Summer Scholarship 2014/15 Projects

Project 1: Nilpotent subgroups of some classical groups over integer ring

Some nilpotent subgroups of general linear groups over integer ring are founded recently. The project is to study the similar subgroups for other classical groups.

Contact: A/Prof Jianbei An (j.an@auckland.ac.nz)

Project 2: Local subgroups of some classical groups

Local subgroups play an important role in the study of groups. The project is to consider some special local subgroups of classical finite groups.

Contact: A/Prof Jianbei An (j.an@auckland.ac.nz)

Project 3: Observing mathematical communication

Observing Mathematical Communication As part of a wider LUMOS research project we wish to observe whether students develop skills and habits in mathematical communication in undergraduate courses. The Summer Scholar would work with us (three researchers in mathematics education) to develop observational tools and trial them on the Summer Semester courses MATHS 102 and 108. This will involve some theoretical reading and writing, hands on mathematics education data-gathering, and preliminary analysis of the data.

Contact: Prof Bill Barton (b.barton@auckland.ac.nz)

Project 4: Desired learning outcomes

Desired Learning Outcomes--Student views As part of a wider LUMOS project on the desired learning outcomes of undergraduate mathematics, the research team has already interviewed many lecturers about what they think are all the desirable outcomes of an undergraduate mathematics degree. We wish to have this data enhanced by a student view. The Summer Scholar will therefore be required to locate and interview graduate students. Some theoretical reading and writing will be required, as well as data analysis and reporting.

Contact: Prof Bill Barton (b.barton@auckland.ac.nz)

Project 5: Modelling and analysis of clustered ventilation in the lung

Asthmatic patients typically exhibit a characteristic pattern of 'clustered' ventilation during an asthma attack (as shown by magnetic resonance imaging (MRI)). These clusters originate via an interesting dynamic phenomenon in which airways may be either open or closed, and which groups closed airways with closed airways, and open airways with open airways, leading to clusters. This project will study a model of clustered ventilation defects using tools from ordinary differential equations and linear algebra.

Requirements: Maths 260 and some matlab experience. No prior biological knowledge is expected, just an interest and willingness to learn.

Contact: Dr Graham Donovan (g.donovan@auckland.ac.nz)

Project 6: Movement of immune cells and the role of HIV

The way that immune cells, such as T cells, move about within the body is crucial to the effectiveness of the immune system; without efficient movement the body is unable to fight disease or infection. Crucially the movement of these cells may be guided by a fibrous network, creating a scaffold for cell movement. HIV infection may damage this network, leading to permanently impaired immune function, even when HIV is later effectively suppressed. This project will study the role of this network via modelling, and analysis of the resulting models. The tools involved are ordinary differential equations, and the geometric structure of the network itself.

Requirements: Maths 260 and some matlab experience. No prior biological knowledge is expected, just an interest and willingness to learn.

Contact: Dr Graham Donovan (g.donovan@auckland.ac.nz)

Project 7: Expander graphs and applications

Graph theory is a topic of great mathematical interest which also has applications in computer science and optimisation. Expander graphs are graphs that can be efficiently sampled by taking random walks. Perhaps the internet is an expander graph? There are interesting constructions of expander graphs from algebra and number theory, and they are connected with many areas of active research in mathematics. The project will be to learn about expander graphs and their construction.

Requirements: Ideally will have taken MATHS 326 and MATHS 328, but the project could be customised for students with less background.

Contact: A/Prof Steven Galbraith (s.galbraith@auckland.ac.nz)

Project 8: Lattice-based digital signatures

A very active area of research is lattice-based public key cryptography. There is much effort into designing and analysing digital signature schemes. You will learn about recent work on this topic. The project will consider some ways to get signatures that are more secure and more efficient. This subject combines algebra, probability theory, computer programming and some basic ideas in cryptography.

Requirements: It would be suitable for students who have taken MATHS 328 and also some courses in either statistics or computer science.

Contact: A/Prof Steven Galbraith (s.galbraith@auckland.ac.nz)

Project 9: Knots and tangles

Have you ever wondered when tying your shoelaces whether tying over then under is different from tying under then over? Topologists have devised many so-called knot invariants to allow them to distinguish between different knots. One of the most famous is the Jones Polynomial, named for a former student (and now part-time Distinguished Alumni Professor) of this Department. You can study this topic algebraically and geometrically. It is helpful to know a bit about groups, but not much, and topological aspects of euclidean space, but again not much.

