The project descriptions that follow are provided to help you to choose your Year Three project. You will need, at a later stage, to list four choices of project in order of preference. A form for making these choices is included at the end of this document. This form is to be returned by Friday 6th June 2014. (Decisions about project allocations to individual students will be made early in the summer recess, after the examination boards.)

You should study the project descriptions carefully, taking note of any prerequisite second year modules and third year modules that are recommended for concurrent study. However, the written information that is provided should only be viewed as a starting point for making your choices. You are strongly recommended to discuss things further with the supervisors of the projects that you are most interested in, as well as with your personal tutor. Some project supervisors may provide a list of times when they will be available to discuss projects with individual students. But in most cases you will need to make your own arrangements to see a potential supervisor, for example by emailing the supervisor to determine a mutually convenient time when you could meet. If you are a student who is currently undertaking professional training, you may wish to use email to arrange times when you could talk, by telephone, to supervisors who are offering the projects that are of most interest to you.

Instead of choosing one of the listed projects, it is sometimes possible for a student to propose an individual project in another area of work that they have already developed an interest in. For example, a student who is currently completing a professional training placement may wish to undertake a year three project to study and develop a problem pertinent to their placement work. Typically, such a project would, if approved, be supervised by an internal supervisor, based in the School of Mathematics, as well as by an external supervisor from the professional training workplace. If you wish to propose such a project you will need to: (i) obtain the support of a supervisor based in the School of Mathematics; (ii) obtain the support of an external supervisor (if this is appropriate); (iii) fill in and return the project proposal form (for Project Code ALTPROJ) that is included at the end of the list of project descriptions.

A few more projects might be made available to students, after the first printed version of this document is handed out. Details of any such additional projects will be included in an updated version of this document that will be accessible from the School of Mathematics homepage on the web.

Contact details for academic staff can be obtained via the School homepage.

Dr Matthew Lettington

April 2014
Title of project:
Gomory-Chvatal Cutting Planes and the Elementary Closure of Polyhedra

Supervisor:
Dr I. Aliev

Project description:
Integer programming is concerned with the optimization of a linear function over the integer points in a polyhedron P. Among the most successful methods for solving integer programming problems is the cutting plane method in combination with branch and bound. In combinatorial optimization, cutting planes are often derived from the structure of the problem. But even then they most likely fit in the Gomory-Chvatal cutting plane framework. The understanding of Gomory-Chvatal cutting planes and the related results on the Elementary Closure of Polyhedra is the aim of the module.

Project offered as double module, single module, or both: double

Prerequisite 2nd year modules:
None, but MA0261 Operational Research, MA0216 Elementary Number Theory II and MA0212 Linear Algebra may help to understand the general background and the mathematical technique applied in for the module.

Recommended 3rd year modules for concurrent study:
MA3500 Discrete Optimization

Number of students who could be supervised for this project: 1
Title of project:
Compositional Data Analysis

Supervisor:
Dr A. Artemiou

Project description:
It is true that in statistical theory most focus has been given in data that are iid, independent and identically distributed data. It is only in recent years that people focused on dependent data, like time series, functional data or other object data. One observation in compositional data analysis consists of a vector whose elements sum at a specific value, which most of the times it is 1. For example, people in Geology are interested to see if the proportion of elements is the same in different samples of soil. Since the proportion of all elements should add up to 1, there is some dependency introduced in these cases. This dependency introduces a different geometry and therefore classic statistical tools need to be redeveloped to handle compositional data. This project objective is to do a careful study on the different geometry introduced for compositional data analysis and do a comparison of the techniques available for iid data with the techniques available for compositional data. Some data analysis with compositional datasets will be performed and areas where no methodology exists will be identified. Some programming will be needed for this project.

Project offered as double module, single module, or both: double

Prerequisite 2nd year modules:
MA2500 Foundations of Probability and Statistics. MA0263 Introduction to Computational Statistics may be helpful

Recommended 3rd year modules for concurrent study:
MA3501 Elements of Mathematical Statistics may be helpful but is not required

Number of students who could be supervised for this project: 1
Title of project:
Statistical Analysis of Population Similarities

Supervisor:
Dr A. Artemiou

Project description:
The main idea of this project is based on Jared Diamond’s book “Guns, Germs and Steel” (http://en.wikipedia.org/wiki/Guns, Germs, and Steel). In that book the author claims that one of the reasons the Eurasian civilizations have survived and conquered other civilizations is not due to their intellectual or any other genetic inherited superiority, but rather due to the Geography of the Eurasian continent. One of the authors claims is that due to the long East West direction (which implies similarities in geography and season cycle in most of its area) Eurasian civilizations were able to easily transfer technological advantages in farming, as well as transfer breeds of animals and also easily spread of diseases. This led to an extensive exposure to certain diseases and therefore a development of better resistance to these diseases through natural selection. On the other hand civilizations on continents with long North - South direction didn’t share the same climate characteristics and therefore they were more vulnerable during their contacts with other people especially when diseases were being transferred.

In this project the aim is to make a statistical analysis to see if Dr. Diamond’s theory can be expanded in different population similarity measures that scientists use nowadays. For example does a long East West direction of a country imply a lower Gini coefficient (income dispersion of its citizen)? Does a long East West direction imply smaller index of dissimilarity (segregation of housing if two mutually exclusive groups based on race or income or both)? Another question that one may attempt to answer, is whether the length of the North South direction affects these metrics when two countries have similar East West direction.

