Department of Mathematics and Statistics
College of Engineering

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Honours 2012

Courses and Projects

12

Department of Mathematics and Statistics

Honours 2012

Welcome to Honours! Honours is an additional year in which you study selected mathematical and/or 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 or Statistics as was done in your earlier undergraduate years. Also in your Honours year, there is the possibility of a project 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 in the library, the use of various computing packages (for example MATLAB, Maple or R) on the Departmental computing system, resources on the internet, or even proving new theorems. At the end of the project, you produce a written report and give an oral presentation.

Who should think about Honours? If you view Mathematics and Statistics as more than a means to an end, then the Honours year will be a year well spent. The Honours year provides that additional mental edge, as well as some specific technical and (in the project) presentational skills that potential employers find valuable. If you intend to proceed on to graduate work, Masters or PhD, then Honours is a good stepping-stone.

To enter Honours in Mathematics, you will need at least 60 points from MATH310-399, 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 STAT courses and another 30 points from 300-level STAT, MATH or other approved courses. Normally you should have maintained at least a B+ average in these papers. Precise details are given in the University Calendar. There is also a joint Mathematics and Statistics Honours degree (see UC enrolment handbook).

The Department offers both a BA(Hons) and a BSc(Hons). The most appropriate degree is best decided on a case-by-case basis. If you decide that you are interested in Honours, you should see the Head of Department, Prof. Jennifer Brown, or the Honours Coordinator Dr Qui Bui (or Dr Mark Hickman, 2012) to discuss your options. You should do this before the enrolment week next year.

Courses are packaged in 20-lecture modules that will run at two lectures a week for a semester. Any proposed programme of study for Honours requires the approval of the Head of Department. 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.

1. BSc(Hons)

In the Science faculty, Honours may be completed in Mathematics, Statistics, Mathematics and Statistics, Mathematical Physics, Computational and Applied Mathematics (CAMS), Mathematics and Philosophy, Economics and Mathematics, Finance and Mathematics, or, Finance and Statistics.

Students enrolled for a BSc(Hons) in Mathematics and/or Statistics are required to complete eight 400-level courses, as well as a project which is worth the equivalent of two courses.

If you are interested in the:

Mathematical Physics programme, see Dr Peter Renaud or Dr David Wiltshire (Physics).

CAMS programme, see Prof. David Wall or Assoc. Prof. Rick Beatson.

Mathematics & Philosophy programme, see Prof. Douglas Bridges or Dr Clemency Montelle.

Economics and Mathematics programme, see Prof. Douglas Bridges or Dr Seamus Hogan (Economics).

Finance and Mathematics programme, see Dr Rua Murray.

Finance and Statistics programme, see Dr Marco Reale.

2. BA(Hons)

In the Arts faculty, Honours may be completed in Mathematics or in Statistics. A BA(Hons) has the same requirements as a BSc(Hons).

3. PG Dip Sci

A Post Graduate Diploma in Science (PGDipSci) can be obtained by completing eight 400-level papers in one year. These courses normally do not include the honours project (MATH/STAT449). Entry requirements are as for a BSc(Hons), 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+. A PG Dip Sci may be used as the first part of an MSc.

4. Proposed Courses for 2012

The proposed courses for 2012 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 Department reserves the right to cancel any course that does not attract four or more students. It is also possible (and in some cases desirable) to include in your Honours programme appropriate courses from other departments or 300-level courses from Mathematics or Statistics. In the latter case, extra work is usually required to bring the paper to a level consistent with other 400-level courses. Note that, subject to having the required background, any STAT courses may be included in a Mathematics degree and vice versa.

5. Proposed Projects for 2012

A broad range of possible projects is outlined in this booklet. 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 2012. It is suggested that you seek out possible supervisors during the enrolment week (or before if you have a clear idea of what sort of project interests you). You will hand in a written report on the project in late September; part of your project assessment will be an oral presentation in Term 4.

6. Department Scholarships

The Department offers up to three full fees scholarships at domestic level. These only cover fees for Mathematics and Statistics courses. The Department also offers up to eight $1,000 scholarships, which are restricted to those doing BSc(Hons), BA(Hons) or PGDipSc in the Department of Mathematics and Statistics. For further details, see the Department Handbook.

7. Important Meeting

During the first week of Term 1, 2012, there will be a meeting for all students enrolling in at least one 400-level paper in Mathematics and/or Statistics. It is important that all prospective Honours students are at the meeting. As well as providing general information, the meeting determines which 400-level courses will run in the first and second semesters. (Most first semester Honours courses will start in the second week of Term 1.)