Requirements: If you have taken 333 you will already have more than you need but if you haven't and are interested have a chat with me before making up your mind.

Contact: Prof David Gauld (d.gauld@auckland.ac.nz)

Project 10: The geometry of equations

The aim is to understand the geometry linked to simple PDE and how that can be used to study the properties of solutions and the existence of solutions.

Contact: Prof Rod Gover (r.gover@auckland.ac.nz)

Project 11: Forecasting and prediction of observations

Forecasting (prediction of future) and general prediction (estimation of unobservable quantities) are central methods in sciences. Time-varying observations (time series) such as economical and financial data, weather, biomedical data and environmental observations can be predicted and forecast. In addition to the predicted values, the accuracy of the predictions is of fundamental importance. How the prediction models are constructed and the related uncertainties are modeled, are a current topic especially in the climate change research. In additon to prediction itself (as an end), the principles are also used to model general relationships between different phenomena. In this project, you will learn how to construct linear prediction models. This summer scholarship project can be extended to a BSc Hons thesis and further to a PhD thesis.

Requirements: Motivation to develop general skills in linear algebra, calculus, numerical methods and scientific programming (Matlab).

Contact: Dr Jari Kaipio (j.kaipio@auckland.ac.nz) and Maryam Alavi (m.alavi@auckland.ac.nz)

Project 12: Synchronisation or not of coupled pulsing lasers

Laser pulses are crucial in applications such as optical telecommunications and material science. The project will consider the dynamics that arises when two pulsating lasers are coupled: depending on the properties of the lasers and the coupling strength, will the lasers pulse in synchrony or not? To answer this question an ODE model of the coupled lasers will be considered. The challenge is to perform a systematic investigation, chiefly via numerical integration of the equations in conjunction with the identification of observed dynamics.

Requirements: Knowledge of ODE theory and experience with Matlab would be an advantage.

Contact: Prof Bernd Krauskopf (b.krauskopf@auckland.ac.nz)

Project 13: Generalised Julia sets and wild chaos

Julia sets are the sets that `carry' the chaotic dynamics of an iterated complex-valued function; they are organised for the quadratic complex family by the famous Mandelbrot set. The project will consider a generalisation of Julia sets in a family of non-complex maps that nevertheless contains the complex quadratic family as a special case. Generalised Julia sets can take the form of Cantor sets, Cantor bouquets and Cantor cheeses. The goal of the project is to investigate where and why these amazing topological sets arise.

Requirements: Experience with Matlab would be an advantage.

Contact: Prof Bernd Krauskopf (b.krauskopf@auckland.ac.nz)

Project 14: Computing the subgroup lattice of the simple groups Sz(q)

These groups have a very well understood subgroup structure and the idea of the project is to really understand this in terms of the lattice of conjugacy classes of subgroups.

Contact: A/Prof Dimirti Leemans (d.leemans@auckland.ac.nz)

Project 15: Triangle generation of groups

Triangle groups are a class of groups that are very straightforward to define and arise naturally (for example, in geometry), and yet have a very rich structure. There has been considerable interest in recent years in understanding which finite groups occur as quotients of a given triangle group, and in particular which finite simple groups. This summer project will focus on understanding these groups and the open problem of understanding their finite simple quotients. Depending on the background of the student, this could involve computation with MAGMA, as well as the theory of group representations and characters.

Requirements: Maths 320 is essential. An interest in computing is potentially useful.

Contact: Dr Alastair Litterick (a.litterick@auckland.ac.nz)

Project 16: Complex dynamics

This project will study the dynamics of holomorphic maps. Iterating such maps on the computer creates exotic pieces of art. The complicated pictures give some idea of the dynamics but may not tell the whole story, just as important properties of a function may not appear in a plot of its graph. Basic tools to study complex dynamics include calculus and linear algebra, complex analysis, topology, and potential theory.

Requirements: No background in these will be required.

