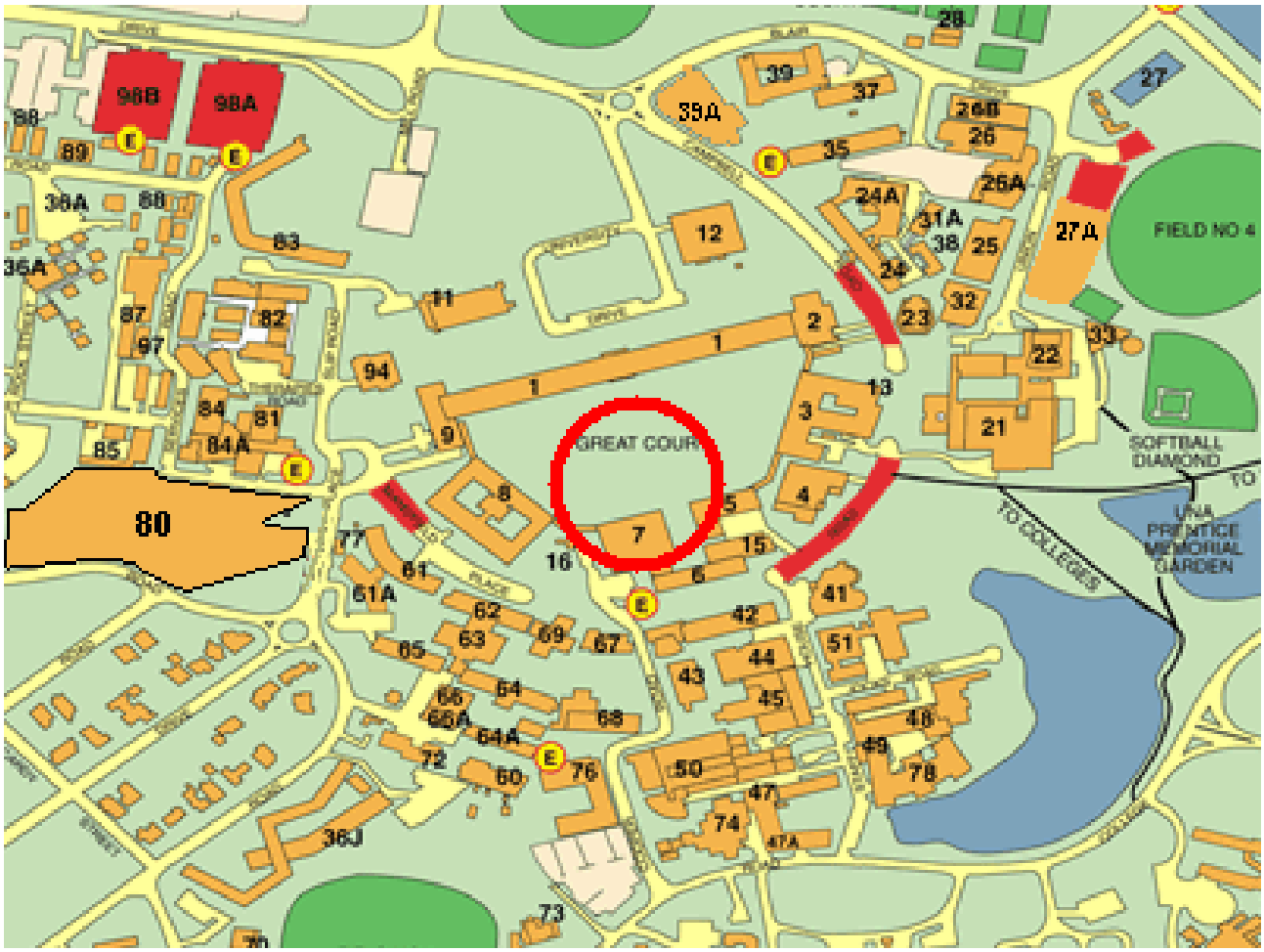
QANZIAM ECR Conference 2021

The University of Queensland

November 4, 2021

Location

The QANZIAM ECR (early-career researcher) Conference 2021 will be held in-person and online via Zoom. The in-person component will be in the Parnell Lecture Theatre, Room 07-222, St Lucia Campus, The University of Queensland.



