School of Mathematics and Statistics
College of Engineering

UC
UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Postgraduate Handbook 2017

17

School of Mathematics and Statistics

Postgraduate Programme 2017

Welcome from our School. Postgraduate study enables you to study selected mathematical and statistical topics in depth. There is a change of emphasis from the preceding undergraduate years: courses tend to be more focused on a specific problem or class of problems, rather than attempting to give a broad coverage of a branch of mathematics and statistics.

There is the possibility of taking one or more projects in which you investigate some problem with the assistance of a member of staff. Depending on the nature of the problem, this may involve literature searches, the use of various computing packages (for example MATLAB, Maple or R), resources on the internet, proving new theorems or data analysis. You will produce a written dissertation and may give an oral presentation.

Any proposed programme of study requires the approval of the 400 level coordinator. It is highly unlikely that any proposed programme that has a high workload in one semester will be approved, so you should try to construct a programme that balances your workload evenly over both semesters.

You can include some courses from other subjects (e.g. COSC480 is recommended for developing programming skills). This is a good way to ensure you have a broad program of study. Check with the School's 400 level coordinator that the courses from other subjects are suitable for inclusion within your program of study. In addition, there are a various joint programs between our School and other Departments/Schools detailed below.

At the Masters and PhD level you will undertake research, often focussed on deep study of a specialised topic. You will learn skills in undertaking systematic investigations, contextualising your work within the current state of understanding, so that your research outcomes can extend beyond the forefront of human knowledge.

Honours or PG Diploma in Mathematics/Statistics?

The School offers both Honours and Postgraduate Diploma programs of study, which can be undertaken under Science or Arts. The most appropriate program is best decided on a case-by-case basis which you should discuss with the 400 level Coordinator, Dr Mark Hickman. The following guide provides some general advice about your options. You are welcome to get in touch as soon as possible, but you must do so before the formal enrolment period. If you are undertaking honours, you must have arranged a supervisor of your project in advance of enrolment. The 400 level coordinator can help you with this.

In addition, we also offer a Postgraduate Certificate in Arts for students interested in a 60 points programme of study, or a Certificate of Proficiency for undertaking a course or courses of interest.

Who should think about Honours? If you view Mathematics/Statistics as more than a means to an end, then doing Honours will be a year well spent. In addition to taught courses, the honours program has a full year 30 point project which will not only deepen your understanding of a specialised topic but will also develop many of the soft skills desired by employers or for further Postgraduate study, like self-motivation, independent learning, research, written and oral communication.

The Honours subject majors are listed below. Formal details are in the UC Calendar. To enter Honours in Mathematics, you will need at least 60 points from MATH301-394, plus at least 30 points from 300-level MATH, STAT or other approved courses. For Honours in Statistics, you need at least 60 points of 300-level STAT301-394, plus at least 30 points from 300-level STAT, MATH or other approved courses. Normally you will have maintained at least a B+ average in these papers.

BSc (Hons) Major Subjects

In the Science faculty, Honours from our School may be completed in:

- Mathematics and/or Statistics, see Dr. Mark Hickman;
- Mathematical Physics, see Prof. David Wiltshire (Physics);
- Compuational and Applied Mathematical Sciences, see Assoc. Prof. Rick Beatson;
- Mathematics and Philosophy, see Dr Clemency Montelle;
- Finance and Mathematics, see Assoc. Prof. Rua Murray;
- Finance and Statistics, see Assoc. Prof. Marco Reale; or
- Financial Engineering, see Assoc. Prof. Marco Reale.

These Honours programs typically require completion of papers totalling 120 points at 400 level or above (typically eight 15 point courses), as well as a 30 point MATH/STAT/CAMS449 project.

BA (Hons) Major Subjects

In the Arts faculty, Honours from our School may be completed in Mathematics or Statistics with similar requirements to the BSc (Hons).

Who should think about a Postgraduate Diploma? The Postgraduate Diploma can consist entirely of taught courses, as there is no requirement that any project is undertaken. The entry requirements are as for Honours, except that you are not required to have a B+ average. It is very strongly recommended that your average grade in your majoring subject at stage 3 is at least a C+. The PGDipSc can also be used as Part I of a two part research MSc.

PGDipSci and PGDipArts Major Subjects

In both the Science and Arts faculty the Postgraduate Diploma can be taken in mathematics or statistics, which require completion of papers totalling 120 points at 400-level or above (typically eight 15 point courses).

Masters in Applied Data Science

Data science is a new profession emerging along with the exponential growth in size, and availability of 'big data'. A data scientist provides insight into future trends from looking at past and current data. Data science is an essential skill in a world where everything from education to commerce, communication to transport, involves large scale data collection and digitalisation. New Zealand and other countries are currently experiencing a skills shortage in this area, and the need for data savvy professionals with applied experience is growing.

This 180 point conversion master's is designed to accommodate students from a range of undergraduate backgrounds (not just those with Mathematics, Statistics and Computer Science majors), who want to enhance or build their data science capabilities and combine these with the skills and knowledge they bring from their previous studies. So long as you are data-hungry and industry-aware; this degree can add to your employability and career prospects.

Masters in Financial Engineering

Financial engineering is a cross-disciplinary field combining financial theory, mathematics, statistics and computational tools to design and develop new financial or actuarial products, portfolios and markets. It also has an important role to play in the financial industry's regulatory framework. Financial engineers manage financial risk, identify market opportunities, design and value financial or actuarial (insurance) products, and optimize investment strategies.

The year long 180 point program consists:

- 135 points from taught courses. There is a core set of required courses in finance, mathematics & statistics and computer science. Further, there are a suite of suggested courses from these topic areas, that make up the majoring subject of Financial Engineering. Depending on your prior education, it is envisaged that around half of the taught courses will be MATH400 or STAT400 papers and the other half will be FINC600 papers; and
- the 45 point paper FENG601 Application of Financial Engineering which provides the opportunity to apply the techniques learned through the programme to real-world financial engineering problems.

