THE UNIVERSITY of ADELAIDE

Adelaide Summer Research Scholarships

School of Mathematical Sciences

PROJECTS OFFERED FOR 2018/19

Diagnostic Testing

An Adelaide based company has developed and manufactured a machine that identifies and counts bacteria on slides prepared from specimens provided by patients who may have a condition known as UTI. The number of bacteria is summarised on a five-point scale. No bacteria indicates no UTI, and high counts indicate definite UTI, but intermediate counts are more equivocal. The aim of the project is to compare the machines summaries with those provided by experienced micro-biologists. However, micro-biologists may themselves make erroneous judgements and the most reliable reference standard is taken as an average of judgements made by several micro-biologists. The plan of work is to first review the literature on using a combination of reference tests to assess the accuracy of a new diagnostic test, starting with Alonzo and Pepe (1999) and then to analyse data provided by the company.

Supervisor: **Associate Professor Andrew Metcalfe**

Quantifying and Modelling Yeast Colony Spatial Patterns

Yeasts colonies can forage for food by either the process of filamentous growth, or the formation of a biofilm. Both are highly non-uniform spatial-temporal processes, often producing complex spatial patterns. The overall goal of this project is to develop models that predict the time evolution of colony morphology. However, an important part of this work is the spatial quantification of yeast growth experiments, which can be used to validate modelling predictions. Therefore, one of our aims is to develop user-friendly open source software that can process experimental images and provide metrics on the spatial patterning of colony morphology. The second aim is the modelling itself, and both continuum and discrete approaches could potentially be explored during the course of the project. The data for the statistical analysis and model validation will be obtained from laboratory experiments.

Supervisor: Associate Professor Ben Binder

Three-dimensional Water Waves Over Topography

The purpose of this project is to study water waves and how they interact with bottom topography. One reason for doing this is to provide a means for using surface observations (of the ocean surface, for example) to infer the shape and structure of the water-bed. Of particular interest to this project is the potential formation of localised three-dimensional waves, which decay in the far-field away from the topographic forcing. Progress will be made on this by studying solutions to the Kadomtsev-

Petviashvili equation. More challenging will be the study of such structures for the fully nonlinear equations, and this will be tackled using boundary integral methods.
Supervisor: Associate Professor Ben Binder

I am happy to supervise projects in the areas of finite geometry and combinatorics. Interested students can email me to arrange a meeting and we can discuss possible project ideas.
Supervisor: Dr Susan Barwick

Algebraic Topology or Category Theory
I am happy to supervise projects in algebraic topology or category theory. If you are interested, please email me to arrange a meeting to discuss possible topics.
Supervisor: Dr Danny Stevenson

Establishing Evidence for a New Policy for Pandemic Influenza Response
Our recent research has suggested a new approach to the use of antivirals (and other interventions) in the event of an influenza pandemic. Further modelling work is required to establish its validity as a useful policy in practice. This project will assist in determining this evidence base. It will involve learning about stochastic models of infectious disease dynamics, and simulation algorithms; some programming (for example in MATLAB) will be required.
Supervisor: Professor Joshua Ross

Do the Rich Get Richer on Reddit?
The "Matthew Effect" is the widely-observed phenomenon whereby the rich get richer, or popular get more popular. Very famous models such as "preferential attachment" in network science have been used to explain diverse phenomena such as word distributions in language, scientific citation networks and more. In this project we will investigate whether the Matthew Effect exists in online social media, particularly in submissions to the popular website Reddit. We'll collect time-resolved data on submissions to various subreddits using the reddit API as well as from massive data dumps like on pushshift.io, and then analyse the statistics of these data to try and detect the Matthew Effect. Along the way we'll encounter Simon's model, preferential attachment, and possibly take detours in other interesting like sentiment analysis, branching processes, and metagraphs.
This project will involve some data mining and analysis using tools like Python and/or MATLAB – familiarity with one or both will be very desirable (and you'll learn much more as the project goes on!). The project can also expand to accommodate as many students as wish to take it on.
Supervisor: Dr Lewis Mitchell

3D Printing for Biofabrication
Biofabrication uses 3D printing (additive manufacturing) techniques to create artificial biological tissues (bone, cartilage, tendons). A new printing technique has been developed that involves melted polymers being stretched into fine threads through the application of an electric field ('melt electrospinning writing'). Subject to interest, this project involves modelling either the fluid mechanics behind the process by which the thread is created or the dynamics of the thread being deposited on a collector plate.

Supervisor: Dr Mike Chen

Mechanics of Artificial Cartilage
Artificial cartilage implants are a proposed alternative to current treatments for osteoarthritis (ie. knee/hip replacements). A key step in developing such implants is the differentiation of stem cells into cartilage cells, a process which is mediated by mechanical and biochemical cues. This project involves modelling the effect of applying mechanical stimulation to stem cells seeded in a variety of different materials (poroelastic gels and related composite materials, for instance).
Supervisor: Dr Mike Chen

How to Heat a Glass Tube
Glass is transparent and therefore difficult to heat. Understanding how radiative heat is transferred to glass is important to a variety of industrial applications which involve heating glass to very high temperatures so that it can be deformed or stretched. In some recent experiments, a glass tube was heated in a furnace and the temperature measured along its length. This project aims to reproduce these experiments with a mathematical model. This will involve developing a differential equation model of heat transfer, and analysis of this model via asymptotic/numerical (eg. MATLAB) techniques.
Supervisor: Dr Mike Chen

Stochastic Modelling
Project description: Randomness affects the world around us every day. In order to make our decisions, it is important to know what the possible scenarios are, and how likely each of them is to happen. Various projects on assessing how systems with uncertainty will evolve over time are available, such as generation/storage of renewable energy, the effects of power-save mode on battery life, and the foraging location of Adelie penguins.
Supervisor: Giang Nguyen

The Classical Groups
The classical matrix groups are defined as invariance groups of certain multilinear maps on real, complex and quaternionic vector spaces. The aim is to study them as curved spaces within the vector space of n- by-n matrices and to establish some of the interesting relations between them that exists for small n. Further exploration can be related to topological properties of the classical groups or to the quotient spaces arising from them.
Supervisor: Dr Thomas Leistner

Quaternions and Octonions
In a similar way how the complex numbers are constructed from the reals, the quaternions are constructed from the complex numbers and the octonions from the quaternions. Thus, both can be considered as generalisations of complex numbers to higher dimensions. Many interesting algebraic and geometric phenomena are related to the quaternions and octonions. To explore these features and relations is the aim of the project.
Supervisor: Dr Thomas Leistner

Other possible projects
Apart from these two topics I am happy to discuss any topic that is related to differential geometry.
Supervisor: Dr Thomas Leistner