This project involves Statistics, programming and possibly constraint optimization (depending on the method one uses to define the East West direction). Several statistical procedures will be considered as well as several different metrics. Programming is not restricted to a specific programming language, since the data are available for a number of packages.

Project offered as double module, single module, or both: double

Prerequisite 2nd year modules: none - MA2500 Foundations of Probability and Statistics may be useful

Recommended 3rd year modules for concurrent study: none

Number of students who could be supervised for this project: 1
Title of project: Dragged viscous sheets

Supervisor:
Dr M.J. Blount

Project description:
The buckling of fluid threads and sheets is a phenomenon that can be seen in several everyday situations, such as when pouring a thread of shower gel into one's hand, or a sheet of cake batter into a baking tray. Theoretical progress has been made by exploiting the slenderness of the thread (or sheet) by modelling it as a line endowed with dynamical properties that correspond to the thread. The 'slender-thread' model thus obtained has been demonstrated to yield remarkable agreement with experiment. The model includes many complicated effects, and it is possible to isolate the key effects by considering the asymptotic limit that the thread is very slender. The aim of this project is to extend this analysis to understand the behaviour of a two-dimensional fluid sheet that is extruded from a stationary slot onto a moving belt.

This project will review recent literature concerning fluid sheets and threads, and will explain the equations used to describe the steady motion of a slender, two-dimensional, sheet. The resulting 'slender-sheet' equations will be compared and contrasted against the corresponding 'slender-thread' equations that instead describe a fluid thread. A recent asymptotic analysis of dragged fluid threads will be adapted to describe dragged fluid sheets, and the steady sheet shapes will be explained in the regimes that the belt speed is faster than, slower than, or approximately equal to some characteristic speed at the bottom of the sheet. If time permits, the stability of these steady configurations to a time-dependent folding instability will be discussed.

Project offered as double module, single module, or both: double

Prerequisite 2nd year modules:
MA0235 Elementary Fluid Dynamics

Recommended 3rd year modules for concurrent study:
MA0332 Fluid Dynamics and MA3304 Methods of Applied Mathematics

Number of students who could be supervised for this project: 1
Title of project:
The Breakup Instability of Confined Threads

Supervisor:
Dr M.J. Blount

Project description:
A cylindrical stream of viscous fluid has been known to be susceptible to surface-tension-driven breakup, known as the Rayleigh-Plateau instability, since the late 19th century. Two different behaviours have been observed, which may be thought of as either an ‘absolute’ instability, in which the entire thread breaks up into droplets, or a ‘convective’ instability, where perturbations are swept downstream as they grow so that rupture occurs only after the thread has travelled a certain distance. More recent work involves the flow of a thread, together with a surrounding viscous fluid through a cylindrical microchannel, which is rather more complicated owing to the dynamical influence of the external fluid and of the confining walls. Theoretical progress has been made by considering the stability of perturbations to the thread whose wavelength is much longer than the width of the channel. The project will begin by explaining how the long-wave evolution equations for the (axisymmetric) shape of the confined fluid thread are derived, and will then linearise these equations to derive the dispersion equation that relates the growth of small perturbations to their wavelength. The project will conclude with a discussion of how this dispersion equation depends on parameters such as the viscosity ratio between the two fluids or on the volume flux of either fluid.

Project offered as double module, single module, or both:
double

Prerequisite 2nd year modules:
MA0235 Elementary Fluid Dynamics

Recommended 3rd year modules for concurrent study:
MA0332 Fluid Dynamics and MA3303 Theoretical and Computational Partial Differential Equations

Number of students who could be supervised for this project: 1
Title of project:  
The spreading and advection of a droplet down a slope

Supervisor:  
Dr M.J. Blount

Project description:  
A fluid droplet on an inclined plane, such as a raindrop on a windscreen, will typically slide down the plane under its own weight. This project will begin by modelling a two-dimensional droplet using a lubrication approximation, which assumes both that the aspect ratio of the droplet is small and that inertial effects are negligible. Such an approximation yields a fourth-order partial differential equation for the droplet’s height profile. Self-similar solutions to this equation, which the droplet’s shape will approach at late times, will be derived. The influence of surface tension near the advancing and receding edges of the droplet will be investigated.  
If time permits, the project may be extended in various ways. These include a modification of the model to describe the effects of a second overlying layer of fluid that shears the droplet, or an extension of the model to three dimensions or to cases where it is not appropriate to omit inertial effects. Another possible extension lies in the validation of analytical results against numerical solutions.

Project offered as double module, single module, or both:  
both

Prerequisite 2nd year modules:  
MA0235 Elementary Fluid Dynamics

Recommended 3rd year modules for concurrent study:  
MA0332 Fluid Dynamics

Number of students who could be supervised for this project: 1
Title of project: Spectral asymptotics for the Laplace (Schrodinger) operator on a graph with small parameter in matching conditions at vertices

Supervisor: Dr M. Cherdantsev

Project description:
Problems for differential or pseudo-differential operators on metric graphs (so-called “quantum graphs”) naturally arise as a limit description of various real world problems, such as thin wave guides, or shrinking wires, etc. In particular, the proposed problem for the project can be obtained as a limit for a wave propagation problem in a thin graph-like structure when the thickness of the channels goes to zero. In the case of the straight channels (graph edges) one gets the Laplace operator $\frac{d^2}{dx^2}$ and the Schrodinger operator $\frac{d^2}{dx^2} + hV(x)$ with small potential ($h << 1$) in the case of the curved channels. The original problem also induces a particular type of matching conditions with the small parameter $h$ in the vertices of the graph.