Participants can also join online via the Zoom link: https://uqz.zoom.us/j/88499276955

Schedule

Time	Speaker	Title
8:30–9:00		Welcome
9:00–9:20	Abbish Kamalakkannan* (Griffith)	Retrieving Cardiac Conductivities through Bayesian Inference
9:20–9:40	Johnathan Adams* (QUT)	Interpersonal Opinion Dynamics: the ways in which we model opinion spreading
9:40–10:00	William Stibbards* (UQ)	Filtering Complex Networks
10:00–10:20	Samuel Barton* (UQ)	Combinatorics of Gene Co-Expression Networks
10:20–10:50		Morning Tea
10:50–11:10	Zach Wegert* (QUT)	Multi-objective structural optimisation of piezoelectric materials
11:10–11:30	Samuel Stephen* (Griffith)	Using the lattice Boltzmann method to simulate oscillatory fluid flow through periodic structures: the effect of varying Reynolds number
11:30–11:50	Ravindra Pethiyagoda (QUT)	Time-frequency analysis for ship waves
11:50–12:10	Steven Kedda* (QUT)	Self-similarity and Fractalisation in Interfacial Hydrodynamics
12:10–13:10		Lunch
13:10–13:30	Cailan Jeynes-Smith* (QUT)	Robust Perfect Adaptation in Ecological Systems
13:30–13:50	Faris Alsubaie* (UQ)	Modelling of Tissue Invasion in Epithelial Monolayers
13:50–14:10	Nizhum Rahman* (UQ)	A mathematical model for the axonal cargo transport
14:10–14:30	Alistair Falconer* (UQ)	Modelling microtubule action in cells navigating crowded environments
14:30–15:00		Afternoon Tea
15:00–15:20	Ryan Murphy (QUT)	Designing and interpreting 4D tumour spheroid experiments
15:20–15:40	Alex Tam (QUT)	Bend, and Snap! How Flexible Actin Filaments Enable Cell Division
15:40–16:00	Aminath Shausan (UQ)	Emulation of Epidemics via Bluetooth based Virtual Safe Virus Spread
16:00–16:20	Fawwaz Batayneh (UQ)	Ergodic invariant measures for multidimensional non-autonomous dynamical systems
16:20–16:30		Closing Remarks

Asterisks denote students.

Talk Abstracts

Retrieving Cardiac Conductivities through Bayesian Inference

Abbish Kamalakkannan

Supervisor(s): Barbara Johnston, Peter Johnston

Griffith University

Accurate values for the six cardiac bidomain conductivities are crucial for meaningful computational studies of electrical conduction in cardiac tissue. Previous studies have proposed an approach using a multi-electrode array to measure cardiac potentials, from which the conductivities can be determined through an optimisation protocol. However, it has been found that the conductivities retrieved through this protocol are often inconsistent and uncertainty in these values cannot be quantified. This talk presents a new protocol, based on Generalised Polynomial Chaos and Bayesian inference, that is able to retrieve the cardiac conductivities accurately and consistently from the cardiac potentials. We verify the use of this protocol on synthetic data and in the simple case of retrieving isotropic conductivities from a set of recent experimental measurements.

Interpersonal Opinion Dynamics: the ways in which we model opinion spreading

Johnathan Adams

Supervisor(s): Gentry White

Queensland University of Technology

Opinions have been around as long as conscious thought. Yet we understand little about how opinion are adopted and spread between individuals. In this talk we discuss the field of opinion dynamics, specifically at interpersonal level. We discuss the ways researchers modeled how people exchange their opinions and ideas, from the simple beginnings of French to the later models of CODA and Martins. Understanding how we spread opinions on an individual level is key to building understanding how society form and polarise.