Contact: Dr Sione Ma'u (s.mau@auckland.ac.nz)

Project 17: Active-Technology in mathematic: attitudes & responses

Are you interested in the use of technology in mathematics? Do you think we make effective use of technology in our undergraduate courses? We have adopted a BYOD approach (bring your own device) to the teaching of Maths 102 in 2013-2014, including the use of MathXL (an online assessment and learning interactive learning tool); graphics and CAS-calculators; programmes such as Desmos, Geogebra, Wolfram Alpha, Kahn Academy; and smartphone apps. In this project, you will assist us with examining and analysing the data we have collected over two semesters about students' use of, and reactions to the technology promoted in Maths 102. How has the technology affected their learning and understanding of mathematics?

Contact: Dr Greg Oates (g.oates@auckland.ac.nz)

Project 18: How do lecturers present mathematical knowledge in their classes?

Of course our lecturers understand the mathematics they are teaching us. But, what do they think about when preparing their lessons? What mathematical points do they consider will be difficult? What ideas do they have to help students understand the difficult points? This aspect of teaching is categorised as pedagogical content knowledge (PCK): How do lecturers know what aspects to highlight and what mechanisms they might employ to help students understand a particular piece of mathematical knowledge or content. In this project, you will examine specific examples of mathematical content, and help us design questions which may shed light on what lecturers think about when preparing their lessons on these particular topics. We will the conduct pilot interviews with volunteer teaching staff from our department using the questions produced.

Contact: Dr Greg Oates (g.oates@auckland.ac.nz)

Project 19: How commutative can a group be?

By definition, in an abelian group every element commutes with every other. But what about a non-abelian group? Can an element of a non-abelian group commute with almost every other element? Is there an upper bound on the proportion of elements in the group which can commute with a fixed element?

Requirements: Minimum prerequisite for the project is Maths 320. Some interest in computation is also highly desirable.

Contact: Prof Eamonn O'Brien (e.obrien@auckland.ac.nz)

Project 20: A hard problem for 2x2 invertible matrices?

Let G be a group of 2x2 matrices defined over a finite field of characteristic p and having generating set X. How can we find an element of order p in G as a word in X? Two approaches have been proposed. One relies on a solution to the Discrete Log Problem. We want to explore and compare both.

Requirements: Minimum prerequisite for the project is Maths 320; preferred is 720. Some interest in computation is highly desirable.

Contact: Prof Eamonn O'Brien (e.obrien@auckland.ac.nz)

Project 21: Measuring up pre-turbulence in the Lorenz system

The Lorenz system is famous for being the first example where chaotic dynamics was found. We consider the so-called pre-turbulent parameter regime, where chaotic dynamics occurs only as a transient before trajectories converge to one of two fixed-point attractors. Numerical results offer a new way to identify the location and size of the space taken up by the transient chaotic dynamics. Are you prepared to take on the challenge of finding the `area under the curve' while the functional form of the curve is not known?

Requirements: Maths 270 - Numerical Computations

Contact: Prof Hinke Osinga (h.m.osinga@auckland.ac.nz)

Project 22: Linear secret sharing schemes

Linear secret sharing schemes are generalisations of the classical Shamir's secret sharing scheme. They have many nice properties and, in particular, they are ideal. In most cases, when somebody proves that the scheme is ideal, they in fact prove that it is linear. In this project we will consider ways of combining simple linear secret sharing schemes into composite ones. We aim to find new proofs of linearity of some known schemes and constructing some new classes of linear schemes.

Requirements: MATHS 328 (or at least MATHS 326)

Contact: Prof Arkadii Slinko (a.slinko@auckland.ac.nz)

Project 23: Electoral equilibria

In the Hotelling-Downs model of competition we will investigate the position-taking behaviour of agents (parties, candidates or firms) under a class of electoral systems known as scoring rules. The agents aim to maximise their support in the society by choosing positions strategically. In equilibrium nobody is interested in changing their position. When the voters opinions are uniformly distributed across one-dimensional political spectrum, these equilibria in many cases are classified. In this project we will investigate how robust these equilibria are with respect to the assumption of the uniformity of the distribution.

Requirements: MATHS 250.

