Queen's University at Kingston
Department of Mathematics and Statistics

SUMMER 2019 Research Projects

Check back for updates

Last updated: 2 January 2019

Supervisor: Troy Day

Project Title: Studying Evolution Using Artificial Life

Open to (expected background/level of study): Experience in computer science/ computer programming is required. Knowledge of C++ is particularly beneficial because Avida is written in this language.

Project description: During the past couple of decades computer scientists have created software platforms that mimic the process of biological evolution within computers. For example, in these platforms the genomes of individual organisms are represented by sequences of programming instructions, and each such "organism" produces offspring by replicating its genome (i.e., by replicating its programming instructions) into a new individual. Mutations also occur during this replication, however, leading to variation among individuals. Some of these individuals thereby turn out, by chance, to be better than others at replicating and so the composition of the population of these "digital organisms" evolves over time, with some programs outcompeting others. A beautiful example of this type of artificial life platform is Avida (http://avida.devosoft.org). In this project we will use Avida to address questions in evolutionary biology, first by learning how it currently works, and then by modifying its code in various ways.

Student role: To explore the use of Avida first by examining its current capabilities and then by examining the code for this platform and modifying it in new ways.

Supervisor: Fady Alajaji

Project Title: The Information Bottleneck Method and Deep Learning

Open to (expected background/level of study): Students at the end of their third or fourth year of studies.
Project description: The information bottleneck (IB) method is an information-theoretic technique that optimizes the tradeoff between the compression length of a potentially complex (high-entropy) signal and the accuracy of predicting from the compressed signal a relevant (low-entropy) signal that is correlated to the original (high-entropy) one. The IB principle provides an interesting information-theoretic connection with machine learning including deep neural networks and data privacy systems. The objective of this project is to construct and analyze a variational version of the IB principle for deep learning networks, numerically implement it for a relevant machine learning application and systematically compare its performance and complexity with the best methods in the literature.

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: Error Control Codes for Bidirectional Communication

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 efficient and reliable transmission of data over Shannon's two-way (or bidirectional) communication channel, where two users exchange messages simultaneously over a common channel. This allows each encoder to interactively adapt the current input to its and all previously received signals, hence rendering it more resilient to channel distortions. The objective is to design, analyze and implement effective block error control codes for two-way memoryless channels, including Blackwell's binary multiplying channel (with and without noise), two-way channels with errors and erasures and Shannon's ``push-and-talk'' channel. One direction is to analyze the maximum likelihood decoding rule for two-way channels in terms of the distance properties of the codes. Another one is identify the key algebraic properties of optimal codes (i.e., codes with minimal decoding error probability).

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: Felicia Magpantay

Project Title: Noisy data and Kalman-type filters

Project description: Kalman filter approaches are used in many applications (robotics, control, meteorology, biological modeling) to infer parameters and underlying states from noisy observations. If dynamics are linear and all the noise is Gaussian, the basic Kalman filter (KF) is the best linear estimator. The Ensemble Kalman filter (EnKF) and Ensemble Adjustment Kalman filter (EAKF) are algorithms based on KF that have been extended to work for nonlinear dynamics. These methods have been applied to high-dimensional problems for which more exact, full-information methods (e.g., sequential Monte Carlo approaches) are computationally infeasible. This will be joint work with Aaron King (University of Michigan).

Student role: The student will conduct a theoretical study of KF, EnKF, and EAKF algorithms and test their usefulness in fitting some simple models to data. The goal is to obtain a good understanding of when these methods are appropriate to be used and how well they can do in some non-Gaussian situations where KF methods are formally inappropriate but may still be useful as approximations. This will help us understand if and how such methods can contribute to full-information inference.

Open to (expected background/level of study): Undergraduate students applying to work on this project should have a theoretical probability background (MTHE/STAT 351 or equivalent) and have some basic familiarity with R.

Supervisor: Serdar Yuksel

Project Title: Stochastic Control under Information Constraints

Open to (expected background/level of study): A strong background in probability/statistics, real analysis, control, and systems would be desirable. 3rd or 4th year students would likely be more suitable for the project, though this is not necessary.

Project description: The interaction between information and control is a phenomenon that arises in every decision and control problem. On the one hand, a controller requires information on the unknowns that affect the operation of the underlying system; on the other hand, the quality of the relevant information itself is typically affected by the choice of the control action. Furthermore, the transmission of information over information channels and the process of shaping the source output and recovering the transmitted signal at the other end can themselves be viewed as controller design problems.

The goal of this project is to understand the design of information structures in stochastic control systems. Two main themes will be (i) decentralized stochastic control and the geometric properties of decentralized information structures, and (ii) optimal control under information constraints.

Student role: The expectation is that the student(s) would study a wide variety of resources, take part in the research discussions through regular meetings, and prepare a technical document at the end of the summer to report the findings. Implementations of some of the findings through Matlab or another software will also be likely.

Supervisor: Mike Roth

Project Title: TBA

Open to (expected background/level of study):

Project description:

Student role: