The Twenty-Eighth Annual Nebraska Conference for Undergraduate Wisdom in Mathematics

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TALK ABSTRACTS

PLENARY TALKS

Dr. Erica Graham
Associate Professor and Chair of Mathematics
Bryn Mawr College
Accidentally on Purpose: The "Mathgic" of Unintended Paths

As a terrible planner and an overachieving procrastinator, serendipity—paired with a series of belated (and occasionally naïve) decisions—has shaped my mathematical journey in unexpectedly fruitful ways. In this talk, I'll explore the *mathgical* power of unintended paths—where chance sparks opportunity, a bit of healthy self-delusion quiets uncertainty, and growth becomes its own form of success.

Dr. Suzanne Sindi
Professor of Mathematics
University of California, Merced
The Uncertain Path: How Mathematical Models Guide Us Through Biology's Complexity

Mathematics is often celebrated for the certainty it provides: precise answers, elegant theorems, and clear conclusions. Yet my own path through mathematics, and my work applying it to biology, has been a journey of continual uncertainty, where the most important discoveries emerged not from what I knew, but from what I was willing to explore. In this talk, I will share how my research in mathematical biology unfolded alongside my personal journey, highlighting two systems where mathematics revealed hidden structure. First, I will discuss prions—infectious protein aggregates responsible for devastating diseases like Creutzfeldt-Jakob disease in humans and "mad cow" disease in cattle. To reconcile puzzling discrepancies between test tube experiments and behavior in living cells, we developed stochastic models integrating prion dynamics with cell division. This work uncovered a previously unrecognized structural distinction between prion variants, bridging a critical gap in understanding their behavior.

I will then turn to hemophilia A, a bleeding disorder marked by unpredictable patient variability. Using mechanistic models of blood coagulation, we conducted computational "synthetic clinical trials" to explore how interactions among molecular players shape clotting behavior.t. This approach revealed new interactions influencing clotting behavior and identified promising therapeutic targets. Together, these examples illustrate how mathematical models can act as engines of discovery, especially when biological systems behave unpredictably. I will close by reflecting on how embracing uncertainty—in both science and life—can open doors to deeper insight and impact. Sometimes the journey is less about knowing where you're going than discovering who you become along the way.

Dr. Carol Woodward
Distinguished Member of the Technical Staff
Lawrence Livermore National Laboratory
Mathematics Meets Science Meets Computer Science: The Value of Internships and the Fun of Multidisciplinary Research

Internships provide an opportunity to experience career paths and work environments outside a typical academic setting and can ignite interest in new fields. Multidisciplinary work combines topics and practitioners from multiple fields to accomplish goals that people with expertise in only one area could never accomplish on their own. In this presentation I will overview my path from almost becoming a microbiologist to working as an applied mathematician at Lawrence Livermore National Laboratory. Along the way, I will discuss how internships shaped my career path and how multidisciplinary work has allowed me to stay passionate about science while retaining my love of mathematics.

Talks by Undergraduate Students

Marissa Ackerman, California State University Northridge
Amoebas Reimagined: Polyominoes Moving in Discrete Spaces

Have you ever played Tetris? Tetris pieces are formed by four small squares. Similar shapes formed by small squares are called polyominoes. Imagine a polyomino sitting on a large checkerboard so that its squares coincide with squares of the board. We study how this polyomino moves on the board iterating these steps: remove one of the squares of the polyomino and place it back on the board so that the "new" polyomino is a copy of the original in a slightly different position. Some polyominoes do not move at all, some spin in-place, others move far but skip parts of the board, and a few cover the entire board. We define and classify the movements of these polyominoes. Polyominoes that are able to cover the entire board are called amoebas. Amoebas have been studied in the context of graph theory to understand the structure of quasi-symmetric graphs. Classifying all polyominoes by their movement is an open problem in combinatorial geometry. We classify the movement of all polyominoes with up to seven squares and present structural results for polyominoes of a given width.

