a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

CMPS Undergraduate Research Conference

Day 1:

- Date and Time: **Friday, April 14, 2023, 9:30 am – 4:00 pm**
- Discipline: Data, Math, Physics, & Stats
- Location: **SCI 333**
- Zoom Link: https://ubc.zoom.us/j/62962089200?pwd=TDFjOExuVHZVL1BQOFJVc1Q1Y0NuUT09
- Organizers: Alex Hill, Xiaoping Shi, and Paul Tsopmene
- Contact: Paul Tsopmene (paul.tsopmene@ubc.ca)
- Website: https://cmps.ok.ubc.ca/undergraduate/conference/

(A) Schedule

Welcome: 9:30 am – 10:00 am

Session 1: 10:00 am – 11:00 am, Phys

- 10:00 am – 10:15 am: **Nolan Koblischke** (honours project) | *Tip of the Red Giant Branch calibration using long-period variable stars* | Supervisors: Alex Hill & Richard Anderson
- 10:15 am – 10:30 am: **Nasser Mohammed** (honours project) | *A Polarimetric Study of 'Tadpole' Feature G137+7 with CHIME* | Supervisors: Alex Hill & Anna Ordog
- 10:30 am – 10:45 am: **Kaleigh Young** (honours project) | *Exploring Race and Gender Disparities in Students' Attitudes Towards Physics* | Supervisors: John Hopkinson & Hiro Nakahara
- 10:45 am – 11:00 am: **Tianle Chen** | *A Physics Perspective in Studying Multiple Sclerosis Electrical Network* | Supervisor: Reza Khanbabaie

Break: 11:00 am – 11:15 am

Session 2: 11:15 am – 12:15 pm, Math

- 11:15 am – 11:30 am: **Ryan DeWolfe** | *An Introduction to Persistent Homology for Data Analysis* | Supervisor: Javad Tavakoli
- 11:30 am – 11:45 am: **Amaury De Burgos** | *Triangle Packings & Transversals in Tripartite Graphs* | Supervisor: Wayne Broughton

- 11:45 am – 12:00 pm: **Heejun Song** | *Calculus of Variations and Its Applications* | Supervisor: Paul Tsopmene
- 12:00 pm – 12:15 pm: **Indira Mishra** (directed studies) | *The Principal Eigenvalue on a Riemannian Manifold* | Supervisor: Sylvie Desjardins

Lunch: 12:15 pm – 1:15 pm, we will offer the lunch (pizzas) in SCI 333

Session 3: 1:15 pm – 2:15 pm, Data and Stat

- 1:15 pm – 1:30 pm: **Daniel Krasnov** (Data, directed studies) | *Exploring Latent Topics in Data Science Curricula* | Supervisor: Irene Vrbik
- 1:30 pm – 1:45 pm: **Xiru Yu** (Stat) | *Graph-Based Relevance Analysis* | Supervisor: Xiaoping Shi
- 1:45 pm – 2:00 pm: **Simon Snymon** (Stat) | *On Data Sharpening in Nonparametric Autoregressive Models* | Supervisor: Lengyi Han
- 2:00 pm – 2:15 pm: **Daniel Krasnov and Keiran Malott** (Data) | *Application of Mahalanobis-Distance Based Fuzzy C-Means Clustering in Breast Cancer Imaging* | Supervisor: Xiaoping Shi

Break: 2:15 pm – 2:30 pm

Session 4: 2:30 pm – 3:45 pm, Phys + Extra Talk (Stat)

- 2:30 pm – 2:45 pm: **Takamitsu Koyano** (directed studies) | *Using numerical Laplace transforms and a low-loss model to replicate the measured transient response of transmission lines* | Supervisor: Jake Bobowski
- 2:45 pm – 3:00 pm: **Alexandra White** (directed studies) | *Designing an Inductively Coupled Resonant Wireless Power Transfer System* | Supervisors: Thomas Johnson & Jake Bobowski
- 3:00 pm – 3:15 pm: **Tianle Chen** (honours project) | *Study of Quantum Dots in Silicon Nitride* | Supervisor: Peter Simpson
- 3:15 pm – 3:30 pm: **Jordan Sawchuk** (honours project) | *Dirac's Approach to Constrained Hamiltonian Systems and Negative Energy Densities in Quantum Field Theory* | Supervisor: Dan Vollick
- 3:30 pm – 3:45 pm (extra talk): **Cynthia Kielpinski** (Stat) | *An Extension of the Binomial Distribution* | Supervisor: Xiaoping Shi

Closing: 3:45 pm – 4:00 pm, Prize Draw

(B) Zoom Link

We will also stream the presentations via Zoom. Here is the zoom link:

