Abstracts

Opening Plenary Address

Discrete Morse Theory as an Introduction to Topology
Dr. Nicholas Scoville, Ursinus College

Like algebra, geometry, and number theory, topology is one of the main branches of mathematics today. Yet unlike algebra, geometry, and number theory, most people are not aware of what topology is. Because of its abstract nature, explaining the main concepts found in topology can be challenging. In this talk, we will discuss some of the main ideas in topology via an introduction to discrete Morse theory. Discrete Morse theory is a tool used in topology, but viewing this tool from the right point of view can shed great light on the important ideas in topology. We will also look at two original research problems, one relating to persistent homology and one relating to merge trees.

Closing Plenary Address

The Power of Lines
Dr. Amy Chapman, Virginia Military Institute

Lines are often seen as simple, easy to work with functions. But what can you do using only lines? In operations research, there's an entire class of problems, linear programming problems, that use only lines to optimize complex systems. In this talk, I will provide a brief introduction to linear programming, and then discuss a humanitarian relief application that approaches the problem of locating relief centers, not just from an operational point of view. This approach takes into account social costs in order to more fairly relieve the suffering of the impacted population.

Student Presentations (Morning)

. **Designing and Implementing a Comprehensive Health Incentive Program for Health Improvement and Economic Growth**
Tommy Dale, Towson University (Advisor: Dr. Ge Han)

Our presentation covers the 2024 Student Research Case Study Challenge held by the Society of Actuaries. Last year over 70 teams at over 70 universities around the world competed for finalist and semifinalist recognition applying their actuarial skills on a real-world problem in a business setting. This year our exploration delves into the fictional country of Lumaria, where SuperLife seeks to enhance policyholder mortality outcomes through a unique approach to life insurance and health incentives. As external consultants, we were tasked with crafting a comprehensive health incentive program to augment SuperLife's long-term life insurance offerings. Our proposed program aims to incentivize healthy behaviors, decrease expected mortality, boost life insurance sales, enhance product marketability, and add economic value to SuperLife. The presentation will thoroughly detail the program's objectives, design, pricing, assumptions, risk mitigation strategies, and data considerations, offering a fresh perspective on achieving SuperLife's ambitious goals.

Phase Transition in Contextuality
Anisah Khattak, Notre Dame of Maryland University (Advisor: Dr. Brian Christy)

Phase transitions in random quantum circuits have recently been a topic of significant study in quantum information theory. For instance, in a monitored random quantum circuit, one can observe a phase transition in the entanglement of the output state from area law to volume law with the intra-circuit measurement rate as the order parameter. We study the existence of a new type of phase transition in random quantum circuits, namely in the amount of contextuality of the measurement outcomes. Contextuality can be viewed as a measure of the observable non-classicality of a set of physical quantities and can be quantified by the ratio of the independence number and the Lovasz theta number of an associated graph. As a toy model, we generated Erds-Reny random graphs to observe a phase transition in this ratio with the probability of an edge between vertices, p, as the order parameter.

Three Qubit Phase Flip, Quantum Error Correction with Coherent Errors
Megan Shirley, Bowie State University (Advisor: Dr. Liu)

In this study, we explore the performance of three-qubit phase flip code with a commonly considered noise model called the coherent rotation about Pauli gate Z. We provide mathematical analysis of the code's performance in terms of fidelity of the resulting state and the probability of obtaining the resulting state after error correction. We find that the probability of finding no error and the aforesaid fidelity are both close to 1 when the error is weak. This shows that the three-qubit phase flip code is efficient at correcting phase flip errors. We employ IBM quantum simulators and find that the simulation results confirm the theoretical analysis. We also implement three qubit phase flip circuit in IBM real quantum computers (IBM quito) and find that the real quantum computer does not work perfectly as expected in the case where no artificial error is imposed. In the other case where we impose weak phase flip errors to the quantum circuit, we find that the real quantum computer reveals bigger errors compared to the artificial error-free case.