Clarice Andorno, Truman State University
The Ramsey Number $R(K_5 - e, K_5)$

The famous Ramsey problem $R(K_5, K_5)$ asks for the smallest integer n such that every red-blue edge coloring of K_n contains a monochromatic K_5. Despite decades of intensive research, the exact value of $R(K_5, K_5)$ remains unknown. In this work, we study a variant of this problem, improving the upper bound for $R(K_5 - e, K_5)$. That is, finding the smallest n such that every red-blue coloring of K_n contains either a red $K_5 - e$ or a blue K_5. Specifically, we prove that $R(K_5 - e, K_5) \leq 31$. Our approach builds upon two recent breakthrough papers by Angeltveit and McKay, which led to the new bound for $R(K_5, K_5)$. In particular, we use a combination of mathematical analysis, algorithm design and coding.

Savannah Bailey, Furman University
Linear Programming in ACC Women's Basketball

We partnered with the Atlantic Coast Conference to explore the scheduling of a women's basketball season with linear programming. A season consists of 162 games spread over 20 play dates, and our initial schedule incorporated constraints related to class schedule, bye-week distribution, end-of-season home games, and away game travel. The addition of three new opponents, Southern Methodist, Stanford, and California, altered the difficulty of the conference and increased travel requirements for all teams. Taking this into account, we minimized CO_2 emissions amassed from travel during the season and added constraints that ensured a fair schedule for each team. Our final schedule included all foundational constraints, gave each team a balanced schedule, and reduced CO_2 emissions by thirty percent compared to the previous season.

Eve Bradley, University of Utah
Crushing Isolation: How Critical Points Partition Lines in the Plane

Persistent homology is a powerful tool in topological data analysis, used to identify the underlying shape of a set of points. Given a data set and a relevant scale parameter, we build a filtration of nested simplicial complexes on the data set, and we obtain a persistence module by looking at the simplicial homology groups of the filtration. The persistence module contains important scale-invariant topological features of the data; these topological features can be summarized as a persistence barcode. However, many complicated data sets warrant investigation with respect to multiple scale parameters. These data sets can't be summarized in just one barcode; instead, there exists a barcode along each one-dimensional path, or fiber, through the multi-dimensional parameter space. Our research aims to enumerate equivalence classes of fibers as partitioned by critical points, points in the parameter space where the homology of the simplicial complexes might change.

Annalise Caulfield, John Carroll University
Reilly Lewis, John Carroll University
Modeling The Spread of The Oropouche Virus

Oropouche is a viral disease with a growing impact in areas of South America and the Caribbean. To study the spread of the disease, mathematical models of Oropouche were developed and analyzed. These models are variations of SIS and SIR compartmental models. A stability analysis was conducted on the disease-free equilibria of these models. To further investigate stability, the next-generation matrix approach was used to find the basic reproduction number of the disease. The basic reproduction number was used to gain insight about the persistence of the disease over time. Simulations were then run with hypothetical parameters to visualize theoretical situations in which the disease either persists or dies out.

Sebastian Corry, Grinnell College
Stable (Equivariant) Ehrhart Theory

A theorem of Ehrhart states that the numbers of lattice points lying in dilations of a rational polytope have a rational generating function and, in fact, are described by a quasi-polynomial in the dilation factor. Often, polytopes appear not alone, but in families: for example, the families of standard simplices, of cross-polytopes, of permutohedra, etc. When considering such families of polytopes, a natural question is that of the quasi-polynomiality of the function encoding the Ehrhart theory of an entire family. In this presentation, we consider families of polytopes admitting high degrees of symmetry and characterize such families have bivariate lattice point enumerators given by quasi-polynomials. Moreover, we show that quasi-polynomiality becomes even nicer in the equivariant setting, where the symmetries of the polytopes are account for.