One tap mobile: +17789072071,,62962089200#,,,,,,0#,,874525#

Meeting URL: https://ubc.zoom.us/j/62962089200?pwd=TDFjOExuVHZVL1BQOFJVc1Q1Y0NuUT09

Meeting ID: 629 6208 9200

Passcode: 874525

(C) Abstracts

Nolan Koblischke

The Hubble tension, a disagreement between measurements of the Universe's expansion rate, is a major unsolved issue in cosmology. In this study, we focus on improving a method called the Tip of the Red Giant Branch (TRGB) which is used for measuring distances to other galaxies to find the Hubble constant. We use the Large and Small Magellanic Clouds as calibrators for the TRGB and select long-period variable stars for our analysis, which we discover make up the majority of stars near the TRGB. Our methodology involves applying reddening and extinction corrections, isolating sequences of variable stars, and addressing potential systematics such as smoothing bias. Our findings reveal that our chosen variable stars provide accurate and consistent results between both Magellanic Clouds. Furthermore, we find that two Period-Luminosity sequences possess distinct TRGB magnitudes, which challenges the idea that the TRGB magnitude is determined from a homogenous set of stars. Our investigation contributes to a better understanding of the TRGB method and highlights the importance of further research to minimize uncertainties in TRGB distance measurements.

Nasser Mohammed

This research employed radio-frequency data obtained using the CHIME telescope to examine the polarization feature G137+7. With the aid of CHIME's 40-arcminute angular resolution, a novel discovery was made regarding G137+7 that had not been previously identified. Specifically, this presentation finds the presence of a tail-like prominence extending from the circular feature G137+7, which bears a resemblance to a tadpole. The investigation of the rotation measure and Faraday depth spectra reveals that the tadpole stands out from the background, exhibiting significant negative Faraday depth along its head and tail, establishing its association with the circular structure. Although several hypotheses have been proposed, including links with nearby stars and the hydrogen structure in the region, no definitive explanation for the tadpole's strong Faraday rotation has been determined. Consequently, additional analyses and investigations are required to gain a comprehensive understanding of the magnetic properties of this intriguing feature in our polarized sky.

Kaleigh Young

At UBCO, the Colorado Learning Attitudes About Science Survey (CLASS) (Adams et al., Phys. Rev. Spec. Top. - Phys. Educ. Res., 2006, 2) has been administered since 2015 to gauge students' attitudes about physics. Previous studies (Adams et al., 2006, 2, 10) using CLASS have noted a gender gap in students' attitudes with men scoring higher than women in several categories including Real World Relation, Personal Interest, and Problem Solving Confidence. We study the gender gap seen at UBCO, its robustness to instruction, variation with individual statements, and whether expert opinions are universally shared with female experts in the field. While gender gaps in the context of CLASS have been written about extensively, gaps in expert-like opinions amongst minorities are understudied. Since 2021 survey respondents have been asked to self-identify as white, Asian, Black, Indigenous, Latina/o or Other. Due to

low numbers of Black, Indigenous, and Latina/o students at UBCO, we investigate trends in three groupings: white students, Asian students and students who are ”not white or Asian”. Noting that high CLASS scores correlate with interest in majoring in physics, it is our hope that insights gained from such studies might help further diversity in the field.

Tianle Chen (talk 1)

An LRCC circuit was made to be analogous to neuron. Myelin sheath is model to be an inductor compare to the conventional model of neuron. Circuit analysis on the response of LRCC circuit is done to find representation for resonance frequency and bandwidth. Multiple Sclerosis is studied in terms of decrease in performance of LRCC circuits. Brain network is model to be a network of LRCC circuits.

Ryan DeWolfe

A review of the persistent homology literature with a focus on data analysis. A review of the prerequisite group theory, and algebraic topology is presented. Filtrations and Persistence modules are motivated and introduced. We examine some important theorems and algorithms for the validity and computation of the method. Two real world examples of the data analysis pipeline focused on global and local properties are explored. Several active research areas are motivated and further research directions are discussed.

Amaury De Burgos

Graph theory studies abstract structures representing networks. These can be visualized as drawings of vertices (points) with edges (lines) joining some of the vertices. Graphs whose vertices are divided into three non-overlapping parts are called tripartite graphs, and the edges between the vertices in any two of the parts is a side of the graph, which can be considered complete or incomplete.
In tripartite graphs, the edges between vertices can form triangles. Our research studies how many triangles can be packed into such a graph without sharing a common edge, how many edges are needed to touch all triangles in the graph, and the conditions under which these two numbers are equal. In 2012, Lakshmanan et al. proved that if all three sides of a tripartite graph are complete, then the number of triangles that can be packed into it is equal to the number of edges needed to touch all the triangles. We proved the same result holds for tripartite graphs with two complete sides.

Heejun Song

A functional is a map from a set of functions to real numbers. The calculus of variations or variational calculus is the branch of mathematics that uses variations to find the extrema of functionals. The fundamental problems in the calculus of variations include the problem of Bolza, the problem of Lagrange, and the problem of Mayer. In this talk, we will explore the Mayer problem following the book “Optimization and Nonsmooth Analysis” by Frank H. Clarke. Then, we will introduce the Lagrange problem with examples and applications to the Lagrangian and Hamiltonian mechanics.

Indira Mishra

The study of spectral geometry is often expressed as an answer to the question: “Can one hear the shape of a drum?” posed by Mark Kac in his 1966 article published in the American Mathematical Monthly. In a

mathematical sense, it is the study of the relationship between the spectra of a manifold, or its set of eigenvalues on a differential operator, and the geometry of the manifold. Most commonly, the Laplace-Beltrami operator, or Laplacian, is studied on Riemannian Manifolds. In this presentation, I discuss several estimations for the principal eigenvalue on a Riemannian Manifold for the Laplacian with Dirichlet boundary conditions. First, the isoperimetric and Faber-Krahn inequalities present a lower bound for the principal eigenvalue based on the simple geometry of the manifold. A large part of the presentation will focus on the Cheeger inequality, which arises from the Co-Area formula. This result is significant because it requires no assumptions about the geometry of the manifold. Yau, Li, and Lichnerowics found lower bounds by placing restrictions on Ricci curvature. Notable upper bounds include Cheng's eigenvalue comparison theorem and Buser's inequality. Finally, I briefly discuss the graph theoretic approach.

Daniel Krasnov

Curriculum Analytics (CA) deals with improving degree structure at a course level by evaluating course competencies and learning outcomes, assessing degree pathways through statistics or modelling, and creating tools to inform course formulation or revision. This study employs Latent Dirichlet Allocation (LDA) to Data Science curricula in order to learn latent themes and concepts being taught across North American universities. It is then possible to identify patterns and relationships between curricula and highlight their differences. This method of analysis can be used to help educators improve degree structure and core competency coverage. This approach can easily be extended to the analysis and improvement of any curricula.

Xiru Yu

Today, many datasets have high dimensionality compared to their number of observations. Traditional relevance analysis methods like MANOVA and Hotelling's T statistics have little power for high-dimensional data. Therefore, efficient and powerful comparison methods are critical for making inferences from data. In this presentation, I aim to explain why a graph-based relevance analysis method is desirable and how the method works. A graph-based relevance analysis is non-parametric and free from assumptions about the distribution of observations, and it can be extended to k-means comparison, which provides convenience, flexibility, and full potential. Conducting the analysis involves the following steps: connecting vertices and defining the weight of the edge, optimizing the graph by using tree-finding or path-finding algorithms, conducting tests based on edge counts, and drawing conclusions from the test results. I will illustrate the idea using a wine quality dataset and discuss the impact of the chosen algorithm on edge count and test power.

Simon Snymon

Data sharpening has been shown to reduce bias in nonparametric regression and density estimation. Its performance on nonlinear first order autoregressive models is studied theoretically and numerically in this paper. Although the asymptotic properties of data sharpening are not as favourable in the presence of serial dependence as in bivariate regression with independent responses, it is still found to reduce bias under mild conditions on the autoregression function. Numerical comparisons with the bias reduction method of Cheng et al. (2018) indicate that data sharpening is competitive in this setting.

Daniel Krasnov and Keiran Malott

Background: Breast cancer is the second leading cause of cancer deaths in Canadian women. Early detection reduces treatment costs and offers a favourable prognosis for patients. Classical methods, like

mammograms, rely on radiologists to detect cancerous tumours, which 1) makes them susceptible to errors, 2) are labour-intensive, and 3) depletes healthcare resources. Recent research supplements classical methods with automated mammogram analysis, including those based on Fuzzy C-Means (FCM) clustering. However, base FCM relies on the Euclidean distance, which is not optimized for non-spherical structures.

Aim: We seek to apply FCM and Mahalanobis-distance-based FCM (FCM-M) to detect cancerous tumours in mammograms. To our knowledge, FCM-M has yet to be applied to mammograms. The objectives of the research are: a) to tune a Mahalanobis distance-based FCM algorithm to separate breast tumours in mammograms, b) to evaluate the effectiveness of FCM-M compared to base FCM in this novel application, and c) to release an R package with optimized implementations of these algorithms.

