Queen's University at Kingston
Department of Mathematics and Statistics

SUMMER 2017 NSERC USRA Research Projects

Last updated: 14 February 2017 Additional projects may be added

Listed below are the proposed USRA projects we have received to date for the coming summer (May-August 2017). Students interested in working in an area not represented on this list are encouraged to contact faculty in other research areas to discuss possible projects. A list of our faculty grouped by research area can be found here. Those interested in learning about past projects/supervisors can view that list here.

You are also advised to check back here prior to submitting your application in case a new project of interest has been added.

Supervisor: Andrew Lewis

Project Title: Computer algebra explorations of controllability

Open to (expected background/level of study): Student will have completed third year in MathEng or Honours Arts & Science

Project description: Controllability is a central problem in control theory, and for nonlinear systems is one of the outstanding unresolved problems in the subject area. The matter of determining conditions, be they necessary or sufficient, for controllability is a challenging problem. In this work, various ideas for exploring controllability conditions will be tested. The idea is to work with some challenging examples in the literature, some understood and some not, and see whether some light can be shed on these by new ideas of the supervisor.

Student role: Design and implement computer algebra code for controllability.

Supervisor: Fady Alajaji

Project Title: Error-Control Codes for Channels with Memory

Open to (expected background/level of study): Students at the end of their third or fourth year of studies.

Project description: This project concerns the construction of optimal binary error-correcting codes for a class of additive noise channels with memory. It is well known that optimal codes (i.e., codes with minimal codeword error probability) designed for memoryless channels, such as the classical binary symmetric channel, satisfy the property of having a maximal minimal Hamming distance (among all codes with identical size and codeword length). This optimality criterion does not necessarily hold for channels with memory. One key objective of this project is to identify new optimality criteria in terms of the code and channel parameters for codes operating over channels with Markovian noise memory. Construction of codes under this more general framework will be carried and a performance study conducted.

Student role: The student will be involved in all aspects of the project, including a thorough literature review and a meticulous understanding of the state-of-the-art results, mathematical derivations, performance analysis, performing numerical simulations and writing a detailed research report.

Supervisor: Fady Alajaji

Project Title: Coding Strategies for Two-Way Source-Channel Systems

Open to (expected background/level of study): Students at the end of their third or fourth year of studies.

Project description: This project will explore source-channel coding strategies for the reliable transmission of (discrete and analog valued) information sources over two-way noisy communication networks, in which the users simultaneously transmit and receive information. The derivation of optimal encoding/decoding functions under different distortion criteria will be examined. In particular, one objective is to elucidate the network conditions under which linear coding strategies are optimal.

Student role: The student will be involved in all aspects of the project, including a thorough literature review and a meticulous understanding of the state-of-the-art results, mathematical derivations, performance analysis, performing numerical simulations and writing a detailed research report.

Supervisor: Ernst Kani

Project Title: The arithmetic theory of binary quadratic forms

Open to (expected background/level of study): Students with a good algebra background (Algebra II, group theory). Some knowledge of Number Theory would also be helpful

Project description: The aim of this project is to investigate positive-definite binary quadratic forms, i.e. functions of the form $q(x,y) = ax^2 + bxy + cy^2$, where a, b, c are integers with $b^2 < 4ac$. We will be particularly interested in those forms which primitively represent squares, i.e., those for which the equation $q(x,y) = n^2$ is solvable for integers x, y with gcd(x,y) = 1.

Student role: In the first part of the project, the student will be expected to learn the basic theory of binary quadratic forms. Later we'll apply this theory to the specific problem mentioned above. Computer computations (using Maple) might also be relevant.

NEW

Supervisor: Ivan Dimitrov and Jamie Mingo

Project Title: Operads and Random Matrices

Open to (expected background/level of study): familiarity with basic probability theory, and standard algebraic constructions (group theory, rings, homomorphisms).

Project description: Let μ be a probability measure on the real line. Let X be a N x N real symmetric random matrix where the entries are independent and identically distributed with distribution μ. Then from X we can create an action of an operad of graphs on N x N matrices. Special cases of this construction has been around the statistics literature for some time but it has not been given a careful mathematical treatment. The goal of the project is to find such a treatment.