Kaley Crosley, University of Central Oklahoma
3-Dimensional Agent-Based Modeling of Fibrin Fiber Interactions

Blood clots are held together by a network of fibrin fibers. Using an 3-dimensional agent-based approach we aim to model accurate fibrin interactions to better understand how fibrin networks form. The model consists of pre-defined fibers represented by line segments discretized by 20 points. Every individual fiber moves randomly every time-step based on a set of rotation and translation parameters. When discretized points from two different line segments get below a set proximity-threshold, they form a connection at those points and continue to diffuse as a component at the fixed angle. We present results about the types and angles of junctions that are formed and how certain junctions are formed. Comparing experimental results with model results allow us to determine formation of fibrin networks. We show that unlike the accepted theory of fibrin branching, fibrin fiber networks are formed by random movement and sticking together of fibrin fibers rather than splitting of fibers during polymerization.

Aurielle Davis, University of Central Oklahoma
Oversampling Algorithms for Archetype-Preserving Data Summarization

Low-rank approximations provide an effective way to summarize large data matrices while preserving key matrix properties. These approximations are typically derived from the matrix's singular value decomposition (SVD) or QR decomposition. However, such methods often fail to retain the original structure of data points in the matrix's rows or columns. This issue can be circumvented by summarizing the data with a subset of data points, that is, rows and/or columns from the original matrix. Several algorithms for this index selection problem, including Leverage Scores, DEIM (Discrete Empirical Interpolation Method), and Q-DEIM, use the rank-k SVD to select at most k representative data points. In cases where the restriction to k selected points is too limiting, oversampling algorithms to select additional points have been proposed. As some such algorithms have shown promise in initial studies, we evaluate existing and novel oversampling algorithms, examining their success in preserving archetypal data points.

Lauren Dragon, Drake University
ChatGPT vs CLAIMBot: Which AI Chatbot is Effective in Assisting Proof Revisions?

With the emergence of artificial intelligence (AI)-based tools, both opportunities and challenges arise in how these tools may impact the quality of students' proof writing. This study explores supportive actions of two AI-based chatbots–ChatGPT, a general-purpose AI chatbot, and CLAIMBot, a purposefully instructed AI chatbot by our research team–in assisting proof revisions. The data includes four student-generated triangle angle sum theorem arguments identified from the literature and responses from each chatbot when asked to support improvement of arguments. Using both inductive and deductive coding, the supportive actions of the chatbots were analyzed. Findings show that during proof revisions, ChatGPT frequently uses "funneling" questions, which guide students toward a pre-determined answer, whereas CLAIMBot typically uses "focusing" questions, which prompt students to justify and refine their reasoning. Pedagogical considerations when integrating AI chatbots in mathematics classrooms to assist students' learning about proof-writing will be discussed.

Eugène Duvert, Wesleyan University
Matroids on Extended Cycles

We show that the unions of edge-disjoint cycles of a graph form a matroid and provide cryptomorphic characterizations via a closure operator and a rank function. We prove that the rank of the matroid agrees with the cyclomatic number and the dimension of the cycle space.

Jasmin Fallin, Carleton College
Exploring the Effects of hurricanes on Coral Stability using Flow-Kick Models

The long-term effects of hurricanes on both the populations of coral and macroalgae can be modeled by Flow-Kick modeling. Flow-kick models describe the growth and behavior of an Ordinary Differential Equation system with respect to time, and then an instantaneous disturbance ('kick'). With this, we can manipulate various parameters such as time and growth rates to examine the behavior of such systems under stress or disturbance. In our case, we used the equations from Blackwood et al. (2011) and examined the behavior of this coral-macroalgae system while also introducing deterministic hurricanes. With our 3D simplified model that captures time, coral, and macroalgae, we found that frequent hurricanes will benefit the population of coral under certain parameters.