8. Engineering Mathematics 600 level

A number of the honours papers are permanently double coded as 600 level (i.e. Masters) engineering mathematics papers. Further honours papers may be given EMTH600 special topic codes to meet student needs as they arise. For more information you should contact the Honours Coordinator, Dr Qui Bui (or Dr Mark Hickman, 2012).

400-level courses

The semesters indicated for these courses are listed as a guide only. The courses may be offered in semester 1 or semester 2 depending on the availability of the lecturer. All 400-level courses are offered subject to sufficient student demand and staff availability, which will be determined at the beginning of each semester. For an up-to-date view of the department's current offerings, please see the department's web page, which is located off the main University web page.

MATHEMATICS

MATH401

Dynamical Systems 1 15 points

MATH401-12S1 (C)

Dynamical systems is a rapidly developing branch of Mathematics with growing applications in diverse fields from traditional areas of applied mathematics to 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. Both 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.

Enquiries: Mike Plank

MATH402

Dynamical systems 2 15 points

MATH402-12S2 (C)

The course will cover the applications of dynamical systems to mechanics.
In particular it will give an introduction to the mathematical theory of Lagrangian and Hamiltonian dynamics.
It will show how chaos can occur in certain dynamical systems. It will be based on the book by: V.I. Arnold: Mathematical methods of classical mechanics, 1989, Springer-Verlag.
Please note: Math401 is NOT a prerequisite for this course.

Enquiries: David Wall

MATH406

Mathematical Models in Biology 15 points

MATH406-12S1 (C)

How did the leopard get its spots? Why should children be vaccinated against measles? This course will try to answer these (and other) questions by using mathematical models to examine biological phenomena.

Some knowledge of dynamical systems and a familiarity with Maple (or MATLAB) are useful pre-requisites to this course.

Enquiries: Alex James

MATH408

Financial Mathematics 15 points

MATH408-12S1 (C)

The course consists of two components.

The first component concentrates on topics in time series econometrics, which may include

- univariate nonlinear stochastic models; stationary nonlinear models; nonlinear time series models; regression analysis of time series;

- discrete and continuous time series with long-range dependence. Applications include risk management and term structure dynamics, nonlinear estimation of interest rate models and nonparametric pricing
- derivatives, selection of time series models for detecting climate change, and trend detection in regional mean temperature series.

Regarding the second, topics will be selected from:

- Discrete time models I (Single period models, pricing a European option, characterizing no arbitrage, risk neutral probabilities);
- Discrete time models II (Multiperiod binary models, discrete parameter martingales, risk-neutral pricing, Cox-Ross-Rubinstein);
- Brownian motion (Definition and Lévy's construction); The reflection principle and hitting times (reflection principle, hitting times, scaling properties);
- Martingales in continuous time (filtrations, adapted processes, Optional Sampling Theorem);
- Stochastic integration and Ito's formula; The Martingale Representation Theorem, Lévy's characterisation of Brownian motion, Girsanov's Theorem;
- The Black-Scholes model; Pricing and hedging European options; Evaluation of price and hedging strategies for European calls and puts.

Enquiries: Patrick Wsaart

MATH409

Cryptography and Coding theory 15 points

MATH409-12S2 (C)

Cryptography is the science of making and breaking secret codes: encryption is what keeps our credit card details safe when we send them over the internet. We will study the mathematics behind some of the main encryption systems in current use. Coding theory comprises a second half of the course. It provides the theory and methods for coding information so that it can be transmitted over a noisy channel and be accurately decoded by the receiver. Cryptography and coding theory draw on ideas from algebra, geometry, number theory and probability theory. See MATH324

Enquiries: Mike Steel

MATH410

Approximation Theory 15 points

MATH410-12S2 (C)

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 topics such as smoothest interpolation of functions of several variables and computational geometry in 3D.

Approximation Theory lies at the interface of many specialties. As such its study involves an interesting mix of pure and applied mathematics, numerical analysis and advanced computation.

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

Enquiries: Rick Beatson

MATH412

Unconstrained Optimization 15 points

MATH412-12S2 (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.

Enquiries: Chris Price

MATH416

Exterior Differential Systems 15 points

MATH416-12S2 (C)

Moving frames and exterior differential systems form a natural backdrop for the study of problems in geometry and partial differential equations. In particular, most (if not all) physical systems exhibit symmetry and so embody geometric content in the differential equations that describe the physics. These systems are naturally described in the coordinate free approach of moving frames. Integrability conditions, the "size" of the solution space and the existence of "singular" branches of the solution space for systems of partial differential equations can be readily found in the moving frame approach.