A Comparison of Olympic Figure Skating Scoring Systems

Grace Stulman, Towson University (Advisors: Drs. Diana Cheng and John Gonzalez)

This project analyzes figure skating scores earned at the Winter Olympic Games (WOG) in 2002, 2018, and 2022. In 2002, there was a judging scandal related to the pairs and ice dance events at the WOG conducted under the 6.0 judging system. Subsequently, the International Skating Union developed a new system in hopes of improving the consistency of judges ratings and reducing biases that were present. We compared the reliability and consistency of scores in WOG across years where different judging systems were used. The results of these analyses can be used to inform skaters training and the development of scoring regulations in international figure skating.

Student Presentations (Afternoon)

Costs Associated with Natural Hazards: A Data Analysis Project

Bryce Benjamin, Glenelg Country Day School (Advisors: Drs. Diana Cheng and David Thompson)

This data analysis project compares the Expected Annual Loss information from the Federal Emergency Management Agencys National Risk Index tool across several geographic regions. I will be presenting the material contained in an Appendix of an educational module that will be distributed through the Department of Homeland Security (DHS), the Center of Discrete Mathematics and Theoretical Computer Science (DIMACS) at Rutgers University, and SENTRY (Soft-target Engineering to Neutralize the Threat RealitY) at Northeastern University.

The Drinfeld Center of Fusion 2-Category

Fabian Espinoza de Osambela, Johns Hopkins University (Advisor: Dr. Thomas Waddleton)

The study of monoidal and fusion categories has become increasingly important in the recent field of Quantum Topology. In this presentation, I will introduce the basic notions of fusion 2-categories and explain how they correspond to a 4-manifold invariant. I will then define the notion of the Drinfeld center in a fusion 2-category and express the computation of a braided monoidal 2-category. I will end with a bit of context as to the importance of this computations to the study of symmetries in mathematical physics.

Propulsion of a Microswimmer in Low Reynolds Number Environments

Alex Holtzman, Towson University (Advisor: Dr. Herve Nganguia)

How does a microswimmer propel in low Reynolds Number environments, specifically in unconstrained spaces and subject to a Poiseuille flow?

Crime and Trips in Baltimore City

Kristin Lloyd, Natalie Brownlowe, Arderi Brown, Kira Parsons, John Nocera, Towson University (Advisors: Drs. Michael O'Leary and Xiaoyin Wang)

This study investigates the correlation between mobility and crime in Baltimore City through various statistical analyses and spatial methods. Chi-square and K-means cluster analyses confirm significant associations between crime clusters and the pandemic. Linear regression and Principal Component Analysis (PCA) explore the mobility-crime relationship. For each crime and each cluster there is always a positive linear regression line. While the correlation is not strong, it is always positive. Overall, this study emphasizes the importance of understanding mobility dynamics in crime prevention strategies.

Coloring Properties of Classes of Graphs

Christian Pippin, Towson University (Advisors: Drs. Vince Guingona and Miriam Parnes)

TBA

Simplified Bardina Turbulence Model

Grace Stulman, Towson University (Advisor: Dr. Jing Tian)

Turbulence is a fluid regime with the characteristics of being unsteady, irregular, seemingly random and chaotic. It can be used for modeling the weather, ocean currents, water flow in a pipe and air flow around aircraft wings. As a modified version of the classical Navier-Stokes Equations, the Simplified Bardina Turbulence Model has significant implications in our understanding of fluid flows and how they behave. Through the utilization of the Python library, DeepXDE, we use deep neural networks to predict the outcomes of the model.

Information Theory Through Games: Optimizing Shut the Box

Jay Whitmon, Stevenson University (Advisor: Dr. Benjamin Wilson)

Information theory is the scientific study of the quantification and communication of information in a system. We work with systems known as stochastic processes consisting of the different states of the system and the probabilities of moving from each state to each other state. The game Shut the Box can be modeled as a stochastic process where a state is which tiles are still up. Modeling Shut the Box as a stochastic process allows for the computation of a variety of quantities and an analysis of the optimal strategy for the game.