Filtering Complex Networks

William Stibbards

Supervisor(s): Diane Donovan

The University of Queensland

Extraction of backbones from complex networks and clustering of multivariate data are two techniques for isolating and studying the structure of large, complicated datasets. This undergraduate honours thesis presentation explores the relationship and overlap between the Disparity filter for backbone extraction and hierarchical clustering with complete linkage. Testing on a set of gene expression data indicates an interesting overlap between the results of the two techniques and suggests that there may be value in using the two of them together to uncover structure they would not find in isolation.

Combinatorics of Gene Co-Expression Networks

Samuel Barton

Supervisor(s): Diane Donovan

The University of Queensland

Gene co-expression networks are weighted graphs where vertices represent genes and edges represent significant gene co-expression, weighted with some metric. However, in order to construct these graphs, we require a definition for a significant expression pattern between genes. This definition is dependent on the metric which is used to measure co-expression. As such, different metrics provide different graphs, which in turn highlights different interactions between genes. With most experimental data providing a large number of genes across a small number of time points, the resulting graph is often large and complex. In this talk, we will discuss various techniques which can be used to filter edges and identify important genes and gene interactions. We will also discuss how hypergraphs can provide a possibly more useful framework for modelling gene interactions.

Multi-objective structural optimisation of piezoelectric materials

Zach Wegert

Supervisor(s): Vivien Challis, Tony Roberts

Queensland University of Technology

Piezoelectricity is the phenomenon in which certain materials convert mechanical energy to electrical energy and vice versa. Such materials are used in sensor, actuator, and energy harvesting technologies. In this talk, we will first introduce piezoelectricity and computational homogenisation of periodic microstructures. We will then discuss the use of inverse homogenisation, which is the combination of computational homogenisation and structural optimisation, to design new single-poled materials which that maximise a linear combination of the effective hydrostatic coupling factor and effective bulk modulus. The materials we have designed have competitive piezoelectric and stiffness properties, and demonstrate the potential of structural optimisation for designing functional materials for industrial applications.

Using the lattice Boltzmann method to simulate oscillatory fluid flow through periodic structures: the effect of varying Reynolds number

Samuel Stephen

Supervisor(s): Peter Johnston, Barbara Johnston

Griffith University

The long-term aim of my PhD project is to study a particle-laden fluid pumped back and forth through a membrane of periodic axisymmetric pores. This physical scenario is relevant to applications such as blood flow, filtration, and development of microporous/nanoporous materials. A particular subproblem of interest, and the focus of this talk, is where the diameter of the pore varies along its length in a periodic but longitudinally asymmetric manner. Current models utilise conventional fluid dynamics techniques (e.g. finite element method, boundary element method), some of which have intrinsic disadvantages; for example, lack of viscous effects and the need to consider multiple periods geometrically. The lattice Boltzmann method overcomes these drawbacks and has easier-to-implement boundary conditions. In this talk, I will discuss the effects of viscosity on the flow field via simulations with varying Reynolds numbers.

Time-frequency analysis for ship waves

Ravindra Pethiyagoda

Supervisor(s): Scott McCue

Queensland University of Technology

Spectrograms have recently emerged as a useful method of visualising ship wakes from surface height measurements taken from a single location, with potential applications in ship detection and coastal management (coastal erosion). It is possible to generate a linear dispersion curve that predicts the location of colour intensity in a spectrogram for a ship moving in a straight line with constant speed or along an arbitrary path with arbitrary speed. In this talk we provide examples for a ship moving in a straight line and a ship traveling in a circle with constant angular velocity. If time permits, we will comment on the nonuniqueness of the dispersion curve is presented, which sheds some light on potential difficulties for applications involving detection.

Self-similarity and Fractalisation in Interfacial Hydrodynamics

Steven Kedda

Supervisor(s): Michael Dallaston, Scott McCue

Queensland University of Technology

Thin film equations are classes of nonlinear partial differential equations, which have extensive application in industrial and scientific modelling to describe the dynamics of viscous liquid flow on solid surfaces. The nonlinear dynamics of such equations is often highly complex and hard to categorise. In this talk we will reproduce the numerical computation and self-similar analysis of a model describing the rupture of a thin film due to van der Waals force, and discuss the challenges in extending these methods to the model of pattern formation due to thermocapillary stresses.