Methods: We replace Euclidean distance with the Mahalanobis distance. We aim to improve runtime through parallelization and improve segmentation quality through 3 centroid initialization algorithms: the Firefly algorithm, the Genetic Algorithm, and the Biogeography-based Optimization algorithm. FCM-M will be tested using images from breast cancer datasets to evaluate its effectiveness compared to base FCM.

Results: The optimized FCM-M decreased computational efforts compared to the original FCM-M, with average runtime per iteration at 46.6s and 24m 25s, respectively. In examining the output images, FCM-M captures the elliptical structure of the tumour far better than FCM. The R package is fully developed and available on GitHub with plans to release to the CRAN.

Takamitsu Koyano

We have measured and modeled the transient response of a length of coaxial transmission line to both voltage steps and narrow pulses. The calculated response was found by first analyzing the transmission line in the complex-frequency or s-domain. An inverse Laplace transform was then used to find the time-domain response. We first considered the case of an ideal (lossless) transmission line and showed that, while the experimental measurements conducted at room temperature captured many of the features found in the calculated response, there were also clear differences. We attempted to capture these non-ideal features by incorporating both conducting and dielectric losses into our transmission line model. In the case of a lossy transmission line, numerical inverse Laplace transforms were used to calculate the desired transient response. Finally, we cooled a semi-rigid coaxial cable to $77\rm\ K$ using liquid nitrogen in order to suppress the losses and observe a measured transient response that better approximates the ideal response of a lossless transmission line.

Alexandra White

Wireless power transmission (WPT) technology is the transmission of electromagnetic energy without the use of electrical wires. WPT technology has seen a surge of research interest due to its potential to make systems increasingly material-efficient, power-efficient, and compact. This presentation details the design of a resonant inductive power transfer system based on the maximum power transfer theorem. The design process focused on the system's mutual coupling coefficient and available power efficiency.

A physical model of an inductively coupled system with series-parallel resonant topology was developed to experimentally test the average power efficiency of the circuit. Experimental results showed significant average power loss due to unaccounted resistances in the receiving and transmitting coils. The equivalent circuit model was enhanced to include the parasitic resistance and capacitance experienced in the

receiving and transmitting coils. An experimental technique for characterizing the mutual coupling coefficient with respect to the transmission distance by changes in reflected impedance is proposed.

Tianle Chen (talk 2, honours project)

We studied the Time-resolved photoluminescence for quantum dots in 6 Silicon Nitride samples. A laser driver is used to excites quantum dots in the samples, and analog PMT is used to record signal coming from the samples. Tripple Exponentials was used to fit the response from the sample. Analysis is done on the life time of each of the sample. The sample was made using plasma-enhanced chemical vapor deposition. Each of the sample is made using different flow rate of NH4 to allow different composition. Analysis on noise signal was done using Euler approximation it removing the sample signal, and root mean square value was used to determined level of noise.

Jordan Sawchuk

Quantum field theory (QFT) has been tremendously successful in its predictions and descriptions of both particle physics and condensed matter physics. The fact that the quantum description of reality is more fundamental than the classical description necessitates a map from existing classical theories onto quantum theories. The difference between the mathematical structures presents a challenge for the construction of a consistent quantization map. In this presentation, I review the ideas behind canonical field quantization, with a particular focus on Dirac's theory for constrained Hamiltonian systems.

Next, I discuss negative energy densities in QFT. In 1965, Epstein et al. demonstrated that local negative energy densities in QFT are unavoidable. If unrestricted, these negative energy densities could lead to a variety of exotic phenomena from naked singularities and warp drives to traversable wormholes and violations of the second law of thermodynamics. This presents a potential contradiction between the predictions of QFT and our observations of physical reality. The contradiction can be avoided by finding quantum energy inequalities (QEIs), i.e. Heisenberg uncertainty principle-like restrictions between the magnitude and duration of negative energy densities. I present abbreviated derivations of QEIs for the Schrodinger and Proca fields in flat spacetime.

Cynthia Kielpinski

COVID-19 has significantly influenced individuals' lives during the past three years. Many people may have experienced different health states of the virus, including testing, diagnosis, hospitalization, intensive care unit, and even mortality. As statisticians, we want to investigate whether the transition probability between any two states has changed and, if so, when it happened. The Markov chain Bernoulli process (Edwards, 1960) has been developed to model two states. Our goal is to extend the two-state Markov chain by allowing more than two states and to propose parametric and non-parametric change point tests to detect the presence of a change point and, if so, to estimate the change point. Introducing these tests aims to develop a robust and powerful test that tracks significant, real-world events captured by time series. We have applied these proposed tests to COVID-19 data which we hypothesize may reveal whether government policies or vaccines implemented during the time of the virus influenced the outcome of COVID-19 throughout the time.