boston Naming Test is a picture naming assessment used to diagnose language impairment. The test has been translated into both Cantonese and Mandarin but it has not been tested out extensively on healthy Chinese speaking populations resident in a Western country. This study will gather data from adult speakers so that the test can be standardised for Chinese populations resident in New Zealand. Students will gather data from either Chinese variety or both varieties.
(Suitable for an off-shore start)
Supervisor: Dr Elaine Ballard, e.ballard@auckland.ac.nz

Chinese language acquisition in second language learners

With China now a global power many New Zealanders have become interested in learning Mandarin. However they may struggle with aspects of the language (tones, consonants, specific grammatical structures). In this study one aspect of Chinese that is problematic to second language learners of the language will be investigated.
(Suitable for an off-shore start)
Supervisor: Dr Elaine Ballard, e.ballard@auckland.ac.nz

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Department of Statistics

Properties of the One Standard Error Rule

The 1-SE rule is a widely-used heuristic modification to help avoid overfitting based on applying a classifier to test data. It is a very popular method in data science and machine learning. However, its properties have received little to no theoretical attention. The aim of this work is to derive the theoretical properties of the 1-SE rule. As well as obtaining its asymptotic properties, we wish to propose practical guidelines to make best use of the rule.
(Suitable for an off-shore start)

Supervisor: Dr Thomas Yee, Email: t.yee@auckland.ac.nz

Vector Generalized Linear Mixed Models

The class of generalized linear mixed models (GLMMs) follows by adding random effects to GLMs, and they are very widely used. The aim of this research topic is to add random effects to the class of VGLMs, which is very large. Thus random effects capabilities could be added to many statistical models simultaneously. Several possible estimation algorithms to be considered include joint maximization methods such as Schall (1991, Biometrika) and quasi-likelihood estimators, Monte Carlo variants of the Newton-Raphson and EM algorithms, restricted maximum likelihood, the Laplace approximation, and adaptive Gaussian quadrature. To fully develop new algorithms for VGLMMs it is expected that the function vglmm() be written and added to the VGAM R package. (Suitable for an off-shore start)

Supervisor: Dr Thomas Yee, Email: t.yee@auckland.ac.nz

Topics in Information Geometry

Information geometry, based on differential geometry in pure mathematics, offers deep insights into certain areas of statistics. It provides a parameterization-independent approach to statistical estimation of parametric models that operates on flat or curved manifolds. This project is to explore parameter space dynamics of distributions based on differential geometrical ideas, e.g., tangent spaces, statistical curvature, tensors and asymptotic theory. It would suit a student with a strong background in calculus/analysis and mathematical statistics. The background to this topic includes the work of Amari, Barndorff-Nielsen and Cox, and Efron, amongst many others.

(Suitable for an off-shore start)
Supervisor: Dr Thomas Yee, t.yee@auckland.ac.nz

Bayesian approaches to estimating the stochastic gravitational wave background

The planned ESA space-based gravitational wave detector LISA will be operating in the low-frequency regime allowing to detect gravitational signal from the stochastic gravitational wave background (SGWB). The SGWB is the gravitational analogue to the cosmic microwave background and results from a large number of weak, independent, and unresolved sources of astrophysical and cosmological origin. An observed SGWB would provide a wealth of information about the universe. This project aims at developing novel Bayesian nonparametric methods for estimating the power spectrum of the SGWB. A good knowledge of and interest in Bayesian inference, MCMC techniques, and time series as well as good programming skills and knowledge of R/Python are essential. This project would be suitable to students of statistics and/or physics. This project will give an opportunity to be involved in an international ESA-led collaboration, see https://www.gravity.ac.nz/people/
(Suitable for an off-shore start)
Supervisors:
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Nelson Christensen, Astrophysics, Observatoire de la Cote d'Azur, nelson.christensen@oca.eu

Inference and control of overflow in Markovian queueing systems

An overflow in a queueing system can happen in a variety of real-world situations such as teletraffic and business networks, and healthcare systems. In this project, we consider an overflow queueing system with Markovian arrival and service processes and apply matrix analytic methods as an approximation method to solve them. We explore relations between different Markovian arrival and service processes, and estimation methods, and design a control system to enhance system performance.
(Suitable for an off-shore start)
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Adaptive control of partially observed stochastic queueing networks

The evolution of queuing systems often happens randomly, and key variables/parameters of the system may be unknown or partially observed. Improving the efficiency of such networks, using online controls that respond to changes in the network state, can lead to reductions in customer waiting times, better service utilization and stability of the network. The main idea of this project is devising appropriate and optimal controls for partially observed networks of queues. It will consider models with applications in a variety of fields, for example biology, health services, energy, manufacturing, traffic and communication networks.

(Suitable for an off-shore start)

Supervisors:

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Ilze Ziedins, i.ziedins@auckland.ac.nz

High dimensional multi-trajectory modelling for characterizing metabolic responses

Multi-trajectory modelling is a commonly used statistical technique to understand population heterogeneity for longitudinal processes characterized by a small number of measures (for instance, a lipid profile with LDL cholesterol, HDL cholesterol, and triglycerides). This project will expand this technique to metabolic assays that include dozens or hundreds of compounds. The focus will be the short time frame response to consuming a specific food or supplement. The dimension of observations on a particular individual may be further augmented by considering different amounts ("doses") of the food in a crossover setting. There are two challenges: to find a computationally tractable model and fitting procedure; and to develop visualizations and summaries that characterize the different clusters discovered.

(Suitable for an off-shore start)

Supervisors:
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Karl Fraser will also co-supervise

Disease risk prediction using deep learning techniques

The use of human genome discoveries and other established factors for predicting disease risk is an essential step in the modern quest for precision medicine. Emerging high-dimensional multi-layer omics data has provided unprecedented opportunities for systematically investigating the predictive effects of biomarkers and their interplay at various molecular levels. However, the high-dimensionality, regulatory dependencies among different omics layers, and complex relationships between predictors and disease outcomes have brought tremendous analytical challenges. New methods and software are urgently needed. The overall goal of this project is to develop explainable deep learning models that can reduce data dimension with theoretical justifications, efficiently integrate heterogeneous multi-omics data, and achieve the state-of-the-art prediction performance.

(Suitable for an off-shore start)

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