There are minimum entry requirements into the program, which if not met you will be required to take FIEC601 in January-February prior to commencement of the program proper. You will be required to complete COSC480 Introduction to Programming, if you do not have equivalent programming skills (e.g. from COSC121, MATH170, EMTH171 or STAT221). Full details are provided in the UC Calendar.

Research Masters

A research Masters in Science (MSc) or Arts (MA) consists of two parts:

- Part I - a 120 points of papers (typically eight 15 point courses); and
- Part II - a 120 points research thesis.

Students can enter directly to Part II, if they have completed a Postgradute Diploma or Honours degree in the same majoring subject. For full details see the UC Calendar.

Our School offers the research MSc and MA in mathematics or statistics. An MSc is also offered in computational and mathematical sciences. Enrolment in a Master's programme requires approval from the Postgraduate Coordinator, Dr Miguel Moyez-Gonzalez. At least one staff member must have agreed to supervise your Part II research study before approval of your programme of study.

PhD Research

The PhD programme is the highest degree offered in UC. How do you know if you are ready to purse a PhD in any of the following subjects we offer?

- mathematics;
- statistics;
- computational and applied mathematical sciences (CAMS);
- mathematical physics; and
- mathematics and philosophy.

The simplest answer is: if you are passionate about a subject and you want to get a deeper understanding of a field of study or want to use sophisticated tools from mathematical sciences to solve real world problems, then you are ready!

If you want to upscale your knowledge in the subject you love then a PhD in mathematics or statistics is the programme for you. On the other hand, if you have an interdisciplinary project in mind then a PhD in CAMS could be a good option for you.

Further details are available from the PG Office website, including scholarship information, here: `http://www.canterbury.ac.nz/postgraduate/phd-and-doctoral-study/` Excellent performance in a BSc (Hons) or BA (Hons) may provide sufficient training to undertake a PhD, thus obviating the need for a Masters degree. However, a PGDipSc or PGDipArts would not normally be sufficient.

400-LEVEL COURSES

The proposed courses for 2017 are outlined in this booklet. The final decision about which courses are to be offered will depend on the availability of staff and on student interest. The School reserves the right to cancel any course that does not attract four or more students, which will be determined at the beginning of each semester.

It is also possible (and often desirable) to include courses from other subjects, see the Regulations in the Calender for details with each degree. Note that any STAT courses may be included in a Mathematics degree and vice versa.

Some of our 400-level courses are dual-coded with the corresponding 300-level courses for which those on offer in 2017are:

- MATH439/MATH321 Rings and Fields;
- MATH433/MATH380 Mathematics in Perspective;
- MATH443/MATH343 Metric, Normed and Hilbert Spaces;
- MATH414/MATH353 Computational Methods/Computational Mathematics and Applications;

- STAT455/STAT312 Data Collection and Sampling Methods;
- STAT461/STAT314 Bayesian Inference;
- STAT463/STAT315 Multivariate Statistical Methods;
- STAT456/STAT317/ECON614/ECON323 Time Series and Stochastic Processes;
- STAT462/STAT318 Data Mining; and
- STAT446/STAT319 Generalised Linear Models.

On these dual coded courses, you will attend the same lectures and tutorials/labs as the 300 level students, but will be assigned additional coursework and assessment to achieve the NZQF Level 8 standard. Students who have done, or are doing, the 300-level course cannot do the corresponding 400-level course.

Mathematics

MATH401 **15 points**
Dynamical Systems 1
MATH401-17S1 (C)

Dynamical systems is a rapidly developing branch of mathematics with applications in diverse fields including numerical analysis, biological systems, economic models and medicine.

It is often difficult or impossible to write down an exact solution to systems of nonlinear equations. The emphasis in this course will be on qualitative techniques for classifying the behaviour of nonlinear systems, without necessarily solving them exactly. Two main types of dynamical system will be studied: discrete systems, consisting of an iterated map; and continuous systems, consisting of nonlinear differential equations. Topics covered will include: chaotic behaviour of simple 1D maps; period-doubling bifurcations; phase portrait analysis; methods for determining stability of fixed points and limit cycles; centre manifolds; and symbolic dynamics.

Enquires: Rua Murray

MATH406 **15 points**
Mathematical Models in Biology
MATH406-17S1 (C)

What's the best way to find your keys? Why should children be vaccinated against measles? How does a bird's wing flapping frequency relate to its size? This course will try to answer these (and other) questions by using mathematical models to examine biological phenomena. In achieving this we will study: deterministic and stochastic population dynamics, foraging theory, infectious disease spread, dimensional analysis, and asymptotic analysis.

A well-rounded selection of MATH300 courses and a familiarity with `Maple` or `MATLAB` (or equivalent) are useful prerequisites to this course

Enquires: Alex James or Phil Wilson

MATH407 **15 points**
Special Topic - Stochastic Processes
MATH407-17S2 (C)

The theory and application of stochastic processes.

Term 3 (Michael Plank): probability theory, continuous random walks, Poisson and pure-birth processes, Markov processes.

Term 4 (Mike Steel):, random graphs, probabilistic method, information theory, branching processes, Polya-urn models, Martingales

Enquires: Michael Plank and Mike Steel

MATH410 **15 points**
Approximation Theory
MATH410-17S2 (C)

Approximation theory lies at the interface of many specialties. As such its study involves an interesting mix of pure and applied mathematics. At the pure end it is the study of the properties certain spaces of functions. Examples being polynomials, splines radial basis functions and Bézier surfaces. At the applied end it is the construction of algorithms to enable efficient use of these spaces of functions in practical problems.

Recent applications of Approximation Theory here at UC include fitting surfaces to noisy point clouds, applied to the custom manufacture of artificial limbs, and fitting geophysical data sets such as gold grade measurements from drill holes in mines.