This course will introduce moving frames and exterior differential systems with an emphasis on the conceptual and operational issues. The "standard" vector calculus will be revisited with the aid of differential forms. Their application to simple geometric problems and the reformulation of Maxwell's equations as an exterior differential system will be considered. If time permits (and depending on student interest) either the exterior differential system formulation of Einstein's field equations or application of moving frames to computer recognition of objects will be considered.

Prospective students should have familiarity with partial differential equations and vector calculus.

Enquiries: Mark Hickman

MATH420

Hilbert Spaces 15 points

MATH420-12S1 (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 $L^2(m)$), operators on them, and basic spectral theory. Applications in dynamical systems (von Neumann’s ergodic theorem) and quantum mechanics will be included as time permits. Prior exposure to MATH343 would be an asset, but is not mandatory.

Enquiries: Rua Murray

MATH424

Wavelets and Data Compression 15 points

MATH424-12S1 (C)

Wavelets are functions, usually defined on the reals, whose graphs resemble highly localized, little waves. They are used to approximate other functions, or data in much the same way as polynomials are used to approximate a function on some interval, or trigonometric polynomials to approximate a periodic function.

In this course we will develop the basic ideas and concentrate on applications to signal processing. This is a large, important area in engineering and science with numerous applications. Here are a few examples. There are many others.

- Image compression - e.g. films have to be compressed to fit on DVDs (and uncompressed to watch them). This must be done *quickly.* The storage and transmission of images might also require compression for practical reasons.
- Denoising signals - getting rubbish (back-ground noise, ...) out of a signal. Important in medical imaging,

seismology, cleaning old audio recording,

- Analysing financial data - The data sets, such as share price indices, typically involve both pseudo--random and intermittent deterministic processes. There is often a large financial incentive to solve prediction problems. (The application of wavelets to this area in still in its infancy when compared with other applications.)

Enquiries: Peter Renaud

MATH427

Lie Groups and Lie Algebras 15 points

MATH427-12S2 (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.

Enquiries: Gunter Steinke

MATH428

Topology 15 points

MATH428-12S2 (C)

Topology, colloquially known as 'rubber-sheet geometry', is the study of continuity in an abstract setting. Topological notions underpin, or are used in, many areas of mathematics, ranging from analysis to algebraic geometry and even set-theory. Accordingly, the fundamentals of point-set topology are an essential part of the training and armoury of the modern research mathematician. In this course, we introduce topological spaces and study continuity, limits, and may other important notions, in that setting. We then take first steps into uniform spaces, the general setting for notions like uniform continuity and uniform convergence.

The topics will be drawn from the following: Topological spaces, continuous functions; filters and convergence; compact and connected spaces; separation properties; the Stone-Čech compactification; uniform spaces.

Enquiries: Douglas Bridges

MATH429

Combinatorics 15 points

MATH429-12S1 (C)

Matroids (also called combinatorial geometries) are precisely the structures that underlie the solution of many combinatorial optimization problems. These problems include scheduling and timetabling, and finding the minimum cost of a communications network between cities. Given this, it is perhaps surprising that matroid theory 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 self-contained course is an introduction to matroid theory, a branch of discrete mathematics that has basic connections with graphs, codes, projective geometries, and combinatorial optimisation. The course is intended for students majoring in Mathematics or Computer Science.

Enquiries: Charles Semple

MATH432

Special Topic in Mathematics (Foundations of Mathematics)

15 points

MATH432-12S2 (C)

An introduction to the philosophy of mathematics, classical and intuitionistic logic, set theory and Gödel's theorems. See MATH 336.

Enquiries: Douglas Bridges

MATH433

Mathematics in Perspective **15 points**

MATH433-12S1 (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.

Enquiries: Clemency Montelle

MATH439

Topics in Algebra **15 points**

MATH439-12S1 (C)

This course in modern algebra is the 400-level extension of MATH321 Rings and Fields.

It investigates the algebraic structure of rings and fields and gives a deeper understanding of these algebraic concepts. It gives a thorough grounding in the algebraic theory which underpins modern applications like cryptography and error-correcting codes, and shows, for example, how the theory can be applied to solve geometric construction problems.