The aim of the project is to write asymptotic expansions for the eigenvalues and eigenfunctions for the above-described operators. A 3rd year project would require construction of formal asymptotic expansions.

Project offered as double module, single module, or both: both

Prerequisite 2nd year modules:
MA2005 Ordinary Differential Equations

Recommended 3rd year modules for concurrent study:
At least one of MA3005 Functional and Fourier Analysis or MA3303 Theoretical and Computational Partial Differential Equations.

Number of students who could be supervised for this project: 1
Title of project: Hydrodynamic stability theory and transition to turbulence in boundary layers

Supervisor: Dr C. Davies

Project description: The stability of fluid boundary-layer flows under the influence of small perturbations is a topic of both fundamental and practical significance. On the fundamental side, it is interesting to try to understand the mechanisms by which a flow disturbance can grow until it reaches a sufficient size to trigger processes that eventually lead to a turbulent state. From a practical point of view, precise prediction - and possibly control - of the point where a flow becomes turbulent is necessary when designing aircraft wings, as well as for many other physical flow configurations that involve fluid boundary layers forming over solid surfaces.

The student will be expected to master various theoretical tools and descriptive methods (for example, normal-mode analysis and the distinction between absolute and convective instabilities) that are helpful in understanding flow disturbance behaviour. There will also be opportunities to undertake numerical studies, which would involve solving boundary value problems for ordinary differential equations and/or the direct simulation of the spatial-temporal evolution for disturbances.

Project offered as double module, single module, or both: double

Prerequisite 2nd year modules: MA0235 Elementary Fluid Dynamics

Recommended 3rd year modules for concurrent study: MA0332 Fluid Dynamics. It is highly recommended that MA3303 Theoretical and Computational Partial Differential Equations and MA3304 Methods of Applied Mathematics are also studies

Number of students who could be supervised for this project: 2
Teitl y project:
System ddadansoddi a chyfansoddi cynganedd

Goruchwyliwr:
Dr D. Evans

Disgrifiad:
Cynganedd, dull o drefnu acenion, cytseiniaid ac odl er mwyn creu ymadroddion a brawddegau persain. Mae egwyddorion sylfaenol yn arwain at system o reolau pendant, sydd yn disgrifi nifer o wahanol ddosbarthiadau ac is-ddosbarthiadau cynganeddol. Eisoes mae rhaglen syml wedi ei ysgrifennu, sydd yn dadelfennu darn ysgrifenedig i mewn i gasgliadau o linellau, geiriau, deuseiniaid a llythrennau. Mae rheolau syml o ran cydwedd cytseiniaid a llafariaid yn rhi o modd i geisio dadansoddi a dosbarthu llinellau unigol. Mae angen helaethu ar y rhaglen ar y rhaglen er mwyn cael adnabod mesurau mwy cymhleth megis cwpled cywydd neu englyn unodl union. Mae hefyd angen creu dull o ddosbarthu llinellau aflwyddiannus yn ol y bai neu’r beiau sydd arnynt, ac i ddatblygu modd cynhwysfawr o wirio cywirdeb y rhaglen. Prif bwrpas y project bydd ceisio dehongli cyfundrefn y gynghanedd fel system iaith ffurfio, a cheisio darganfod casgliad o reolau cystrawen a fydd yn cymhleth is-set ffurfio o frawddegau dilys yr iaith naturiol. Os yn llwyddiannus, bydd system ffurfio o’r fath yn rhoi sail cadarn i ran olaf y project, sef dechrau ar y gwaith o ddatblygu rhaglen sydd yn cyfansoddi llinellau cynganeddl syml.

Cynnigir y project fel modiwl ddwbl, sengl neu’r ddau: y ddau

Rhagofynion modiwlau’r ail flwyddyn:
Mae rhywfaint o waith MA2500 Foundations of Probability and Statistics a MA0261 Operational Research yn berthnasol, ond nid yn angenrheidiol.

Argymhellion modiwlau trydydd flwyddyn i’w hastudio’n gyfamserol:
MA3700 Mathematical Methods for Data Mining

Nifer o fyfyrwyr y gellid eu goruwchwylio am y project hwn: 1

Llyfryddiaeth:
https://github.com/dimbyd/ebrydydd/
Title of project: Statistical methods for detecting clusters in spatial data

Supervisor: Dr D. Evans

Project description: The purpose of this project is to investigate methods of detecting clusters in spatial data. First the student will compile a survey of existing techniques, then proceed to investigate a series of novel methods currently being developed by the supervisor. The student will be expected to implement these methods as a software package, written in Python or R (some of the work has already been implemented in Python), and to develop a real-time system for detecting anomalous clusters in spatio-temporal data streams. The final part of the project will be to apply methods of cluster detection to epidemiological data, and evaluate their efficiency in detecting outbreaks of disease.

Project offered as double module, single module, or both: double

Prerequisite 2nd year modules: MA2500 Foundations of Probability and Statistics

Recommended 3rd year modules for concurrent study: MA3501 Elements of Mathematical Statistics; MA0355 Medical Statistics and MA3700 Mathematical Methods for Data Mining.

Number of students who could be supervised for this project: 1

Background reading:
Title of project:
Multi-class Queueing Systems

Supervisor:
Prof J. D. Griffiths

Project description:
In many real-life queueing systems, there are several distinct categories in
the arrival process. So, for example, admissions to a hospital could consist of
two classes: elective patients (planned admissions) and emergency patients
(unplanned admissions). It is often the case that different arrival classes
also have different service times. A further possibility is that customers
in the queues that develop for the different arrival classes could be served
via a single queue in just one service facility, or customers could be served
via multiple queues in differing service facilities. The aim of this project is
to investigate analytic solutions to such problems, and to compare results
with simulation output. The queueing theory needed will be an extension
to the models introduced in the Year 2 Operational Research module, so
it is essential that the student should have attended this module. Good
programming skills are also essential, so students must produce evidence of
their capability in this respect (e.g. a good grade in the “B for OR” module).

Project offered as double module, single module, or both:
either

Prerequisite 2nd year modules:
MA0261 Operational Research and MA0276 Visual Basic Programming for
OR

Recommended 3rd year modules for concurrent study:
MA3600 Operational Research II

Number of students who could be supervised for this project: 1
Title of project:
Low rank approximations to given matrices (related to statistical applications)

Supervisor:
Dr J. W. Gillard

Project description:
Let $X$ be a real valued matrix. Often, for many statistical applications, it is desired to find another matrix (say $Y$) such that:

(a) $X$ is ‘close’ to $Y$
(b) $\text{rank}(Y) < \text{rank}(X)$

This is the problem of low rank approximation.

For example, in regression analyses, we wish to write a dependent variable as a linear combination of $p$ independent variables. If $n$ observations made on these $p + 1$ variables are embedded into a $n \times (p + 1)$ matrix $X$ where $\text{rank}(X) = (p+1)$, then finding a matrix $Y$ which approximates $X$ but with $\text{rank}(Y) = p$ allows one column of $Y$ to be written as a linear combination of the other $p$ variables. There are many established results which offer solutions to this problem.

More difficult however is the so-called structured low rank approximation problem, where $Y$ not only has to be of smaller rank than $X$, but of the same structure. For example, if our matrix $X$ has some pattern in it, we also require $Y$ to have the identical pattern.

This project will survey and analyse some of the methods which have been established to form low rank approximations (unstructured, and structured) of a given matrix. The project will involve an investigation of some results from linear algebra; and some simulation studies extending and comparing existing methods (which can be done in MAPLE). The project will also describe how such results are related to certain statistical methods (such as regression, as outlined earlier).

Project offered as double module, single module, or both:
double

Prerequisite 2nd year modules:
MA0212 Linear Algebra and MA2500 Foundations of Probability and Statistics

Recommended 3rd year modules for concurrent study:
MA3502 Regression and Experimental Design

Number of students who could be supervised for this project: 1
Title of project: 
Modelling a game of rugby using Markov processes

Supervisor:
Prof P. Harper & Dr V. Knight

Project description:
Operational Research has been widely applied to various sports, especially for fixture scheduling, tactics and strategy, and forecasting. For an extensive review of past research, see Wright (2009). Relatively little OR has been applied to rugby union. Recently the School of Mathematics has established collaborative links with the Welsh Rugby Union (WRU) which has resulted to-date in several UG and MSc projects on topics such as line-out strategies, optimal match scheduling and player rankings.

In this project we consider the problem of modelling a rugby union match to help explore what strategies a team should adopt. This will be through the development of a multi-state Markov process. A game of rugby could be considered as progressing through a series of phases of play, whereby one of the teams has possession of the ball and is trying to score. Progression of the match then would be through a set of stochastic transitions occurring due to change of possession or a team scoring. If one assumes exponential transition times, in which each phase of play occurs independently of past play, this may be a fairly good approximation of reality, is computationally tractable, and thus permits the representation of the game using Markov processes.

A previously published paper by Wright and Hirotsu (2002) developed a similar approach to modelling a soccer game. They adopted a four-state model:
State 0: team A scores a goal
State 1: team A is in possession of the ball
State 2: team B is in possession of the ball
State 3: team B scores a goal.

The authors then used the Markov model in order to estimate the optimal time to change tactics using dynamic programming, either by making a substitution or by some other conscious change of plan.

For rugby, factors to consider might include:
(a) The match consists of a number of phases of play that take place in different defined geographical regions of the pitch (distance from the try line, for example).
(b) The state of the game is represented by which phase we are up to, the points difference and the region (or distance from the try line).
(c) At the beginning of each phase the attacking team must choose from a number of strategies, based on the state of the game.
PH1-14
VK1-14 (continued)

Estimation of transition probabilities would be a challenge for the project and would require reviewing match data from the WRU.

The specific requirements of the project are thus:

– Understand previous related research including the Wright and Hirotsu (2002) paper.
– Learn about Markov processes.
– Consider how best to capture a game of rugby as a multi-state Markov process.
– Obtain transition probabilities.
– Develop a model of a rugby match and use this to explore various strategies that could be adopted by the teams.
– Programming will be required and the student will be expected to learn Sage and/or Python.

Those interested in selecting this project are encouraged to contact the supervisors to discuss suitability.


• Project offered as double module, single module, or both: double

• Prerequisite 2nd year modules:
  MA0261 Operational Research and MA0276 Visual Basic Programming for OR (desirable)

• Recommended 3rd year modules for concurrent study:
  MA3600 Operational Research II

• Number of students who could be supervised for this project: 1
Title of project:
Heavy-tailed distributions in financial econometrics

Supervisor:
Prof N. Leonenko

Project description:
Recent work on modelling observational series of financial assets have described log price processes as processes with heavy tailed distributions, such a Student one. The desirable starting key features are heaviness of tails and of the one-dimensional marginal distributions. The main aim of this project is to introduce and exploit a class of distributions with heavy tails.
The purpose of the project is statistical analysis of certain financial data. The works on the project require a lot of reading and some programming.

Project offered as double module, single module, or both:
single (Spring)

Prerequisite 2nd year modules:
none

Recommended 3rd year modules for concurrent study:
MA0367 Time Series Analysis and Forecasting and MA3503 Stochastic Processes for Finance

Number of students who could be supervised for this project: 1
**Title of project:**
Statistical estimators of entropy of random vector and its applications in testing of statistical hypothesis

**Supervisor:**
Prof N. Leonenko

**Project description:**
In the field of finance, distributions of asset returns can often be fitted extremely well by normal inverse Gaussian distributions.
The purpose of the project is the entropy-based tests of goodness of fit for Gaussian and normal-inverse Gaussian distributions.
The main idea for the construction of tests of goodness of fit is based on the maximum entropy principle. Consider a class of densities satisfying certain restrictions. Find a consistent estimator of entropy for the members of the class. Using so called maximum entropy principle, determine a member of the class maximizing entropy and find its parametric consistent estimator. Finally take a function of the above estimators as a test statistic of goodness fit for the member maximizing the entropy.
The works on the project require a lot of reading and some programming.

**Project offered as double module, single module, or both:**
double

**Prerequisite 2nd year modules:**
none

**Recommended 3rd year modules for concurrent study:**
MA0367 Time Series Analysis and Forecasting and MA3503 Stochastic Processes for Finance

**Number of students who could be supervised for this project:** 1
MCL1-14  

- Title of project:  
  Diophantine Equations

- Supervisor:  
  **Dr M. Lettington**  
  This project would consist of a guided reading exercise, the material from which would written up by the student.
  
  This assignment is to study a branch of Number Theory not heavily represented in the lecture courses given in the School of Mathematics, namely the question of solving specified equations, such as $x^4 + y^4 = z^4$ for example, in *integers* $x, y, z$. The project would be an extended essay on selected topics within this (large) subject area.
  
  Examples could be selected which would illustrate some or all of the following aspects:
  
  - Equations for which some (or all) of the solutions are given by simple polynomial formulas
  - Equations having no solutions
  - Equations having only finitely many solutions.
  
  Source material would be obtained from a guided selection of volumes held in the Senghennydd Library, and assembled into an organised account by the student.

- Project offered as double module, single module, or both:  
  both

- Prerequisite 2nd year modules:
  MA0216 Elementary Number Theory II

- Recommended 3rd year modules for concurrent study:
  none

- Number of students who could be supervised for this project: 1
Title of project: Quadratic Forms

Supervisor: Dr M. Lettington

Project description:

An example of a quadratic form is

\[ Q(x, y, z) = ax^2 + by^2 + cz^2 + 2hxy + 2gxz + 2fyz. \]

Two hundred years ago a lot of effort was put into the question: can you solve the equation \( Q = n \) with integer values of \( x, y, z, \ldots \)? The question led to the discovery of a lot of relations between quadratic forms, and to ways of classifying them. The symmetric matrix of the quadratic form and its determinant are very important. The ‘final’ answer was that if \( n \) passes certain tests, then, if you can’t solve \( Q = n \), you must be able to solve \( Q' = n \) for some other quadratic form \( Q' \) very like \( Q \). This was one of the first indications that Maths doesn’t have a nice answer to every problem.

Project offered as double module, single module, or both: double

Prerequisite 2nd year modules:
MA0216 Elementary Number Theory II, MA2002 Matrix Algebra

Recommended 3rd year modules for concurrent study: none

Number of students who could be supervised for this project: 1
Title of project: 
Investigation into the Late Acceptance Hill-Climbing algorithm (LAHC)

Supervisor: 
Dr R. Lewis

Project description: 
The Late Acceptance Hill-Climbing (LAHC) is a new optimisation meta-heuristic that can be considered an extension to a basic random descent technique. In LAHC, rather than accepting a neighbourhood move only if it is not worse than the current one, it accepts a candidate solution if it is not worse than that solution, which was "current" several steps before. A number of advantages of LAHC over a similar metaheuristic, simulated annealing (SA), have been claimed by LAHC’s creators. These include the fact that LAHC uses just one parameter, it has a strong performance and wide application area, and that it is very simple to implement. Further reading can be found at the following website: http://www.cs.nott.ac.uk/~yxb/LAHC/

A suitable 20-credit project in this area would involve researching and implementing LAHC and SA algorithms for a small number of combinatorial optimisation problems, and then producing results that will enable us to critically compare the general performance of the 2 algorithms. These implementations could be written using VBA, Java, or another programming language of your choice. It will require good programming skills, problem solving ability, and good statistical and writing skills. Interested students should first consult the above link, which gives further details on LAHC as well as various links to relevant papers and presentations.