The first part of this course will concentrate on the fundamentals of approximation of functions of one variable. Central topics will be approximation by algebraic and trigonometric polynomials, and the existence, characterisation and uniqueness of best approximations from finite dimensional normed linear spaces.

In the latter part of the course we will develop some more recent topic. The exact topic will be chosen by the class. Examples of possible topics are radial basis functions, the use of Bézier surfaces in modeling, and penalized least squares and L_1 methods for modeling noisy data.

Enquires: Rick Beatson

MATH411 **15 points**
Topics in Algebra
MATH411-17S1 (C)

The focus of this course is Galois theory, which provides a beautiful connection between field theory and group theory. It can be used to reduce certain problems about fields to group theory which is, in some sense, simpler and better understood. Topics in the theory of finite groups will be covered as needed. Goals of the course include proofs of the Abel-Ruffini Theorem (concerning insolubility of a general quintic equation by radicals) and the Fundamental Theorem of Algebra. Useful prerequisites are MATH240 or MATH321, and ideally both.

Enquires: Brendan Creutz

MATH412 **15 points**
Unconstrained Optimization
MATH412-17S1 (C)

This course looks at the minimization of smooth functions of several variables. The first part of the course examines gradient based methods using line searches, including Newton, quasi-Newton, and conjugate gradient methods. A selection of other topics is then introduced, including trust region methods and methods for constrained optimization. Demonstration software is used to illustrate aspects of various algorithms in practice.

Enquires: Rachael Tappenden

MATH414 **15 points**
Computational Methods
MATH414-17S1 (C)

This course looks at a variety of algorithms for solving important computational problems that arise in science, engineering, and commerce. Topics covered include an introduction to the numerical solution of partial differential equations, and numerical methods for the eigenvalue problem. Other topics include the Fast Fourier Transform, and numerical approximation techniques.

See MATH353.

Enquires: Miguel Moyez-Gonzalez

MATH420 **15 points**
Hilbert Spaces
MATH420-17S2 (C)

The theory of Hilbert spaces is fundamental in many areas of modern mathematical analysis, having a clear and easy-to-grasp geometric structure, just like Euclidean spaces. However, unlike Euclidean spaces, Hilbert spaces may be infinite dimensional. The course will be self-contained, introducing important spaces (especially L2(m)), operators on them, and basic spectral theory. Prior exposure to MATH343 would be an asset, but is not mandatory.

Enquires: Hannes Diener

MATH427 **15 points**
Lie Groups and Lie Algebras
MATH427-17S1 (C)

Lie groups are an essential tool in many areas of mathematics and physics. They are often found as groups of symmetries of 'nice' mathematical objects like geometries or dynamical systems. The most important Lie groups are finite-dimensional and occur as groups of matrices over real or complex numbers. For example, the group $SO(3)$ of all rotations of Euclidean 3-space or its closely related groups $SU(2)$ and $Spin(3)$ are Lie groups. One is interested in their properties and how these groups can be realised in higher dimensions.

Every Lie group has an associated Lie algebra which is a very good linear approximation of the group. Many properties of the Lie group can be deduced from its Lie algebra.

This course gives an introduction to the basic theory of finite-dimensional Lie groups and their associated Lie algebras and linear representations.

Enquires: Gunter Steinke

MATH429 15 points
Combinatorics
MATH429-17S1 (C)

Matroids (combinatorial geometries) are precisely the structures that underlie the solution of many combinatorial optimisation problems. These problems include scheduling and timetabling, and finding the minimum cost of a communications network between cities. Matroid theory also unifies the notions of linear independence in linear algebra and forests in graph theory as well as the notions of duality for graphs and codes. This course is an introduction to matroid theory and is designed for mathematics and computer science students.

Enquires: Charles Semple

MATH431 15 points
Special Topic - Graph Theory
MATH431-17S2 (C)

In a nutshell, graphs are mathematical structures which model relationships between objects. Graph theory is the branch of combinatorics concerned with their study, and has grown to become a very rich and diverse discipline in its own right. It has applications in almost every scientific field, from analysing the spread of epidemics to modelling social networks.

In this self-contained course we will explore a range of topics from graph theory, considering both theory and applications. The course is intended for students majoring in Mathematics or Computer Science. Does not require MATH120 or MATH220.

Enquires: Jeanette McLeod

MATH433 15 points
Mathematics in Perspective
MATH433-17S1 (C)

What is Mathematics? What are some of the key moments in the history of Mathematics? What kinds of mathematical result are considered important, and why?

This course is about the history, philosophy, people and major results of Mathematics over the centuries. Since we will minimise the attention paid to technical details, the course should be accessible not only to those with a 200 level Mathematics background, but also to intellectually mature students in Philosophy and related subjects. In particular, it is strongly recommended for anyone who intends teaching Mathematics at any level from primary school onwards.

See MATH380.

Enquires: Clemency Montelle

MATH438 **15 points**
Special Topic - Advanced Complex Variables
MATH438-17S2 (C)

This is a second course in complex variables that introduces the student to some beautiful results and important applications of complex analysis. Topics covered include: Liouville's theorem, open mapping theorem, Cassorati-Weierstrass theorem, argument principle, Rouché's theorem, maximum modulus principle, Schwarz's lemma, normal families, Riemann mapping theorem. Additional material (time permitting) may be chosen from the following: infinite products, Runge's theorem, univalent functions, subharmonic functions, value distribution theory, Hardy spaces.

Enquires: Ngin-Tee Koh

MATH439 **15 points**
Rings and Fields
MATH439-17S1 (C)

This course formally introduces rings and fields, which have been encountered at 100- and 200-level in special situations, and investigates their algebraic structure. It gives a deeper understanding of these algebraic concepts and thus provides a thorough grounding in the algebraic theory which underpins modern applications like cryptography, error-correcting codes, number theory or finite mathematics. If you are interested in any of these subjects or if you want to see how algebraic theory can be applied to solve certain geometric construction problems or prove their impossibility, then this is the course to take.

