Online Proceedings

2M

Modern Quantitative Methods for Real World Problems

Session Moderator: J. Nathan Kutz, Applied Mathematics

Mary Gates Hall 288

3:30 PM to 5:00 PM

* Note: Titles in order of presentation.

Automated Optical Coherence Tomography Alignment

Harrison Cheng, Senior, Bioengineering
Mentor: Ruikang Wang, Bioengineering

Modern healthcare and education have allowed people to age more gracefully. Consequently, healthcare cost continues to rise and an emerging population of people has deteriorating visual perception. The need to perform routine ocular checkup to diagnose diseases at an early stage is necessary to provide effective treatment plans. Fourier Domain Optical Coherence Tomography (FD-OCT) imaging technique is an emerging low-cost non-invasive medical imaging technique that is capable of obtaining high spatial resolution images of biological tissues in vivo. Relative to other medical imaging modalities, OCT system requires the lowest financial cost and least regulatory issues because it can image the eye non-invasively. However, because OCT measures the interference pattern of light to acquire vital information of the tissue of interest, the light emitted to the sample arm must to have the same optical path length as the light emitted to the reference mirror. The process of adjusting the position of the sample to match the optical path length as the reference mirror for in vivo imaging of the human eye is a very operator-dependent and patient reliant process. To solve this problem, we designed an augment system that allows automatic alignment of the reference mirror and focusing lens in the OCT system so that the optimal imaging is always achieved without any manual interventions. We tested the designed system on the tissue phantoms and found that the system worked well toward our expectations. In future, we will integrate the system with a pre-clinical OCT system for in vivo imaging of human eyes for the diagnosis and treatment of ocular diseases, such as glaucoma.

Lower Bounds on Free Branching Decision Diagram Size

Jerry Zheng (Jerry) Li, Senior, Mathematics (Comprehensive), Computer Science
Mary Gates Scholar
Mentor: Dan Suciu, Computer Science and Engineering

Given a boolean function, we can construct a Free Branching Decision Diagram (FBDD) which we can then use to calculate the function. Any query on a database that returns true or false creates a boolean function, and the existence of FBDDs whose sizes are polynomial in the size of the database for these derived expressions can be used to evaluate these queries quickly. In a recent paper, Suciu and Jha proved that one query in particular, which they called h_1, creates boolean functions which cannot have polynomial sized FBDDs. We are currently attempting to generalize this result to a class of queries h_k which are intimately related to h_1. While we are fairly certain that it is true that the h_ks do not have polynomial sized FBDDs because they cannot be evaluated in polynomial time, many of the properties used to prove the hardness of h_1 are lost when k is greater than one. Hence we are currently attempting to generalize and apply ideas first formulated by Simon and Szegedy in their paper "A New Lower Bound Theorem for Read Only Once Branching Programs" to our boolean formulae and their resulting FBDDs. While we currently have no positive results, we have definitively ruled out a number of approaches and we believe that a positive result is forthcoming. Such a result would prove a number of conjectures made by Jha and ultimately we hope that it will lead to a complete characterization of queries which have a polynomial sized FBDD.

Factor Analysis of Martian Infrared Spectra: A Method for Analysis of Complex Datasets

Nancy Helen (Nancy) Thomas, Junior, Astronomy, Physics
Mary Gates Scholar, NASA Space Grant Scholar
Mentor: Joshua Bandfield, Earth And Space Sciences

Orbital spectroscopy allows for the analysis of surface composition on the planet Mars, and is providing evidence for the presence of liquid water throughout the planet's history. We use hyperspectral images from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) aboard the Mars Reconnaissance Orbiter (MRO) to identify a variety of compositions on the planet. These compositions can provide information about the conditions present at the time of their formation. In many cases, as where carbonates are identified, these compositions are clear evidence for the presence of liquid water in the martian past. We identify minerals by their unique absorptions at specific wavelengths through the examination of CRISM surface reflectance data across 438 wavelengths from 1.0 to 3.9 microns. For identification, the CRISM spectra are matched to spectra of laboratory samples from Earth. However, there are differences between these spectra that give some new insight into the combination of minerals present and their formation process. By applying factor analysis to the CRISM dataset where the spectral signature of the mineral components vary independently from one another, the measurements can be expressed as a linear sum of the components. We have applied this target transformation and factor analysis technique to CRISM spectra to identify and isolate the various mineral components present, even under circumstances where the mineral components are only present in minor abundances and mixed with other spectral signatures. Because the entire dataset is used to retrieve mineral spectral signatures, this analysis greatly reduces instrumental error to provide well-defined CRISM spectra. Ultimately, by applying our data analysis technique to the global CRISM dataset, we will have a stronger and more detailed understanding of surface composition and aqueous processes on Mars. Based on these processes we can then invoke different conditions conducive for the development of life on Mars.

Humans Versus Pigeons: The Monty Hall Dilemma with Uneven Probabilities

Shanglun (Shawn) Wang, Junior, Economics-Math, Psychology, Whitman College
Mentor: Walter Herbranson, Psychology, Whitman College

The Monty Hall Dilemma (MHD) is a counterintuitive probability problem adapted from the game show Let's make a Deal. The participant is presented with three doors, one of which contains a valuable prize. After the participant chooses a door, the host opens one of the doors not chosen by the participant to reveal a "zonk" prize. The participant is then asked if he or she wants to switch to the remaining door. Contrary to intuition, switching would double the chance of winning the prize. Previous research has shown that pigeons (Columba Livia) optimize their performance after basic training, while humans fail to learn to switch, even after extensive practice. However, very little comparative research has been conducted on the MHD variants with uneven probabilities of each door containing the prize. Uneven probabilities would introduce a new level of complexity because the advantage of switching or staying would vary depending on the initial choice, whereas previously the initial choice is irrelevant. I will present on an experimental study that compares the performance of humans and pigeons in the MHD with uneven probabilities of each door containing the prize. My study found that humans underperformed in way consistent with previous experiments while pigeons optimized their performance after some period of training. This result strengthens the hypothesis that humans underperform on the MHD and other probability tasks due to their reliance on heuristics and intuition rather than empirical learning.

The Ihara Zeta Function on Graphs

Elizabeth Landicho (Elizabeth) Wicks, Senior, Mathematics (Comprehensive), Physics
Mary Gates Scholar
Mentor: Ralph Greenberg, Mathematics

The Ihara Zeta Function (IZF) of a finite graph encodes its spectral, combinatorial and number theoretic properties. Our aim is to calculate the IZF of the Cayley graph of the modular group PSL(2,Z), which can be thought of as a special group of square matrices. Since this group plays a central role in number theory and other areas of mathematics and physics, we hypothesize that the zeta function will reflect important information about modular forms and elliptic curves. Our previous research has yielded an algorithm that computes the IZF of a sequence of finite approximations of this group, but it does not give the IZF of the entire graph. The IZF can be expressed as a product of L-functions, which encode how successive graphs in the sequence are related. Our ultimate aim is to use the L-functions of the finite approximations to compute the IZF of the modular group. We are currently exploring L-functions of simpler Cayley graphs, in the hope that the methods can be generalized to calculate the IZF of PSL(2,Z).