Enquiries: Gunter Steinke

MATH442

Special Topic in Mathematics

(Viscous Fluid Dynamics) **15 points**

MATH442-12S2 (C)

This course is intended as a continuation of Inviscid Fluid Dynamics although is not set as a prerequisite. In the course we will give a quick review of the conservation equations and derive constitutive relations for Newtonian and generalized Newtonian fluids. Afterwards we will concentrate on examples of flows at low Reynolds numbers, for example highly viscous flows, porous media flows, thins films and lubrication theory to name some.

Enquiries: Miguel Moyers-Gonzalez

MATH443

Metric, Normed and Hilbert Spaces

15 points

MATH443-12S1 (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.

Enquiries: Chris Price

MATH444

Special Topic in Mathematics (Inviscid Fluid Dynamics) **15 points**

MATH444-12S1 (C)

Fluid Dynamics is the study of how aeroplanes fly, flags flap, blood flows, rivers run, waves break, and galaxies turn.

Anything remotely fluid-like, from desert sand dunes through water fountains to the slow flow of mountains, can be described and studied by the methods of fluid mechanics. In this course, we will learn the fundamental definitions, theorems, and results of the basis of the subject, concentrating on flows which can reasonably be approximated by modelling a non-sticky (or *inviscid*) fluid. This course will be excellent preparation for the Semester 2 course in viscous fluid dynamics.

Enquiries: Phil Wilson

MATH449

Project 30 points

MATH449-12W (C)

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

Enquiries: Department of Mathematics and Statistics Reception

MATH469

Computer-Aided Proofs 15 points

MATH469-12S1 (C)

The aim of the course is to identify the inherent limitations of floating-point computations, and show how to overcome these by the use of a different class of algorithms. We will describe the basics of auto-validating methods, and systematically cover various problems that can successfully be handled using C++ class libraries. These methods were used in the proofs of the existence of the Lorentz attractor and Kepler's sphere packing problem, for instance.

Enquiries: Raazesh Sainudiin

MATH491

Summer Research Project 15 points

MATH491-12SU2 (C)

This 150-hour course provides students with an opportunity to develop mathematical research skills and to extend and strengthen their understanding of an area of mathematics.

Enquiries: Alex James

STATISTICS

STAT446

Generalised Linear Models 15 points

STAT446-12S1 (C)

How do you analyse data that does not fit the standard methods such as ANOVA and regression? How do you deal with data that are very non-normal, are counts rather than measurements, are correlated and have interdependencies? In this course we introduce you to the very useful toolbox of Generalised Linear Models (GLMs). This is a natural progression from understanding ANOVA, regression and multivariate techniques. We will learn about the general framework for GLMs, and how to use GLMs for analysing data. We will introduce you to the package R, and will use this software throughout the course. Some background in statistical analysis methods is necessary, and useful courses to have completed are STAT220, STAT212 and STAT315. No experience in R is necessary. See STAT319.

Enquiries: Jennifer Brown

STAT449

Project 30 points

STAT449-12W (C)

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

Enquiries: Department of Mathematics and Statistics Reception

STAT450

Advanced Statistical Modelling 15 points

STAT450-12S1 (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.

Enquiries: Elena Moltchanova

STAT452

Applied Statistics 15 points

STAT452-12S1 (C) STAT452-12S2 (C)

A project-based course in Applied Statistics. Project choice is by mutual arrangement between the student and the project supervisor. Students should make sure supervision arrangements are in place before enrolling in the course.

Enquiries: Any Statistics lecturer.

STAT455

Sampling Methods 15 points

STAT455-12S1 (C)

This course looks at practical methods for gathering new data, the raw material of Statistics. See STAT312.

Enquiries: Marco Reale

STAT456

Time Series and Stochastic Processes 15 points

STAT456-12S2 (C)

Here we explain some techniques to model observations taken sequentially over time. This kind of data is very common in Biology, Environmental Sciences, Economics and Finance. Time series methods are widely used for forecasting. This course is application oriented, and computers are used to analyse real time series data. See STAT317.

Enquiries: Marco Reale

STAT459

Advanced Computational Statistics 15 points

STAT459-12S1 (C)

Computational and theoretical aspects of modern randomized algorithms will be covered. Such algorithms include Markov chains on graphs, Glauber dynamics, Markov random fields, Gibbs sampler, simulated annealing, interacting genealogical particle systems, etc. for statistical estimating, testing and learning. Students and researchers in physics and biology as well as operations research and engineering will find it accessible and relevant.

Prerequisite: (MATH103 or EMTH119 or equivalent) AND STAT221, OR Permission of Instructor.

Enquiries: Raazesh Sainudiin

STAT460

Extreme Value Statistics 15 points

STAT460-12S1 (C)

This course aims to develop the theory and methods for modelling the extremes of random processes. Extreme value theory moves away from more traditional statistical techniques where the aims are to model the usual (or in some sense average) behaviour, to consider the unusual or rare events. It has received wide application in many fields where the risk associated with rare events are of concern, e.g. finance/economics, hydrological modelling, climate change, engineering (structural design) and material science (material fatigue/failure).

The course will cover the mathematics underlying extreme value models, statistical inference using likelihood and applications to real data, with implementation in the software package R. Recommended preparation includes second year Statistics (preferably STAT214) and at least full first year Mathematics (MATH103 or EMTH119 or equivalent).

Enquiries: Carl Scarrott

STAT 461

Bayesian Inference 15 points

STAT461-12S2 (C)

This course explores the parametric Bayesian approach to Statistics by considering the theory, methods for computing Bayesian solutions, and examples of applications. The key advantage of the Bayesian approach is that it naturally provides probabilistic measures of uncertainty along with the inference. Topics that may be covered include: Theoretical foundations of Bayesian Statistics, choice of prior distributions, Bayesian estimation and credible regions, Bayesian tests and model selection, methods for computing Bayesian solutions, hierarchical models, and applications to linear models. Students should have a sound mathematical background and a good foundation in Statistics and Probability, at least up to the level of STAT213 or STAT214. See STAT314.

Enquiries: Dominic Lee

STAT462

Data Mining 15 points

STAT462-12S2 (C)

Data mining refers to a collection of tools to discover patterns and relationships in data, especially for large data bases. It involves several fields including data base management, statistics, artificial intelligence, and machine learning, and it has had a considerable impact in business, industry and science.

This course provides an introduction to the principal methods in data mining: data preparation and warehousing, supervised learning (tree classifiers, neural networks), unsupervised learning (clustering methods), association rules, and the dealing with high-dimensional data (PCA, ICA, multidimensional scaling). Students will see applications from various fields, such as commerce (fraud detection, product placement, targeted marketing, assessing credit risk) and medicine (diagnostics). We will use data mining software to illustrate methods with data sets from these fields.

Students must (i) do problems that are assigned throughout the term and (ii) research an area and write an account of it; the instructor will give suggestions for topics in class. See STAT318.

Enquiries: Marco Reale

STAT463

Multivariate Statistical Methods 15 points

STAT463-12S2 (C)

Multivariate statistical methods extract information from datasets which consist of variables measured on a number of experimental units. The application of these methods is blooming with the availability of large datasets from a wide range of scientific fields, combined with the advent of computing power to implement them. Examples abound in fields as diverse as bioinformatics, internet traffic analysis, clinical trials, finance and marketing. This course will cover the theory and applications of various multivariate statistical methods. See STAT315.

Enquiries: Marco Reale

STAT464

Statistical Inference 15 points

STAT464-12S1 (C) STAT464-12S2 (C)

This course looks at the foundations of statistical inference. It covers estimation and test of hypotheses from the classical viewpoint and includes the introduction to the Bayesian approach.

Enquiries: Department of Mathematics and Statistics Reception. Subject to lecturer availability.

STAT471

Special Topics in Statistics 15 points

(Nonparametric Bayesian Inference)

STAT471-12S2 (C)

The goal of nonparametric inference is flexibility in modelling and robustness of the resulting inference. In Bayesian nonparametrics, this is achieved through the use of random processes as priors on infinite-dimensional function spaces. This course looks at some of these priors together with the computational methods for using them.

Their use will be illustrated through appications such as density estimation, regression, classification and clustering. Students should have a sound mathematical background and a good foundation in Statistics and Probability, at least up to the level of STAT213 or STAT214. They should preferably also have taken, or are concurrently taking, STAT314 or STAT461 or a similar course in parametric Bayesian statistics.

Enquiries: Dominic Lee

STAT472

Special topic in Statistics

(Forecasting) 15 points

STAT472-12S2 (C)

Forecasting plays an important role in decision making in industry, financial services, government, environmental management, public health, and many other areas. For example in an uncertain environment, the success of a business or economic policy depends on the ability of managers to foresee and prepare for the future.

This course is ideal if you are keen to advance your career as a modeller or forecaster or are working in a related area that would benefit from training in modelling 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.

Enquiries: Marco Reale

STAT474

Special topic in Statistics

(Official Statistics) 15 points

STAT474-12S2 (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.

Enquiries: Jennifer Brown

STAT475

Independent course of study

15 points

STAT475-12S1 (C) STAT475-12S2 (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.

Enquiries: Any Statistics Lecturer

STAT491

Summer Research Project 15 points

STAT491-12SU2 (C)

This 150-hour course provides students with an opportunity to develop statistical research skills and to extend and strengthen their understanding of an area of statistics.

Enquiries: Alex James

Honours Projects

A broad range of possible projects are outlined. 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 2012. It is suggested that you seek out possible supervisors during the enrolment week (or before if you have a clear idea of what sort of project interests you).

You will hand in a written report on the project in late September; part of your project assessment will be an oral presentation during Term 4.

Projects in Mathematics

Apartness spaces and topology

Douglas Bridges

In this project, the student will first study the basics of Bishop-style constructive mathematics (BISH — that is (roughly) mathematics with intuitionistic logic and a corresponding (naive) set theory. Intuitionistic logic, as distinct from the so-called classical logic that we normally use in mathematics courses and research, captures the idea that in order to prove that some object exists, we should show how to find it, using an algorithm.
Once the fundamentals of BISH have been dealt with, the project will delve into the constructive approach to topology that uses a primitive notion of apartness between sets and is based on five simple axioms. Particular attention will be paid to the constructive connections between several classically equivalent types of continuity for functions. By the end of the project, the student should have a good grasp of the distinction between constructive and non-constructive, and will have experienced a view of topology that is quite different to the one gained in standard courses.
Reference: D.S. Bridges and L.S. Vîţă, Apartness and Uniformity: a Constructive Development, Theory and Applications of Computability 2, Springer Verlag, Heidelberg, 2011

Bezier curves and surfaces

Rick Beatson

Visualisation and surface design is an all pervasive task in modern science and technology. A key approach is via the mathematics of Bezier curves and surfaces. The underlying task is to build parametric interpolatory surfaces of a specified continuity, say G^1 or tangent plane continuity. This project will explore some of the the beautiful mathematics of Bezier curves and surfaces, and also use software tools to visualize the results.

Cloaking, Inverse problems and Harry Potter’s invisibility cloak

David Wall

The goal of cloaking is to render an object invisible with respect to some probing energy source. For example, in the Harry Potter child's fiction book series the hero Harry passes unnoticed by many an inquisitive person by virtue of his invisibility cloak. In this case it is not that the cloak simply conceals what is underneath it, but that it actually conceals that anything is being concealed! So Harry and his associates are undetected by the human eye. In this case the invisibility cloak cloaks what it is covering when the energy source is light energy - a spectral window of the electromagnetic spectrum.
The goal of this project is to apply the mathematical theory of inverse problems and homogenisation to understand how a thermal invisibility cloak could be constructed. The underlying inverse problem in this case comes from the parabolic heat equation and the imaging energy is thermal. This cloaking problem has direct application to many areas of science and engineering.

Dynamics of the double pendulum: matching experiment with rigorous analysis

Rua Murray and Raazesh Sainudiin

Several students have previously helped with the construction of a mechatronically measurable double pendulum. This device can be fitted with springs and weights that are difficult to model analytically, but can produce streams of easy to capture nonlinear time series data. The project will use dynamical systems theory (symbolic dynamics and ergodic theory) and novel computational methods to understand this real experimental data! The project could grow into a good published paper and/or postgraduate research proposal.

Escape from a dynamical system

Rua Murray

Many dynamical systems have holes! The system may be born with these (in the case of a system of hard scatterers, or a billiard table --- so called "open systems"), or holes may be introduced as leaks from a closed dynamical system. Typical orbits escape from open systems with a characteristic exponential rate, depending on delicate nonlinear phenomena. The details of this project are flexible, but will include some exciting mathematics!

Flow in pipes

Phil Wilson

Pipe flows are ubiquitous in nature and industry, including blood in arteries and air in engine ducts. The flow may be of a viscous or inviscid fluid, compressible or not, and be predominantly one, two, or three-dimensional, as well as being steady or unsteady. Particles, such as blood cells or ice grains, may also be present in the flow. This project will choose from a range of pipe flows a motivating example based on the student's interests. The situation will be studied with a combination of analytical and numerical techniques, being principally asymptotic analysis and finite difference methods.

Fractional calculus and the Klavier of Matheron

Rick Beatson

Fractional calculus is a beautiful part of analysis with many applications. This project will survey some of the basic theory of fractional calculus and then consider some applications to radially symmetric functions in R^d. In particular the project will consider a circle of results due to Matheron which allow one to calculate the convolution of two radially symmetric functions in R^d by means of a convolution two dimensions below in R^{d-2}. Matheron's results have found much practical application in geostatistics and approximation theory. He is known particularly for the turning bands method for conditional simulation in several dimensions.