See MATH321.

Enquires: Gunter Steinke

MATH442 **15 points**
Special Topic - Number Theory
MATH442-17S2 (C)

Number Theory is the study of properties of the integers. Building on only basic knowledge of prime factorization and modular arithmetic (from MATH120) we will study further properties of the whole numbers. The course will cover the following topics: Solutions of quadratic congruences, quadratic residues and the quadratic reciprocity law. The latter relates the question of whether p is a square $\mod q$ to whether q is a square $\mod p$, for primes p and q and is a pivotal result that has motivated a lot of modern number theory. Representation of integers as sums of squares, in particular we'll prove Fermat's theorem that primes congruent to $1 \mod 4$ are a sum of two squares and Lagrange's theorem that every integer is a sum of four squares. We will also study quadratic Diophantine equations in some generality. We will study some other topics, such as distribution of primes if time permits.

Enquires: Felipe Voloch

MATH443 **15 points**
Metric, Normed and Hilbert Spaces
MATH443-17S1 (C)

This course introduces those parts of modern analysis that are essential for many aspects of Pure and Applied Mathematics, Physics, Economics, Finance, and so on. For example, if you want to understand the convergence of numerical algorithms, approximation theory, quantum mechanics, or the economic theory of competitive equilibrium, then you will need to know something about metric, normed and Hilbert spaces.

See MATH343.

Enquires: Hannes Diener

MATH449 **30 points**
Project
MATH449-17W or CY (C)

A whole year research project in mathematics (see Honours projects).

Enquires: Mark Hickman

MATH475 **15 points**
Independent Course of Study
MATH475-17S1 or S2 (C)

This course allows a student to perform directed reading of a particular topic under a Mathematics lecturer. The topic choice is by mutual arrangement with the lecturer. Students should ensure these arrangements are in place before enrolling in the course.

Enquires: Any mathematics Lecturer

MATH491 **15 points**
Research Project
MATH491-17SU2 and A (C)

This 150 hour course provides students with an opportunity to develop mathematical or statistical research skills to extend and strengthen their understanding of an area of mathematics or statistics. Students will be involved in a research project with a supervisor. The project will be closely aligned with the supervisor's existing research programme.

The research project cannot be used towards your degree requirements, but does contribute to your GPA.

Enquires: Jeanette McLeod

Data Science

DATA401 **15 points**
Statistics
DATA401-17S1, S2 or SU (C)

This course covers the development of statistical concepts and their application to complex systems. This course is one of the foundation courses that applied data science students may be required to enrol in.

Enquires: Jennifer Brown

Statistics

STAT445 **15 points**
Financial Time Series
STAT445-17S2 (C)

In many applications, in particular in finance and economics, observed data series often exhibit a behaviour which cannot be modelled with linear time series models (i.e. ARMA processes). Thus alternative models allowing for a nonlinear behaviour are called for and are successfully used. For instance, Robert Engle was awarded the Nobel Prize in 2003 for introducing the so-called (G)ARCH model. In this course we will first review some materials on linear time series methods, then consider and analyse several classes of nonlinear time series models, such as GARCH, Markov-switching as well as threshold autoregressive time series models. We study their common probabilistic and statistical concepts and theory (Markov chains with uncountable state space, stochastic recurrence equations, ergodicity and mixing). Finally, we will derive and apply estimators for the model parameters.

STAT445 course is required for the BSc (Hons) in Financial Engineering.

Enquires: Marco Reale

STAT446 **15 points**
Generalised Linear Models
STAT446-17S1 (C)

STAT319 and STAT446 are courses in Generalised Linear Models (GLM), suited to anyone with an interest in analysing data. In these courses we introduce you to the components of GLM and other advanced data analysis techniques. We cover analysis of data from continuous distributions, models for binomial response data, models for count response data and models for multinomial data. `R` is the free-ware equivalent to `S-Plus`, and is becoming the preferred computer package for many statisticians. In these courses we will show you how to use the package, enter, manipulate and analyze data in `R`. Suited to anyone with an interest in analysing data.

Enquires: Jennifer Brown

STAT447 **15 points**
Official Statistics
STAT447-17S2 (C)

This course provides an overview of the key areas of Official Statistics. Topics covered include data sources (sample surveys and administrative data); the legal and ethical framework of official statistics; an introduction demography; the collection and analysis of health, social and economic data; data visualisation including presentation of spatial data; data matching and integration; the system of National Accounts.

STAT447 is co-taught via our School's video-conference facilities between experts at NZ universities.

Enquires: Jennifer Brown

STAT448 **15 points**
Big Data
STAT448-17S1 (C)

STAT448 is suited to anyone with an interest in data, and how it can be used in decision making. In this course we introduce you to big data and some of the techniques you can use to access, explore and investigate it. Students enrolling in this course should be familiar with statistics and with programming.

STAT448 is co-taught via our School's video-conference facilities between experts at NZ universities.

Enquires: Jennifer Brown

STAT449 **30 points**
Project
STAT449-17W (C)

A whole year research project in Statistics (see Honours projects).

Enquires: Elena Moltchanova

STAT450 **15 points**
Advanced Statistical Modelling
STAT450-17S1 (C)

This course provides an introduction to a range of statistical techniques used in the analysis of spatial data. It will cover the basic concepts and techniques of spatial data analysis (SDA) and provide a wide range of applications examples from various fields such as geology, demographics, epidemiology and environmental sciences. A comprehensive lab programme uses a variety of software packages (including `ArcGIS`, `Geoda`, `geoR` and `WinBUGS`) to explore and analyse spatial data using the techniques taught in the course.

STAT450 is dual coded with GISC404.