Robust Perfect Adaptation in Ecological Systems

Cailan Jeynes-Smith

Supervisor(s): Robyn Araujo

Queensland University of Technology

Robust perfect adaptation is a common signalling behaviour found in cellular biology, whereby a protein abundance consistently returns to a basal level following any perturbation to an input of the network. This behaviour can be readily observed in a wide array of systems ranging from chemotaxis in single cell organisms to complex olfactory systems. Despite its prevalence in cellular systems, robust perfect adaptation is an unstudied behaviour in ecological systems, even though this could have major implications for applications in fields such as conservation biology and agriculture. In this study, we examine ecological networks consisting of three species and use novel methods which utilise Gröbner bases to determine a network's capability for robust perfect adaptation. We found that from approximately four thousand possible network configurations, only eight networks could achieve the robust perfect adaptation behaviour.

Modelling of Tissue Invasion in Epithelial Monolayers

Faris Alsubaie

Supervisor(s): Zoltan Neufeld, Hamid Khataee

The University of Queensland

Mathematical and computational models are used to describe biomechanical processes in multicellular systems. Here, we model how two types of epithelial cell layers interact during tissue invasion, simulating cancer cells expanding into a region of healthy cells. Cancer cells divide faster than normal cells and if their mitosis is not prevented the disease will spread to other body parts, We model the invasion process using the Cellular Potts Model and implement our two-dimensional computational simulations in the software package CompuCell3D. We investigate how the invasion speed and direction vary depending on the cell division and death rates and on mechanical properties of the cells. We found that differences in mechanical properties can lead to tissue invasion even if the division rates and death rates of the two cell types are the same.

A mathematical model for the axonal cargo transport

Nizhum Rahman

Supervisor(s): Dietmar Oelz

The University of Queensland

Axonal transport is the process by which cargo is delivered by motor proteins through the axon of neuron cells. Actin plays a crucial role in this phenomenon through perpendicular actomyosin rings which are wrapped around the circumference of axons. Some cargo vesicles are larger in diameter than the axon so the axon and with it actomyosin rings are locally dilate as the cargo vesicle moves. We construct a mathematical model to describe the resulting deformation of the axon. The model is reminiscent of the classical obstacle problem. It allows to relate the cargo velocity to the mechanical properties of the actomyosin rings and to explain the observation that the speed of axonal cargoes is inversely correlated with their size.

Modelling microtubule action in cells navigating crowded environments

Alistair Falconer

Supervisor(s): Dietmar Oelz

The University of Queensland

Migrating cells must navigate complex and crowded 3D geometries, requiring them to actively modulate both their mechanical and biochemical properties. Microtubules have been observed to play a crucial part in guaranteeing a successful migration, but their exact role is unclear. It has been proposed that microtubules form a cage around the rear of the nucleus, insulating it from mechanical forces and allowing a pressure differential to develop. We describe a mathematical model of a cell travelling through a channel smaller than its own nucleus and investigate how microtubule action can affect the success of the transmigration. We identify a realistic parameter set where this microtubule action is essential for the migration to succeed.

Designing and interpreting 4D tumour spheroid experiments

Ryan Murphy

Supervisor(s): Mat Simpson

Queensland University of Technology

Tumour spheroid experiments are routinely used to study cancer progression and treatment. Various and inconsistent experimental designs are used, leading to challenges in interpretation and reproducibility. Using multiple experimental designs, live-dead cell staining, and real-time cell cycle imaging, we measure necrotic and proliferation-inhibited regions in over 1000 4D tumour spheroids (3D space plus cell cycle status). By intentionally varying the initial spheroid size and temporal sampling frequencies across multiple cell lines, we collect an abundance of measurements of internal spheroid structure. These data are difficult to compare and interpret. However, using an objective mathematical modelling framework and statistical identifiability analysis we quantitatively compare experimental designs and identify design choices that produce reliable biological insight. Measurements of internal spheroid structure provide the most insight, whereas varying initial spheroid size and temporal measurement frequency is less important. Our general framework applies to spheroids grown in different conditions and with different cell types.