Starting papers:

arXiv:0909.4277v1
arXiv:1111.4662
arXiv:1503.02792
arXiv:1601.02188v1

Student role:

NEW

Supervisor: Bahman Gharesifard

Project Title: Passivity-Based Stability of Interconnected Network Control Systems

Project description: The main thrust of this project is based on the theory of passivity-based control, which hinges on the idea that the controller should somewhat shape the energy of the system in order to stabilize it at a desired state. The main goal is for the student to learn the mathematical theory of passivity, and how it applies to networked control systems; in particular, the student will learn how to model large-scale systems as dynamical systems that evolve over graphs, and will investigate limitations to the possibility of stabilization of these systems using tools from the theory of passivity. The mathematical aspects of the project will involve control theory, stability theory of dynamical systems, and graph theory.

Student role: The student assigned to this project will study topics related to stabilization of large-scale interconnected systems, in which collections of smaller subsystems interact with each other, using selected number of control inputs. Examples of systems considered in this project are cooperative robotic systems and biochemical reaction networks.

NEW

Supervisor: Michael McIsaac

Project Title: Addressing measurement error in a cumulative exposure variable: the relationship between light at night and breast cancer risk

Open to (expected background/level of study): The successful applicant will be an upper-year statistics student with a strong math background who is primarily interested in biostatistics and the application of statistical methods to Epidemiologic problems. The student will understand advanced statistical methodology and be able to develop sufficient understanding of the health research problem to appropriately apply the statistical methods in this application. Finally, the student will be self-motivated with excellent oral and written communication skills.

Project description: Exposure to high levels of light at night may suppress melatonin production and lead to a variety of negative health outcomes, including increased breast cancer risk. However, appropriate causal inference is hampered by the challenges inherent in obtaining accurate measurements of light-at-night (LAN) exposure; previous retrospective studies have relied on estimates of outdoor LAN based on imprecise satellite imagery. More recent satellite images offer more precise measures of outdoor LAN, but it is unclear how this modern outdoor LAN exposure relates to the outdoor LAN in the time frame of interest and, importantly, it is unclear how outdoor LAN relates to the cumulative light exposure actually experienced by at-risk subjects (individuals could wear sleep masks or use black-out curtains that nullify any effects of outdoor LAN). However, if a gold standard exposure measurement can be established for a validation sample, then we can model the relationship between these LAN measures and imprecise satellite imagery and qualitative measures of indoor LAN. This will allow for the use of regression calibration or multiple-imputation for measurement-error corrections to be applied in order to establish true relationships between the mis-measured exposure variable and any outcomes of interest.

Student role: The student assigned to this project will study topics related to covariate measurement error and apply this methodology to a breast cancer case-control study in order to study the relationship between breast cancer risk and light-at-night exposure. The student will need use the disparate exposure measurements and additional information on infrastructure changes to develop a gold standard exposure. The student will need to model this gold standard exposure as a function of more-easily accessible imprecise exposure measurements and will employ modern measurement error methods to examine the true relationship of interest. In addition to the methodological challenges arising from imprecise estimation of outdoor light-at-night from satellite imagery, the student will need to account for self-reported qualitative measures of indoor light, and overcome challenges arising from missing data and selection bias. The methodology developed in this project will be useful for studies of cumulative effects of light at night on many health outcomes beyond this particular consideration of breast cancer risk.

NEW

Supervisor: Dan Offin

Project Title: Dynamics of conservative systems: Celestial mechanics and the three body problem

Open to (expected background/level of study):

Project description: TBA

Student role:

Supervisor: Devon Lin, Glen Takahara and David Thomson

Project Title: TBA

Open to (expected background/level of study):

Project description:

Student role:

The following project is being offered by Mohan Chaudhry of the Department of Mathematics and Computer Science at the Royal Military College of Canada. Students interested in applying for this project should contact Dr. Chaudhry directly.

Project Title: Inverting transforms that arise in the study of Markov models

Project description: Many of the analytic solutions in queueing and other stochastic processes are derived in various transforms such as probability generating functions and Laplace transforms. The problems become more complicated if there are unknowns in the transforms. Several complicated algorithms/methods have been proposed to invert such transforms. We have developed a software program which inverts such transforms using the roots of high degree polynomials and transcendental functions. Our method of inverting such transforms is much more efficient and fast when compared with other methods.

Student role: The student's role will be to invert such transforms using mathematical tools such as MAPLE/MATLAB or MATHEMATICA and QROOT, a software developed by us as well as do some mathematical typing.