Nayda Farnsworth, Colgate University
Establishing an Improved Lower Bound on $HJ(3,3)$

At first glance, tic-tac-toe may seem unexciting, often ending in a tie. However, the Hales-Jewett theorem transforms this simple game into a rich combinatorial phenomenon. What if we extend the game-board to higher dimensions, and allow several people to play the game at once? How high must the game-board dimension be to necessarily avoid a draw? These questions are answered by the Hales–Jewett number $HJ(n,m)$, the minimal dimension d of a hypercube $[n]^d$ such that any m-coloring of its cells admits a length-n monochromatic combinatorial line. In 2014, the first and only non-trivial Hales–Jewett number was computed; in particular, it was shown that $HJ(3,2)=4$. We investigate the undetermined Hales–Jewett numbers $HJ(3,3)$ and $HJ(4,2)$. By leveraging SAT solvers and van der Waerden-based Hales–Jewett bounds, we establish the improved bound $HJ(3,3) \geq 14$ and present the first machine-assisted proofs on known bounds of $HJ(3,3)$ and $HJ(4,2)$. The bound $HJ(3,3) \geq 14$ is also noteworthy as the first lower bound that is strictly larger than the bound implied by van der Waerden's Theorem.

Evelyn Fiore, Augustana University
Decomposing Dice into Square Sided Dice

We continue the exploration of a question of dice relabeling posed by Gallian and Rusin: Given n dice, each labeled 1 through m, how many ways are there to relabel the dice without changing the frequencies of the possible sums? We answer this question in the case where $n=2$ and m is a product of two distinct natural numbers. We find a method for decomposing two m-sided dice into two dice of different sizes and discuss the results on relabeling two dice of different sizes.

Shaye Fordring, Northern Arizona University
Pattern Avoidance in Signed Cayley Permutations

Any permutation of n may be written in one-line notation as a sequence of entries representing the result of applying the permutation to the identity $12 \cdots n$. If p and q are two permutations, then p is said to contain q as a pattern if some subsequence of the entries of p has the same relative order as all of the entries of q. If p does not contain a pattern q, then p is said to avoid q. One of the first notable results in the field of permutation patterns was obtained by MacMahon in 1915 when he proved that the ubiquitous Catalan numbers count the 123-avoiding permutations. We study pattern avoidance in the context of signed Cayley permutations. Introduced by Mor and Fraenkel in 1983, a Cayley permutation is a finite sequence of positive integers that include at least one copy of each integer between one and its maximum value. In a signed Cayley permutation, each entry can be positive or negative. In this talk, we explore pattern avoidance in signed Cayley permutations with the aim of providing species, exponential generating series, and counting formulas. We also include several conjectures and open problems.

Arabella Fuzak, College of Saint Benedict/Saint John's University
An Analysis of a Family of Root-Finding Methods

This project is on mathematical root finding functions and creating images to visually see where they converge. Root finding is calculating where a function converges to zero, otherwise known as the zero or root of the function. This project focuses on using different root finding methods to see the difference in how they depict convergence to a root, diverge to infinity or move around in a complicated set commonly referred to as a fractal. This research question has been dealt with before however, I hope to find if untried complex parameter values cause the methods to converge which have not been done before. To help answer this question, I have coded the different root finding methods in the Hansen-Patrick Family, will analyze the behavior of finding roots for various families of polynomials.

Rebecca Gabrielsson, Coe College
A New Bound for the Maximum Number of Plane Graphs on n Points

In this work, we push our understanding of plane graphs in two related ways by improving the current best bounds for two properties that have been studied by many past works. First, we prove that for any set of n points, the expected number of isolated vertices in a random plane graph is at least $\frac{n}{2079}$, improving upon the previous $\frac{n}{3083}$. As an application of this bound, we obtain that any set of n points have at most $O(181.26^n)$ plane graphs, improving upon the previous $O(187.53^n)$.