Geodesics in semi-Riemannian manifolds

Gunter Steinke

Geodesics are locally shortest curves but can exhibit interesting global behaviour. They are of significance in physics, since they describe, for example, the path light travels in the universe or a free-falling particle is moving along. Geodesics are described by certain differential equations that can be hard to solve explicitly.
The project investigates semi-Riemannian manifolds and explores the notion of geodesics therein.
It looks at geodesics in some low-dimensional semi-Riemannian manifolds and at geodesical completeness of Riemannian manifolds.

History of Mathematics: People, Propositions, Proofs

Clemency Montelle

Mathematics has a history spanning more than 4000 years. Many key results mathematicians use on a daily basis and the way they operate is due to critical insights made in the past.. This project will take one such key result that interests you and subject it to a thorough historical and technical analysis.

How do microorganisms swim?

Miguel Moyers-Gonzalez

Organisms of various kinds ranging from the very small (for example, amoeba or spermatozoa) to the very large (for example fish, dolphin, whale), make their way through a fluid (often water) using one or more of a multitude of strategies, usually involving self-deformations. One question is how a deformation translates into motion, another is how much energy does the resulting motion require the organism to expend. These questions have been of interest to many people over the years and the purpose of the project is to review some of the models that have been created in order to study the problem. The references provide a starting point but there are many others to be found.

Knots

Gunter Steinke

In geometric topology one is often interested in how one manifold sits in a higher dimensional space. This is the basic problem in knot theory where the unit circle is embedded in 3-dimensional Euclidean space in different ways, and one wants to have invariants that allow to distinguish different knots.
The project explores the concepts of knots, their representations and some of their invariants.

Kruskal and Prim algorithms: Why do they work?

Charles Semple

The Kruskal and Prim algorithms are two methods for finding a minimum-weight spanning tree in a graph. Very fast and simple algorithms, each work by sequentially selecting edges of minimum-weight. The criteria for selecting edges are different, yet the algorithms appear to work in a similar way. The purpose of this project is to investigate why they work and to explore the apparent underlying similarity.

Lax Pairs

Mark Hickman

Given a non-linear differential equation, a *Lax pair* is a pair of *linear* differential operators $\mathcal{L}$, $\mathcal{M}$ whose commutator vanishes only on solutions of the differential equation. A Lax pair allows one to potentially solve the differential equation by reducing the problem to an eigenvalue problem (if the operator $\mathcal{L}$ is second order, this is a Sturm-Liouville problem) and a time evolution of the eigenfunction; the so-called inverse scattering method. If $\mathcal{L}$ is first order then the Lax pair gives a conservation law of the differential equation.
In this project, we will be looking at a method to compute the Lax pair of prescribed order for a differential equation (if it exists). This will involve Maple and would suit a student who has completed MATH361.

Modelling problems in biology and ecology

Alex James

These cover a wide range of topics from epidemiology through invasive species to fluid flow in bugs. Modelling techniques are primarily taken from dynamical systems, PDEs and stochastic processes. For more information please get in touch.

Neurovascular coupling in the brain

Mike Plank

Autoregulation of blood flow in the brain is reliant on effective communication between cells of the nervous system (neurons) and the smooth muscle cells that line the blood vessels. This communication, termed neurovascular coupling, is thought to be mediated by cells called astrocytes and is crucial to healthy brain function. The aim of this project is to use mathematical modelling to investigate the various pathways involved in neurovascular coupling. These pathways are complex and not fully understood and the mathematical model will be used to compare the various mechanisms that have been suggested to play an important role in neurovascular coupling, for example extracellular diffusion of signalling molecules or gap junctions between neighbouring cells. A mixture of analytical and numerical methods will be used to explore the model. Some experience of ordinary differential equations or dynamical systems, and basic computer programming (e.g. MATLAB) would be useful for this project.

Optimisation methods in transient dynamics

Rua Murray

The traditional focus of dynamical systems and ergodic theory is on determining asymptotic behaviour (ie infinite time). However, many interesting features are not amenable to this kind of analysis, and important features persist only for finite times (eg "coherent structures" blocking mixing in ocean systems, cells in your body responding to changing ion concentrations). This project will involve numerical work to test out some new optimisation based methods for computing "locally invariant" structures.

The Paradox of the Plankton

Mike Plank

The Principle of Competitive Exclusion predicts that species that compete for the same resource cannot stably coexist. However, many real ecosystems contain a wide variety of different species, apparently contradicting this prediction. One of the best known examples of this is the "paradox of the plankton".