Enquires: Elena Moltchanova

STAT451 **15 points**

Survival and Longitudinal Data Analysis

STAT451-17S1 (C)

Failure in mechanical systems, death or disease in biological organisms, occurrence of historical events - all these can be analysed using the branch of statistics known as survival analysis. The course will cover various censoring mechanisms, exploratory analysis and visualisation of event data, and various ways to model them, including Kaplan-Meier estimators, Cox regression, hierarchical models, and change-point analysis. R will be used for analysis of datasets from varying fields including epidemiology, engineering, biology and sociology. Students are encouraged but not required to know R beforehand.

Enquires: Daniel Gerhard

STAT455 **15 points**

Data Collection and Sampling Methods

STAT455-17S1 (C)

STAT312 and STAT455 are courses in survey methods, concentrating mainly on sample designs. The course is designed to give students an understanding of how to select samples from various types of populations of varying characteristics and produce population estimates along with measures of uncertainties in those estimates. Also you will gain some insights in the practical applications of the design of survey collections.

Richard Penny, one of the lecturers for this course, has worked for many years designing samples and surveys for Statistics New Zealand.

Enquires: Blair Robertson

STAT456 **15 points**

Time Series and Stochastic Processes

STAT456-17S2 (C)

STAT317/ECON323 and STAT456/ECON614 are courses in Time Series Analysis. These courses introduce to the analysis of repeated observations over time, a type of data extremely common in every discipline.

These courses are suited to anyone with an interest in analyzing data. We cover a wide range of topics, from the basic decomposition of a time series to advance topics such as spectral analysis. The methods explained during the lectures are complemented by practical computer lab tutorials which make use of the software R, one of the preferred computer packages by many statisticians. In these courses we will show you how to use the package, enter, manipulate and analyze time series data in R.

Enquires: Marco Reale

STAT461 **15 points**

Bayesian Inference

STAT461-17S2 (C)

STAT314 and STAT461 introduce the Bayesian approach to Statistics using elementary parametric models and inference problems. Usually, these are the Bernoulli, Poisson, normal and linear regression models used in problems such as parameter estimation, hypothesis testing, model selection and prediction. Some comparisons with results from the frequentist approach, will be made to illustrate similarities and differences between the two approaches.

Enquires: Elena Moltchanova

STAT462 **15 points**
Data Mining
STAT462-17S2 (C)

STAT318 and STAT462 are courses in statistical learning and data mining, suited to anyone with an interest in analysing large datasets. The courses will introduce a variety of statistical learning and data mining techniques for classification, regression, clustering and association purposes. Possible topics include, classification and regression trees, random forests, A-priori algorithm, FP-growth algorithm and support vector machines. The lectures will be supplemented with laboratory sessions using the statistical software package `R`.

Enquires: Blair Robertson

STAT463 **15 points**
Multivariate Statistical Methods
STAT463-17S1 (C)

STAT315 and STAT463 are courses in multivariate statistical methods. Multivariate statistical methods extract information from datasets which consist of variables measured on a number of experimental units. Due to the large memory capacity available and with the advent of computing power, these methods are now widely applied in a variety of fields, including bioinformatics, epidemiology, finance and marketing.

The course will cover the theory and application of various multivariate statistical methods, namely: multiple regression, principal component analysis, factor analysis, discriminant analysis, and clustering methods.

It will also introduce the statistical analysis software `SAS`, which is a powerful tool when dealing with large multivariate datasets. `R`-syntax will also be briefly explained. Special attention will be given to practical applications and the interpretation of the results.

Enquires: Daniel Gerhard

STAT464 **15 points**
Statistical Inference
STAT464-17S1 (C)

Advanced likelihood inference.

STAT464 course is normally required for the BSc (Hons) and BA (Hons) in Statistics if you have not taken STAT213.

Enquires: Raaz Sainudiin

STAT472 **15 points**
Special Topic in Statistics - Advanced Data Analysis and Statistical Consulting
STAT472-17S2 (C)

In most undergraduate courses, you are taught the theory behind a method and then given neat examples to which it can be applied and software to apply it. In reality, the most common question you will hear from a non-statistician is ’how do I analyse my data? So you are the one who has to come up with the appropriate research question and choose the suitable method (and sometimes learn it quickly too) . It is common in real world applications for the experiments have not been well planned and for data to be missing, which will need to be taken it into account. The assumptions underlying the statistical model (e.g. homoscedasticity and normally distributed) often do not hold and you will have to know what to do. Finally, your fellow scientists, laymen and policymakers are all interested in different aspects of the research question and that is rarely the statistical significance of your

ANOVA: you have to know how to communicate your results clearly, correctly and efficiently and how to defend your choices in data analysis and collection.

This course is about the reality of being an applied statistician. Besides covering the above points in class, individual statistical consulting session will provide you with hands-on experience.

Good knowledge of multivariate statistical methods, GLMs, and basic sampling theory expected. Working knowledge of `R` is recommended.or forecasting methods. It provides extensive training in forcasting and modelling techniques such as smoothing, dynamic regressions, multivariate autoregressions, state space models, and neural networks with a wide range of applications.

Enquires: Elena Moltchanova

STAT475 15 points
Independent Course of Study
STAT475-17S1 or S2 (C)

This course allows a student to perform directed reading of a particular topic under a Statistics lecturer. The topic choice is by mutual arrangement with the lecturer. Students should ensure these arrangements are in place before enrolling in the course.

Enquires: Any Statistics Lecturer

STAT478 15 points
Special Topic - Scalable Data Science
STAT478-17S1 (C)

Scalable data science is a technical course in the area of Big Data, aimed at the needs of the emerging data industry in Christchurch and those of certain academic domain experts across UC's Colleges, including, Arts, Science and Engineering. This course uses `Apache Spark`, a fast and general engine for large-scale data processing via databricks to compute with datasets that won't fit in a single computer. The course will introduce SparkâĂŹs core concepts via hands-on coding, including resilient distributed datasets and map-reduce algorithms, data frames and `Spark SQL` on catalyst, scalable machine learning algorithms and vertex programs using the distributed graph processing framework of `graphX`. We will solve instances of real-world big data decision problems from various scientific domains.