Bend, and Snap! How Flexible Actin Filaments Enable Cell Division

Alex Tam

Supervisor(s): Mat Simpson, Dietmar Oelz

Queensland University of Technology

Contraction of actomyosin networks underpins active movement and division of biological cells. These networks exist in the cell cortex beneath the plasma membrane, and consist of the proteins actin and myosin. Actin molecules form polarised filaments approximately one micron in length, with distinct plus and minus-ends. Myosin forms shorter molecular motors that attach to these filaments and move actively towards their plus-ends. This motion generates either contractile or expansive force. In the cell cortex, filaments have random positions and orientations, and we might expect myosin movement to generate contraction or expansion with equal probability. However, these disordered networks are contractile, and the mechanism of contraction is not immediately clear.

We investigated how filament bending facilitates contraction. We first developed a two-dimensional agent-based model, to simulate network evolution and quantify the stress generated. Comparing simulations of rigid and semi-flexible filaments, we found that bending gives rise to network-scale contraction. We then analysed a simplified system of two filaments to understand the microscopic origin of contraction in more detail. Asymptotic analysis and numerics show that bending induces a geometric asymmetry that inhibits expansion. The net result is contraction — it works every time!

Emulation of Epidemics via Bluetooth based Virtual Safe Virus Spread

Aminath Shausan

Supervisor(s): Yoni Nazarathy

The University of Queensland

The COVID-19 pandemic is the most significant global event of the 21st century to date. In response to the pandemic, multiple technological solutions are being developed and deployed. These include vaccines, contact tracing solutions, and others. As part of this effort, the integration of AI systems (artificial intelligence for pandemics) is being thought out as a key component in measuring the spread of pathogens as well as the level of physical human contact. The Safe Blues project is one such idea, where virtual safe virus like tokens are spread between cellular phones in an attempt to mimic biological virus spread for purposes of measurement and analysis. The Safe Blues project complements mathematical modelling of epidemics via real-time measurements.

As part of the Safe Blues project, an experiment is currently running at The University of Auckland City Campus in New Zealand. The experiment involves voluntary use of the Safe Blues Android app by participants. The app spreads multiple virtual safe virus strands via Bluetooth where the spread depends on the unobserved social and physical proximity of the subjects. The evolution of the virtual epidemics is recorded as they spread through the population simultaneously. Through these measurements, we are able to detect SIR type dynamics and phenomena such as 'heard immunity', which are sometimes not easy to observe in more complex settings.

This talk describes the experimental setup, dataset description, and current results in view of a lockdown that started in New Zealand on August 18, 2021.

Ergodic invariant measures for multidimensional non-autonomous dynamical systems

Fawwaz Batayneh

Supervisor(s): Cecilia González Tokman

The University of Queensland

In the area of dynamical systems, a deterministic discrete dynamical system is given by a map $f : X \to X$, where $X \subset \mathbb{R}^n$, $n \geq 1$. The set X is usually taken to be compact. One main question is to statistically understand the long term behavior of trajectories of the map f for a large set of initial conditions $x \in X$. The existence of invariant measures provides key information about the dynamical behavior, especially when these measures are absolutely continuous (ACIP) with respect to the Lebesgue measure.

In this talk, we introduce a more general type of discrete dynamical systems, called non-autonomous or random. In our case, we deal with a collection of multidimensional maps $\{f_\omega : X \to X : \omega \in \Omega\}$ where $X \subset \mathbb{R}^n$, $n > 1$, indexed by a probability space (Ω, P). In real life applications, the relevance of random dynamical systems is clear due to the fact that systems are influenced by external factors or noise. In this talk, we comment on the ergodic properties and existence of random ACIPs for such dynamical systems.