Contact: Prof Arkadii Slinko (a.slinko@auckland.ac.nz)

Project 24: Voting manipulation games

The classical Gibbard-Satterthwaite theorem implies the ubiquity of potential manipulators in elections who are the voters who can change the election outcome in their favor by casting an insincere vote. If several such voters exist they have to take into account possible actions of other manipulators. The strategic interactions among these voters is modeled by a non-cooperative game which is called voting manipulation game. We will investigate which games may appear as voting manipulation games and whether or not they have Nash equilibria in pure strategies.

Requirements: MATHS 250

Contact: Prof Arkadii Slinko (a.slinko@auckland.ac.nz)

Project 25: Alternative methods of discounting

Dollar today costs more than dollar tomorrow. So future costs and benefits should be adjusted to their present value. This is what a discounting function does. The exponential discounting, which is predominantly used in the business world, discards distant profits and disasters (like effects of global warming) exsessively and it was noticed in experiments that people's discounting of long term events is rather hyperbolic than exponential. We suggest a series of intermediate discounting methods with exponential method as one extreme and hyperbolic as the other. We would like to try them to see which one of them is the best fit for the existing experimantal data.

Requirements: Require use of statistical packages and some basic programming

Contact: Prof Arkadii Slinko (a.slinko@auckland.ac.nz)

Project 26: Modelling calcium oscillations and waves in epithelial cells and smooth muscle

Oscillations in the concentration of intracellular calcium are a ubiquitous control mechanism in almost every cell type. For example, in epithelial cells (such as parotid acinar cells) they control the flow of water through the cell, and thus the secretion of saliva, while in airway smooth muscle they control the contraction of the cell and are thus related to diseases such as asthma. Such oscillations (and waves) are a complex dynamical system that we can study using the techniques of nonlinear dynamical systems, numerical methods, and modelling. The summer project will be an introduction to how models of calcium oscillations are constructed and analysed, and will be based closely on experimental data.

Requirements: An interest in cell biology and physiology, knowledge of Matlab, willingness to do computations, knowledge of differential equations at the 260 level.

Contact: Prof James Sneyd (j.sneyd@auckland.ac.nz)

Project 27: Cell diffusion

This project models the random diffusion of cells on the surface of tissues, taking into account the size of cells and cell division

Requirements: Maths 361, Maths 270

Contact: Dr Steve Taylor (s.taylor@auckland.ac.nz)

Project 28: Monte Carlo solution of the Schrodinger equation

The Schrodinger equation is a PDE from which one can calculate the probability density function of position for quantum mechanical particles. This project looks at finding approximate solutions by using random variables.

Requirements: Maths 361, Maths 270

Contact: Dr Steve Taylor (s.taylor@auckland.ac.nz)

Project 29: Vortex dynaimics and vortex stability

The primary aim of the Vortex Dynamics and Vortex Stability Research Project is to develop the global stability analysis for vorticity-dominated flows. It was well said by Kuchemann in 1965 that “vortices are the sinews and muscles of fluid motions”. The vortex dynamics is the key for us to understand complicated unsteady fluid motions such as the vortex breakdown phenomenon and turbulences. Specifically, student will conduct numerical analysis of a global stability equation, developed by the research groups in Auckland and USA in the past 20 years. This will enhance student's computation skills in numerical PDEs and linear Algebra. The obtained results are of significant physical implications and through interpreting the results, student will learn some basic knowledge of vortex dynamics.

Contact: Dr Shixiao Wang (sh.wang@auckland.ac.nz)

Project 30: The study of a nonlinear PDE with critical behaviours

Research will be focused on finding a existence proof of Nirenberg-Brezis equation in a bounded domain in R^3. Student will learn to use global analysis technique to find the solutions by seeking critical points of a nonlinear functional, defined in a suitable Sobolev space. Numerical analysis will also be used to compute the solutions and to find out the borderline for the existence. The research blends the tastes of pure and applied Math.

Contact: Dr Shixiao Wang (sh.wang@auckland.ac.nz)

Project 31: In search of mathematical thinking

What counts as mathematical thinking? How can we observe it? Document it? Measure it? This project will involve collecting data from students working on mathematical tasks, and considering what conclusions we can draw about their mathematical thinking.

Contact: Dr Caroline Yoon (c.yoon@auckland.ac.nz)