Enquires: Raazesh Sainudiin

STAT491 15 points
Research Project
STAT491-17SU2 or A (C)

This 150 hour course provides students with an opportunity to develop mathematical or statistical research skills to extend and strengthen their understanding of an area of mathematics or statistics. Students will be involved in a research project with a supervisor. The project will be closely aligned with the supervisor's existing research programme.

The research project cannot be used towards your degree requirements, but does contribute to your GPA.

Enquires: Jeanette McLeod

400-Level Projects

A broad range of possible projects are outlined below. However, this list is not exhaustive and other possibilities for projects are certainly possible. Project supervision is by mutual agreement of the supervisor and student. You should arrange your project by the end of the first week of term in 2017. It is suggested that you seek out possible supervisors before enrolment week.

You will hand in a written report on September 21 2017, which will contribute 80% of the grade; the remaining 20% will be an oral presentation in Term 4.

Projects in Mathematics

Algorithms for tangent plane continuous surface fitting
Rick Beatson

This project considers the fitting of tangent plane continuous surfaces to points and normals data sets. The end goal is to efficiently model underground rock formations, and other blobby shapes, occuring in applications. The project will build on an existing algorithm which uses quintic Bézier elements.

There are diverse aspects that could be considered. An algorithmic aspect is to consider and experiment with some local optimisation steps, which would be used to improve a given fit when the normals are noisy.

Another aspect is to recast the current theory in terms of a different parametrisation of the Bézier elements. This would quite probably give rise to a cleaner theory, and probably a more efficient implementation.

Finally, on the implementation end, a core task in the current code is to solve a sparse semi-definite system. The current solver is crude. The theory and implementation of a more efficient solver would be an interesting task for someone who enjoys numerical analysis, and wants to experiment with parallel algorithms.

A Mathematical Approach to Optimal Filtering
Miguel Moyers Gonzalez, Rua Murray and Phil Wilson

Porous media are materials composed of a network of pores in a solid matrix. They are important for a large range of real life applications in the oil, gas and process industries, structured lightweight materials, and studies of flow properties. 3D printers offer the opportunity to control the size, shape and location of the voids in the porous morphology. The goal of the project is to develop and study a mathematical approach to the different geometrical morphologies that can be theoretically designed in porous media. The problem can be formulated as an optimal control problem and will be studied using `MATLAB` or an equivalent.

Random Dynamical Systems
Rua Murray

Random dynamical systems are obtained by coupling a known family of deterministic systems to a driving stochastic process. The resulting behaviour is one kind of "non-autonomous dynamics". For deterministic dynamics, questions as simple as "how do you define an attractor?" have fairly straight-forward and unambiguous answers. However, in the random setting, the answers are more complicated and interesting. This project will investigate ergodic properties of random dynamical systems, focussing particularly on what insights “random transfer operators” can give about the behaviour of random dynamical systems. Some numerical calculation in `MATLAB` (or similar) will be required. Applications include mass transfer/mixing in nonlinear fluid flows.

Chaos and Communication
Rua Murray

One of the more surprising applications of chaos theory is to the encryption of signals. The idea is that the inherent unpredictability in a chaotic time series can be exploited to encode and communicate messages in a way that is secure, and decipherable after transmission via a noisy radio channel. This project will build on practical work done at UC’s Spatial Engineering Research Centre, and can be co-supervised by Dr Branislav Jovic (NZ Defence Technology Agency).

Integer Optimization
Chris Price

Discrete optimization has a number of important applications including scheduling tasks, choosing the most efficient routes for delivery vehicles, facilities location, rostering, and satisfying a set of logical constraints. Such problems can be written as optimization problems with integer (or sometimes a mix of integer and real) variables. A variety of solution methods exist for such problems, including those using branch and bound techniques, and cutting planes.

This project is to examine common types of discrete optimization problems, and how they can be solved using methods such as those listed above. MATH303 is recommended.

Computational Optimization and Applications
Rachael Tappenden

Optimization plays a crucial role in many modern, real-world applications, from finance to medical imaging, and from scheduling problems to big-data. Below is a list of several projects that students may be interested in working on.

- Portfolio Optimization: Given some initial budget, and a basket of financial instruments (stocks, bonds, etc), how should one allocate their funds in order to maximize their expected profit? Two questions that one may wish to answer are: (i) What kinds of algorithms can be used to efficiently solve such problems, and (ii) There are many ways of modeling portfolio optimization problems, but what is ‘best’?

- Medical Imaging and Optimization: For many imaging modalities, including Computed Tomography (CT) and Magnetic Resonance Imaging (MRI), one must solve an ‘inverse problem’ to obtain an image. In this project we will investigate CT image reconstruction. We will see that the CT ‘inverse problem’ often involves the solution of a large linear system of equations, and the student will investigate algorithms for solving such systems.

- There are many other projects that may be of interest to students. General topics include: solving large scale linear systems efficiently, algorithms for determining the eigenvalues of large, sparse matrices, and algorithms for big-data problems. See me for further details.

For these projects, it would be helpful if the student had some knowledge of `MATLAB` and of applied linear/matrix algebra.

Computing the Infinite

Hannes Diener

Since most mathematical objects are ideal/infinite, but computers can only ever deal with discrete/finite objects, it seems that we almost always have to confine ourselves to using approximations and shadow types (such as 'float' instead of the reals, or 'int' instead of the natural numbers) when transferring mathematical ideas to a computer.

Surprisingly though, it is possible to compute with (a large class of) infinite subsets of natural numbers, real numbers, and so on, not just as approximations, but as the actual objects.