List of Participants

Name	Email	Institution
Johnathan Adams	johnathan.adams@hdr.qut.edu.au	QUT
Nawal Alomar	n.alomar@uqconnect.edu.au	UQ
Faris Alsubaie	faris.alsubaie@uqconnect.edu.au	UQ
Claudio Arancibia	claudio.arancibiaibarra@qut.edu.au	QUT
Samuel Barton	s.barton@uqconnect.edu.au	UQ
Fawwaz Batayneh	f.batayneh@uq.edu.au	UQ
Kaitlyn Brown	kaitlyn.brown@hdr.qut.edu.au	QUT
Pascal Buenzli	pascal.buenzli@qut.edu.au	QUT
Nicholas Buttle	n.buttle@qut.edu.au	QUT
Meagan Carney	m.carney@uq.edu.au	UQ
Vivien Challis	vivien.challis@qut.edu.au	QUT
Alistair Falconer	alistair.falconer@uqconnect.edu.au	UQ
Cecilia González Tokman	cecilia.gt@uq.edu.au	UQ
Cailan Jeynes-Smith	cailan.jeynessmith@hdr.qut.edu.au	QUT
Abbish Kamalakkannan	a.kamalakkannan@griffith.edu.au	Griffith U.
Christina Kazantzidou	christina.kazantzidou@qut.edu.au	QUT
Steven Kedda	s.kedda@hdr.qut.edu.au	QUT
James Lefevre	j.lefevre@uq.edu.au	UQ
Scott McCue	scott.mccue@qut.edu.au	QUT
Ryan Murphy	r23.murphy@qut.edu.au	QUT
Zoltan Neufeld	z.neufeld@uq.edu.au	UQ
Dietmar Oelz	d.oelz@uq.edu.au	UQ
Ravindra Pethiyagoda	ravindra.pethiyagoda@qut.edu.au	QUT
Nizhum Rahman	nizhum.rahman@uq.edu.au	UQ
Robert Salomone	robert.salomone@qut.edu.au	QUT
Ronél Scheepers	ronel.scheepers@hdr.qut.edu.au	QUT
Aminath Shausan	a.shausan@uq.edu.au	UQ
Samuel Stephen	samuel.stephen@griffith.edu.au	Griffith U.
William Stibbards	w.stibbards@uq.net.au	UQ
Alex Tam	alexander.tam@qut.edu.au	QUT
Zach Wegert	zach.wegert@hdr.qut.edu.au	QUT
Mengchen Zhang	m64.zhang@hdr.qut.edu.au	QUT

Code of Conduct

QANZIAM is dedicated to providing a harassment-free conference experience for everyone, regardless of gender, gender identity and expression, age, sexual orientation, disability, physical appearance, body size, race, ethnicity, religion (or lack thereof), or technology choices. Conference participants are to abide by the ANZIAM Conference Code of Conduct, which is as follows:

Harassment in any form will not be tolerated. This includes, but is not limited to, speech or behaviour (whether in person, in presentations, or in online discussions) that intimidates, creates discomfort, prevents or interferes with a person's participation or opportunity for participation in ANZIAM's vision and mission. We aim for ANZIAM to be an organisation where harassment in any form does not happen, including but not limited to harassment based on race, gender, religion, age, colour, national or ethnic origin, ancestry, disability, parental status, caring responsibilities, marital status, sexual orientation, or gender identity. Harassment includes but is not limited to verbal comments that reinforce social structures of domination; sexual images in public spaces; deliberate intimidation, stalking, or following; unwelcome photography or recording; sustained disruption of talks or other events; inappropriate physical contact; unwelcome sexual attention; and advocating for or encouraging any of the above behaviour.

All participants have a responsibility to speak out against breaches of this code of conduct. Depending on the situation, this could mean raising it with the transgressor, or reporting the behaviour to a conference organiser. If a QANZIAM member engages in harassing behaviour, the Executive Committee may take any action they deem appropriate, including warning the offender or expulsion from the Society.

Acknowledgements

Conference Organisers: Dietmar Oelz (UQ), David Harman (Griffith), Christina Kazantzidou (QUT), Nizhum Rahman (UQ), Alex Tam (QUT).

The organisers thank all participants and speakers for supporting the QANZIAM ECR Conference 2021.

The in-person part of this conference is being held on the lands of the Turrbul & Jagera people, and the organisers wish to acknowledge them as Traditional Owners. We also pay our respects to their Elders, past and present.

The organisers thank ANZIAM for helping fund this event.

THE UNIVERSITY OF QUEENSLAND

AUSTRALIA