Project offered as double module, single module, or both: 
double

Prerequisite 2nd year modules: 
MA0276 Visual Basic Programming for OR and/or CM0123 Java I

Recommended 3rd year modules for concurrent study: 
None

Number of students who could be supervised for this project: 1
Title of project:  
Ordinary differential equations and differential inequalities

Supervisor:  
Prof M. Marletta

Project description:  
This project will cover the theory of initial value problems for ordinary differential equations and will extend it to cover differential inequalities. For example: if \( \frac{dy}{dx} = f(x, y) \) and \( \frac{dz}{dx} = g(x, z) \) and \( y(0) > z(0) \), under what conditions does one have \( y(x) > z(x) \), and for what \( x \)? An important application to be covered is the Prüfer theory of eigenvalues and eigenfunctions of Sturm-Liouville problems.

Project offered as double module, single module, or both:  
double

Prerequisite 2nd year modules:  
MA0221 Analysis III, MA0212 Linear Algebra essential;  
MA0232 Modelling with Differential Equations may be helpful

Recommended 3rd year modules for concurrent study:  
none

Number of students who could be supervised for this project:  1
Title of project:
Numerical solution of eigenvalue problems for the Laplace equation

Supervisor:
Prof M. Marletta

Project description:
The purpose of this project is to investigate the spectrum of the Laplacian on bounded two-dimensional domains. In particular, the project aims to examine the extent to which the MATLAB PDE Toolbox software can be used successfully to examine some recent conjectures of Burenkov and Lanza de Cristoforis on the continuity of eigenvalues with respect to the domain in the presence of boundary cusps.

Project offered as double module, single module, or both: double

Prerequisite 2nd year modules:
MA0221 Analysis III, MA0212 Linear Algebra. Students should have some experience of programming in MAPLE, or Visual Basic, or MATLAB.

Recommended 3rd year modules for concurrent study: none

Number of students who could be supervised for this project: 2
Title of project: Polynomial Chaos

Supervisor: Prof T. N. Phillips

Project description:
In most engineering problems, the aim is to solve physical problems by converting them into a deterministic mathematical model. This is an approximation of reality, as many physical input parameters describing the problem are fixed through this conversion. In reality, however, these parameters (material properties or boundary conditions, for example) exhibit some randomness which influences the behaviour of the solution of the problem. This randomness is not incorporated into deterministic models.

In order to include this uncertainty in the mathematical model, probabilistic methods have been developed. Statistical approaches, which use a large sample of random numbers, can be very expensive computationally. However, a new nonstatistical approach, called polynomial chaos, has recently been developed and shown to be very efficient in a range of engineering applications.

The original form of polynomial chaos is a spectral expansion based on the orthogonal Hermite polynomials in terms of Gaussian random variables and using deterministic coefficients. Optimal convergence is only achieved when dealing with Gaussian stochastic processes. In order to obtain optimal convergence for more general stochastic processes, the approach has been extended into a broader framework called generalized polynomial chaos.

This project will involve a review of the literature on polynomial and generalized polynomial chaos, and the application of the technique to some simple ordinary differential equations in which either the coefficients or boundary conditions are subject to an element of randomness. There will be a computational element to the project involving the implementation of the method using Matlab, for example.

- Project offered as double module, single module, or both: double
- Prerequisite 2nd year modules: MA2700 Numerical Analysis II
- Recommended 3rd year modules for concurrent study: MA3303 Theoretical and Computational PDEs
- Number of students who could be supervised for this project: 1
Title of project:
The Proper Generalized Decomposition with Applications to the Solution of Differential Equations

Supervisor:
Prof T. N. Phillips

Project description:
Many differential equations do not possess analytical solutions and in these cases one must resort to numerical techniques. If the equation is defined in a high-dimensional space, even the direct numerical simulation may be intractable due to the sheer size of the problem. This problem is known as the so-called curse of dimensionality.

The proper generalized decomposition is a technique for circumventing the curse of dimensionality and is based on the use of separated representations of the solution to the problem. Instead of expressing the solution as a tensor product of one-dimensional basis functions, a single expansion is generated dynamically. The basis functions are determined in a progressive fashion to give the best representation to the solution in a succession of lower-dimensional spaces.

In this project, some simple model problems will be considered such as Poisson’s equation and the heat equation. Numerical solutions will be generated using the proper generalized decomposition and the performance of the method will be assessed.

This project will involve a review of the literature on the proper generalized decomposition, and the application of the technique to some simple partial differential equations. There will be a computational element to the project involving the implementation of the method using Matlab, for example.

Project offered as double module, single module, or both:
double

Prerequisite 2nd year modules:
none

Recommended 3rd year modules for concurrent study:
MA3303 Theoretical and Computational PDEs

Number of students who could be supervised for this project: 1
MP1-14

- Title of project:
The Representation Theory of Groups

- Supervisor:
Dr M. Pugh

- Project description:
A group is a set of symmetries of an object which are closed under composition and under taking inverses. More concretely, a group is a set G with a binary operation which is associative, has a unit element and for which inverses exist.

In the mathematical field of representation theory, group representations describe abstract groups in terms of linear transformations of vector spaces. In particular, group elements can be represented as matrices so that the group operation can be represented by matrix multiplication. Representations of groups are important because they allow many group-theoretic problems to be reduced to problems in linear algebra.