In this project a student should investigate some of the mathematical background of such an approach, and ideally implement some of the ideas. Depending on the student's background the project can either focus on the theoretical mathematical foundations, or on the practical implementation. For the first a background in logic is welcomed (for example MATH130, 230, or 336), for the second some familiarity with a programming language which allows elements of 'functional programming' (such as `Python`, `Haskell`, `C++`) is useful.

Ecological Networks

Alex James

From the Amazon rainforest to the Okeover stream species interact with each other in complex systems. These interactions come in many forms: competitive - they both compete for the same resource, predator-prey - eat or be eaten, mutualistic - both benefit from the relationship. How does the architecture of these interactions affect the behaviour of the system? Should a species interact with as many others as possible? Should they form groups or cliques? Is there a conflict between good for an individual and good for the system?

Useful pre-requisites for this project could include dynamical systems, discrete maths and some `MATLAB` or other computer programming. An interest in ecology is also helpful.

I also have other projects available that combine maths and ecology. Please contact me to find out more.

Modelling Collective Cell Movement

Mike Plank

Collective cell behaviour is the driving force behind many physiological processes, including embryonic development, tissue repair and tumour growth. Experiments on collective cell behaviour typically collect data at the level of the population rather than the individual cell. WeâĂŹd like to be able to translate data from observing populations of cells into knowledge about how individual cells work and how they interact with their neighbours. This project will approach this problem using approximate Bayesian computation (ABC). At its simplest, this involves sampling model parameters from a prior distribution and simulating cell behaviour. If the model output is "close" to the experimental data, the parameter values are accepted as part of the posterior distribution, otherwise they are rejected. This will be used to estimate quantities such as cell proliferation and movement rates and the strength of interactions with neighbouring cells.

This project will require some experience of a computer programming language, e.g. MATLAB and an interest in working with biological data. Prior knowledge of Bayesian statistics is NOT required.

Smaller Fish to Fry?
Mike Plank

Modern fisheries management is almost universally based on the principle of protecting small fish from capture and targeting large fish. Fisheries that do no conform to this dogma, such as small-scale African fisheries, are seen as destructive. But mathematical modelling and empirical experience has shown that, actually, these fisheries can be more sustainable than you might expect. The aim of this project is to investigate the optimal size of fish to catch from the point of view of an individual fisher. This is a game theoretical problem, because the choices made by one fisher can affect the fish population, and therefore the outcomes for other fishers. Of primary interest is the question: if each individual fisher behaves so as to maximise his/her own yield, what does the aggregate fishing pattern look like across the whole fishery? Are regulations needed to stop the fishers driving the fish population to extinction and/or driving each other to economic penury? Or can a self-organising group of individual fishers be ecologically and economically sustainable?

This project will require some experience of a computer programming language, e.g. MATLAB and an interest in using mathematical models to investigate problems in ecology, sociology or economics.

Phylogenetic Networks
Charles Semple

Phylogenetic networks generalise phylogenetic (evolutionary) trees by allowing for non-treelike evolutionary events such as lateral gene transfer and recombination. The mathematical study of phylogenetic networks is recent and, arguably, no more more that fifteen years old. From a mathematical viewpoint, phylogenetic networks are simply rooted acyclic directed graphs. Many questions concern the structural properties of phylogenetic networks such as how hard is it to decide if a given tree is embeddable in a given network, and when is a network determined by its path-length distances? In this project, we investigate these and other related questions. There are no prerequisites for the project.

Negative Correlation
Charles Semple

It follows from the work of Kirchhoff (1847) that the spanning trees of a connected graph G are negatively correlated. That is, for edges e and f of G, it is more likely that a spanning tree chosen at random contains e than one that contains e knowing that it also contains f. This seems intuitively clear but, nevertheless, still requires proof. What if, instead of choosing a spanning tree, we choose a forest at random? Does the analogous result still hold? The purpose of this project is to explore this question and related problems. While some knowledge of graph theory would be helpful, it is not a prerequisite for the project.

Topology (via Uniform Spaces)
Hannes Diener

A topological space is the most general notion of a space in mathematics. Even though topological spaces are governed by only three axioms many ideas of analysis, such as continuity and compactness, can be easily formulated in topology. In fact, many complicated and intricate ε-δ proofs actually become simpler once formulated in the language of topology.

In this project you will familiarise yourself with the basic ideas of a topology and then study uniform spaces, which are slightly less general than topological spaces, but allow one to talk about notions like uniform continuity and uniform convergence.

A background in either MATH336 or MATH343 would be helpful, but is not required.

How to have your cake and eat it too, and other mathematical delicacies
Gunter Steinke

It seems quite simple: cut your cake in little pieces and reassemble them into two cakes each the size of the original one. Then you can eat one and keep the other. If this sounds too good to be true it is — for real life cakes that is. However, for mathematical cakes with all the intellectual nourishment they provide this can be done.

Constructions like this in which sets in n-pace can be partitioned into subsets which, after certain transformations, can be rearranged to yield sets with very different properties, are known as paradoxes (in particular, the Banach-Tarski Paradox). The construction will depend on the transformations one is allowed to use, and one typically has a group involved.

For example, the project may look at sets that when reassembled produce two copies of themselves and ways to reassemble a disk into a square of equal area using rigid motions.

Why has n-space $\mathbb{R}^n$ dimension n?
Gunter Steinke

While one has a precise notion of dimension for vector spaces, there often is an intuitive understanding of the dimension of a space (not necessarily a vector space) as the number of coordinates or parameters used to describe the space. However, this notion proved to be imprecise as discoveries in the early 20th century showed. There exist bijections between a line and a plane and also continuous maps from the unit interval onto the unit square. This led to the question of whether or not m-space and n-space can be *topologically* the same for different m and n. To answer this question various topological invariants have been devised.