This project will use differential equations to model the population dynamics of marine species, taking into account variations in size between individuals of the same species. This is called a size-structured model and these variations in size can have important consequences for the population dynamics. The main goal of the project is to decide whether a particular set of species can stably coexist, or whether only one species will dominate in the long term.

Some experience with ordinary differential equations, dynamical systems (e.g. MATH363) and basic computer programming (e.g. Matlab or Maple) would be useful (though not essential) for this project.

Projects in Statistics

Adaptive sampling designs for environmental science

Jennifer Brown

Adaptive sampling designs are becoming increasingly popular in environmental science particularly for surveying rare and aggregated populations. An adaptive sample is where the survey design is modified, or adapted, in some way on the basis of information gained during the survey. There are many different adaptive survey designs that can be used to estimate animal and plant abundances. In this project we will review these designs and designs for targeting survey effort to areas of high interest.

Bayesian Modelling and Inference

Dominic Lee

This project can be customized to address any aspect of Bayesian modelling and inference that is of interest to the student. The student can choose to work with parametric, semiparametric or nonparametric Bayesian models. The project can be matched to the strengths of the student by emphasizing one or more elements of Bayesian theory, computation or application. Through this project, the student can expect to acquire substantive experience in Bayesian statistics.

Extreme Value Statistical Modelling

Carl Scarrott

The statistics you meet on undergraduate course typically focus on the capturing the "usual" characteristics of a process (e.g. properties of mean, median or variance). Extreme value statistics focus on understanding the unusual or rare events of a process. Extremes are of interests in all sort of different fields, for example:

1) financial risk (e.g. estimating Value at Risk for risk and portfolio management)

2) engineering (e.g. designing structures to withstand the stongest forces they could be exposed to, e.g. wind exposure on bridges or forces on buildings due to earthquakes!)

3) environment (e.g. are Christchurch's winter air pollution extremes reducing due to government interventions?)

4) IT (e.g. can our servers and network cope with peak demand when your assignments and projects are due in?)

I have various honours projects in extreme value modelling for financial, environmental, medical and industrial applications. So if you are thinking of becoming a statistical "extremist" then get in touch

Geospatial Analysis

Elena Moltchanova

The aim of the project will be to demonstrate application of spatial statistical techniques in practice. A suitable dataset may either be selected from the field of interest by the student or will be supplied by the lecturer. A short report should then be produced with the short description of the data, some results of the exploratory data analysis and, finally, the description of the method of choice and the results of its application.

Population genetics

Raazesh Sainudiin

We will study basic Markov processes in coalescent theory from a computationally efficient statistical perspective and characterise the distributions of some classical measures of variation in natural populations. Such classical measures that summarise the data are gaining popularity due to the massive size of current population-genomic data. We will rigorously approach the subject by reading the primary literature, programming, computing, simulating and theorising.

Vector autoregressive modelling with short time series

Marco Reale

This project will look at building sparse vector autoregressive models with a stepwise approach so that degrees of freedom will be saved and such models identified even with relatively short time series.
This kind of problem is very common in practice in every field, from biology to economics, and to date no strategy has been proposed.

Projects in Mathematics or Statistics

These projects may be taken either as Mathematics or Statistics projects. It is possible that other projects not listed below may be taken in either area subject to HOD approval.

Computational Network Science

Raazesh Sainudiin

Mathematical and statistical articulation of networks are at the foundations of computational challenges in network inference. Some examples of network inference include current problems in conservation biology, plant and animal breeding, human disease mapping, statistical classification and inferring social links on the world wide web. In this project, you will get an opportunity to develop the theory, methodology and code toward solving a concrete network inference problem of mutual interest.

Optimization in the presence of noise

Chris Price

This project looks at minimizing a function corrupted by noise. Direct search optimization techniques will be used, which means that gradient information is not available, and might not exist. There is significant flexibility in this project. One can look at a variety of optimization methods, in conjunction with different types of corrupting noise. One could also focus on numerically testing various methods, or on their convergence properties. Knowledge of MATLAB is highly desirable.

NOTES:

University of Canterbury
Te Whāre Wananga o Waitaha
Private Bag 4800
Christchurch 8140
New Zealand

Telephone: +64 366 7001
Freephone in NZ: 0800 VARSITY (0800 827 748)
Facsimile: +64 3 364 2999
Email: info@canterbury.ac.nz
www.canterbury.ac.nz