This project would consist of a general introduction to representation theory, including irreducible representations and characters, as well as the study of the representation theory of certain finite groups (e.g. the symmetric group $S_n$, the group $SU(2)$ of special unitary 2x2 matrices).

- Project offered as double module, single module, or both:
both

- Prerequisite 2nd year modules:
none

- Recommended 3rd year modules for concurrent study:
MA3003 Groups, Rings and Fields and MA3004 Combinatorics

- Number of students who could be supervised for this project: 1
NS1-14

- Title of project:
The dynamics of thin liquid sheets

- Supervisor:
Dr N. Savva

- Project description:
Fluid sheets are encountered in a wide range of natural and industrial processes, making their study of interest to both scientists and engineers. The disintegration of fluid sheets into droplets is desirable in a variety of industrial applications, such as spray painting and fuel injection. Conversely, the instabilities leading to sheet breakup are to be avoided in other applications, as in glass-blowing, the commercial filling of containers or in curtain coating, where a thin layer of fluid is deposited on a moving substrate.

The principal aim of the project will be the review of experimental and theoretical literature of the subject. The student undertaking the project will gain a basic understanding of the area while developing new skills in the modelling and theoretical analysis of free surface flows. Apart from the analytical element, there will also be a computational element to the project, involving the numerical solution of related boundary value problems in MATLAB. No previous experience with MATLAB is necessary.

- Project offered as double module, single module, or both:
double

- Prerequisite 2nd year modules:
MA0232 Modelling with Differential Equations and MA0235 Elementary Fluid Dynamics

- Recommended 3rd year modules for concurrent study:
MA0332 Fluid Dynamics and MA3303 Theoretical and Computational Partial Differential Equations

- Number of students who could be supervised for this project: 1
NS2-14

- **Title of project:**
  The method of matched asymptotic expansions in differential equations

- **Supervisor:**
  Dr N. Savva

- **Project description:**
  The main ideas underlying the method of matched asymptotic expansions appeared in the early 1900s and its early history is strongly associated with aerodynamics and the seminal work of Prandtl, in which he investigated the flow of a fluid past a solid body (e.g. an airplane wing). Since then, the method was refined further and applied to a wide variety of physical problems and is now regarded as one of the key tools of applied mathematical analysis.

  The principal aim of matched asymptotics is to obtain approximations to solutions of differential equations and it relies on a singular perturbation expansion in terms of a small parameter, such as the viscosity of the fluid in the case of fluid flow past a solid body. It is typically applicable when the small parameter multiplies terms containing the highest derivative of the differential equation, which can become important in a narrow region of the domain. By treating such regions in a way that allows the matching of their behaviour to the rest of the domain, it is often possible to obtain analytical approximations to complex problems that compare favourably to fully numerical solutions.

  In this project the foundations of matched asymptotic expansions will be considered to gain a basic understanding of how they can be applied to ordinary differential equations. A number of illustrative examples will be considered drawn from various branches of science. Apart from the analytical element, there will also be a computational element to the project, involving the numerical solution of related boundary value problems in MATLAB. No previous experience with MATLAB is necessary.

- **Project offered as double module, single module, or both:**
  double

- **Prerequisite 2nd year modules:**
  MA0232 Modelling with Differential Equations

- **Recommended 3rd year modules for concurrent study:**
  MA3303 Theoretical and Computational Partial Differential Equations

- **Number of students who could be supervised for this project:** 1
Title of project:
A Topological Obstruction to Eigenvector Continuity

Supervisor:
Dr K.M. Schmidt

Project description:
The eigenvectors of a matrix which depends on a parameter can often be chosen such that locally they depend continuously on the parameter. Hence one could hope that in any continuous family of matrices which have (at least) one eigenvalue all equal, one could choose a corresponding eigenvector for each matrix which also varies in a continuous manner.

In a recent paper by Fefferman and Weinstein, it was shown that, a bit surprisingly, this is not the case: consider the set $M$ of all $n$ by $n$ matrices for which 0 (or any other fixed number) is a single eigenvalue; then it is impossible to find a continuous vector-valued function $v$ on $M$ such that $v(A)$ is an eigenvector for eigenvalue 0 of $A$, for all $A$ in $M$.

This is related to the classical 'hedgehog' theorem: it is impossible to comb a (spherical) hedgehog without creating a vortex.

The aim of this pure mathematics project is to work through and understand the proofs for these statements; this requires knowledge of matrix algebra, calculus of several variables and elementary analysis, and the willingness to get to know some fundamental ideas of topology, especially homotopy.

The project is also available as a single project, with reduced content.

- Project offered as double module, single module, or both: both

- Prerequisite 2nd year modules:
MA0212 Linear Algebra

- Recommended 3rd year modules for concurrent study:
none

- Number of students who could be supervised for this project: 1
Title of project:
Data Envelopment Analysis

Supervisor:
Dr J.M. Thompson

Project description:
Data Envelopment Analysis (DEA) is an Operational Research technique for measuring the efficiency of one decision making unit in comparison to others. It is a linear programming technique particularly applicable for decision making units with several “inputs” and “outputs”.
For example a company may own several factories. These each produce different quantities of a number of different items; these would be considered the outputs. They each use different amounts of resources such as numbers of staff, cost etc; these would be considered the inputs. The company would like to know which of their factories are operating efficiently and which are not.
DEA has been used to assess the efficiency of hospitals, schools etc. This project will involve investigating the various linear programming formulations of DEA, implementing one such method for an example data set and then producing a piece of software in Excel that will do DEA analysis on a problem such as measuring the efficiency of Premier League football teams or the efficiency of university departments.