Obviously, any useful invariant should assign n-space dimension n. While it is often easy to verify that n-space has dimension at most n, it is harder to establish equality.

The project investigates some possible definitions of the dimension of a (metric) space, their properties, when these dimensions agree and what examples of topological spaces there are for which they are different.

The Mathematics of Natural Disasters
Phil Wilson & Miguel Moyers-Gonzalez

Geologic processes can adversely impact human life and infrastructure, representing a significant risk to national security. For example, volcanic ash can choke emergency generators, pollute reservoirs, and damage hydroelectric turbines. This project will model selected aspects of natural disasters using mathematical and numerical techniques. The aim is to better understand the underlying physical processes in order to mitigate their consequent adverse effects. The project is part of a broader inter-disciplinary research group. The ideal candidate would have a good background in PDE's and MATLAB, but all applicants will be considered.

In a Spin: Identifying Vortices with Coherent Sets
Rua Murray, Miguel Moyers-Gonzalez & Phil Wilson

The biggest unsolved problem in classical physics is the mystery of turbulence. Still poorly understood, turbulent flows are ubiquitous and important. The key mechanism of turbulence is known to be energy transfer between spinning vortices of different sizes. This project aims to build towards a better understanding of vortices in both turbulent and laminar flows. We will use dynamical systems techniques to identify and characterise coherent structures in flows. A background and interest in dynamical systems and PDEs is useful, as is some computational experience.

Projects in Statistics

Environmental Statistics
Jennifer Brown

Environmental monitoring is a fast moving, and important field of research. Data on environmental processes such as changes in water quality, endangered species distribution, weed invasion, and biodiversity are used to inform and guide how we manage our environment.

One use of environmental data is to build models to predict species distribution, and to predict the effect of environmental changes. In this project we will look at different methods used to collect field data and the effect of these differences on prediction models. We will use computer simulations to model data collection and analysis.

Bayesian Data Analysis
Elena Moltchanova

Bayesian statistics offers a different world view and often allows for richer and more flexible inference than the standard classical techniques.

1. One area where Bayesian approach is particularly useful is in jump processes where an unknown number of abrupt changes might have occured during the monitoring period. Reversible Jump Markov Chain Monte Carlo (RjMCMC) is one of the methods applicable in such situations. The project will concentrate on construction and implementation of this algorithm to a long-term multivariate time series.

   Good R programming skills and previous familiarity with Bayesian Inference (STAT314/STAT461) are required. (No prior knowledge of time series analysis is necessary)

2. Estimation of parameters of stochastically truncated distributions is another area where Bayesian approach is useful. Instead of having a clear cut-off points, samples from stochastically truncated distributions include observations from the original non-truncated distribution with some probability. The estimation is thus concerned not only with the original distribution but also with the inclusion function. Reconstruction of historical distribution of population heights from the records available for army and navy recruits is one area of interest to economists, social scientists and anthropologists and forms the focus of this project.

   Good R programming skills and previous familiarity with Bayesian Inference (STAT314/STAT461) are required.

Goanna microhabitat usage
Alex James & Daniel Gerhard

Australian Goanna are subject to a range of predators (mostly introduced!). In this project you will use new data collected by researchers at Landcare Research to understand how Goanna respond to predators in different habitats.

This project will give you an opportunity to do novel research on real ecological data. The project will have a co-supervisor from Landcare Research giving you a chance to make important contacts there and learn how data analysis is done outside a university environment.

Statistical Sampling
Blair Robertson

A spatially-balanced sampling design selects sample locations that are well-spread over a study area, a sample with few 'clumps' or 'voids'. These designs are particularly useful when sampling natural resources because nearby locations interact with one another and are influenced by the same factors. In this project, the student will apply various spatially-balanced designs on simulated populations to investigate measures of spatial balance and variance estimation techniques.

Nonlinear Statistical Modelling
Daniel Gerhard

In many real-life applications the assumption of a simple (generalised) linear model might not be adequate to represent the process of interest. Instead we might need to model a trend in the expected response by function, which is nonlinear in at least one unknown parameter. In many cases these parameters have a direct biological or physical interpretation, e.g. the growth rate of cell cultures or the maximum root length of plants.

The project focusses on dose-response modelling in toxicology and pharmacology, e.g. for risk assessment of pesticide applications or reducing the number of animals in drug development studies. We will look in particular into model selection strategies, deriving parameters to summarise the dose-response relationship, and/or effectively planning a dose-finding experiment.

Good R programming skills are required and a good understanding of (generalised) linear models is a bonus.

Other Project Opportunities

Industry or Other Research Projects
Jennifer Brown

In addition, opportunities to work with industry partners or researchers at UC arise from time to time. These provide an excellent opportunity to work on problems of direct interest to industry or academic researchers, to learn more about working in an organisation outside of UC or as part of a research team at UC (or mixture of the two!).

These opportunities will usually be advertised on the School's website.

UC Summer Research Projects
Jeanette McLeod

The UC offers summer research scholarships to high performing students in a wide range of topics. These projects are often associated with industry partners or funded research programmes at UC. These are for final year undergraduates only (so typically for the summer between your BSc/BA and commencement of PG study). The last for 10 weeks (Novemeber-February) and are valued at $5,000. The application deadline for 2017is 19th September.

These opportunities will be advertised on the UC summer scholarships website: `http://www.canterbury.ac.nz/summer-school/summer-scholarships`

School of Mathematics and Statistics Summer Research Projects
Jeanette McLeod

Our School offers a range of research projects opportunities over the summer period. Some projects may have scholarships available. Depending on your level of study you are able to undertake these as MATH/STAT395 or MATH/STAT491, which can contribute to your GPA but cannot be used to fufil your subject majoring requirements. You will write a dissertation and give a presentation on your project. These project are a great way to broaden your studies and deepen your understanding of a specialised topic and develop your research and communication skills.

These opportunities will be advertised on the School's website.