Project offered as double module, single module, or both: double

Prerequisite 2nd year modules:
MA0261 Operational Research and MA0276 Visual Basic Programming for OR

Recommended 3rd year modules for concurrent study:
MA0358 Mathematical Programming

Number of students who could be supervised for this project: 2
Title of project:
**Numerical analysis of time-dependent queues**

Supervisor:
Dr J. Vile & Dr V.K. Knight

Project description:
A large proportion of early queueing theory literature is devoted to the steady-state (long-run average) behaviour of queues with stationary (constant) arrival rates. The application of such theories to model the behaviour of many real-life services, which experience significant variations in demand throughout the day, is however inadequate.

Over the last few decades, mathematicians have proposed various numerical methods to obtain explicit solutions to such queueing systems and this project aims to evaluate how accurate and efficient some of these methods are. Good programming skills are essential to allow the student to evaluate the potential of the methods to solve the differential-difference queueing theory equations, thus they must be able to demonstrate their capability in this area and knowledge of ordinary differential equations. Study of the 2nd year Operational Research module is also desirable, but not essential.

Project offered as double module, single module, or both: double

Prerequisite 2nd year modules:
MA0276 Visual basic programming for OR (Desirable: MA0261 Operational Research; MA0232 Modelling with differential equations or MA2005 Ordinary Differential Equations)

Recommended 3rd year modules for concurrent study:
MA3600 Operational Research II

Number of students who could be supervised for this project: 1
• Title of project:
  Innovative approached to e-assessment in Mathematics

• Supervisor:
  Dr R.H. Wilson

• Project description:
  Since its inception, there have been significant advances in how e-assessment has been implemented in mathematical education. This project will look to review these advances and will require:
  - A literature review of latest e-assessment software and its implementation across the HE sector in mathematics.
  - Development of an e-assessment tool to be embedded into the curriculum at Cardiff School of Mathematics.
  - Investigation of how e-assessment could effectively supplement the Cardiff University Maths Support Service.

  The student undertaking this project would require knowledge of and/or have a keen interest in the application of a variety of mark-up languages e.g. LaTeX, HTML, MathML, Javascript, etc. in developing assessment materials for mathematics. This project is ideally suited for students with an interest in teaching and in particular the use of learning technologies in teaching and learning.

  NOTE: Those interested in selecting this project MUST arrange to see the supervisor in order to discuss their suitability as far as the computing background is concerned.

• Project offered as double module, single module, or both:
  double

• Prerequisite 2nd year modules:
  none

• Recommended 3rd year modules for concurrent study:
  none

• Number of students who could be supervised for this project: 1
Title of project: Forecasting results of football games

Supervisor: Prof A. A. Zhigljavsky & Dr A. Pepelyshev

Project description:
The main statistical model used by most betting agencies for forecasting results of football games assumes that the number of goals scored by both teams are random variables which have Poisson distribution with different intensities. The aim of the projects is to test the validity of this assumption and suggest alternative models which may have better forecasting capabilities. Both projects involve analysis of large quantities of football results data.

An optional activity within one of the projects is the development of statistically based in-play betting strategies which interact with betting web-sites. The students who would wish to consider doing this project must: (a) know what football (=soccer) is, (b) have some knowledge and appreciation of statistics, and (c) be prepared to do a fair amount of programming.

Project offered as double module, single module, or both: double

Prerequisite 2nd year modules: none

Recommended 3rd year modules for concurrent study: none

Number of students who could be supervised for this project: 2
ALTPROJ – Student proposal form for an alternative final year project

To be completed and returned to Dr Matthew Lettington by Wednesday 28th May 2014.

Student name:

email:

Degree course title:

Personal tutor:

– Title of project:

– Supervisor(s):

(i)

(ii)

If the second supervisor is based in a professional training workplace, please provide full contact details.

email:

phone (including extension):

work address:

– Project description:

This should be produced in consultation with the potential supervisor(s). It should be included overleaf or attached on a separate sheet of paper.

– Project proposed as double module or single module:

Note: It is very important that you obtain the support of the potential supervisor(s) for any alternative project that you propose.
YEAR 3 PROJECT CHOICE FORM

To be completed and returned to Mrs Vicky Reynish by Friday 6th June.

Student name:

email:

Degree course title:

Personal tutor:

Please choose **FOUR** projects, in order of preference. Unless you have already obtained approval for an alternative project (ALTPROJ), you **must** provide details for all four preferences - failure to do so will reduce your chances of being allocated your first choice of project.

<table>
<thead>
<tr>
<th>Project Code (e.g. IA1, MJB2)</th>
<th>Project Title</th>
<th>Project Supervisor</th>
<th>Double/Single Module</th>
<th>Have you taken all prerequisite 2nd yr modules?</th>
<th>Recommended 3rd yr modules you will also be studying (list codes)</th>
<th>Have you discussed this project with the supervisor?</th>
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- **Additional information:**

  *Please give any further information that you would wish to be taken in to consideration when the projects are allocated.*