Lenora Grygiel, Western Washington University
Creativity in Mathematics: How the Fundamentals of Mathematics Relate to the Fundamentals of Acting in Theatre

Today, mathematics is known for being a rigid subject, especially among people who do not study mathematics. However, math is an inherently creative subject. Throughout the history of mathematics, people have used their creativity and imaginations to discover theorems and create proofs that define how mathematics works. Similarly, acting in theatre is known for being a completely creative process. Instead, many actors use logical practices and systems to improve their acting skills and create their characters. This research is working to bridge the gap between these two subjects by showing that these subjects are both human endeavors that are used to better understand the world. This has been done by exploring the systems actors use and comparing them with how mathematicians create proofs, thus highlighting both the creative and logical aspects within each practice.

Stella Gulledge, Park University
Straightening Identities in the Universal Enveloping Algebra of the Witt Algebra

The Poincaré-Birkhoff-Witt (PBW) Theorem states that we can rewrite elements of the noncommutative universal enveloping algebra of a Lie algebra (or $U(L)$) as unique linear combinations of products with the factors in any fixed order. The PBW theorem does not state how these products can be reordered, only that it is possible. This reordering process is known as "straightening." Our research lies in the universal enveloping algebra of the Witt algebra, a Lie algebra over $\mathbb{C}$ with basis elements d_n, $n \in \mathbb{Z}$. The Witt algebra's Lie bracket is defined as $[d_m, d_n] = (n-m)d_{m+n}$. This, along with the commutator bracket, defined as $[d_m, d_n] = d_m d_n - d_n d_m$, are tools for straightening products of the basis elements. We aim to derive a general closed formula for straightening products of the form $d_m^r d_n^s$, $m, n, r, s \in \mathbb{N} : m > n$. We will present previously derived straightening identities proven via induction on r and s. Additional straightening identities have been found by via a Lie algebra isomorphism with the well-studied Lie algebra $\mathfrak{sl}_2$. Straightening identities have applications in representation theory. Basis elements of $U(W)$ "act upon" vectors in an arbitrary vector space V. In this space, the actions of $d_0.v$ and $d_m.v$ are defined and $d_{-m}.v$ is unclear. By using these straightening identities to reorder basis elements, we may perform known operations first and delay uncertain operations.

Destiney Housley, California State University, Sacramento
Noah Niederklein, Concordia University, Nebraska
Prediction of Stochastic Processes Indexed by a Dyadic Tree

Stochastic processes indexed by vertices of a homogeneous tree – an undirected, acyclic, connected graph where every vertex has the same degree – play an important role in applications such as signal processing and wavelet transforms. We adapt the Schur-Levinson algorithm to solve a prediction problem and a covariance extension problem in this setting.

Olivia Kaminske, Keene State College
New Methods for Identifying Important Structures in a Neural Network Model of the Brain

Combinatorial Threshold-Linear Networks (CTLNs) are a neural network model that is used to simulate the firing rates of neurons. This model is based on a system of differential equations that compute the firing rates of each neuron in the system. In particular, we are interested in a special family of CTLNs called core motifs. Identifying these core motifs is integral to extrapolating CTLN findings to larger networks like the brain, but checking if CTLNs are core is computationally complex and difficult to scale. In an effort to more easily identify core motifs, I formed two conjectures that rule out large numbers of CTLNs as not core using simpler computations. These two conjectures use determinant sign and out-degree uniformity respectively to drastically reduce the computations required to find core motifs, allowing for greater scalability and computability.

Preetinder Kaur, Saint Louis University
Binary Pullback Parking Function

A variant of parking functions is the (k, ℓ)-pullback parking function (PPF). In these, if a car's preferred spot is occupied, it may look up to k spots behind its preferred spot to check for an available spot. If it still cannot park, the car then checks up to ℓ spots ahead of its preferred spot and parks if one is available. Our work studies a specialization of PPFs in which there is a collection of (k, ℓ)-tuples, and each car i has its own (k_i, ℓ_i) which determine how many spots it can check back (the parameter k_i) and how many it can check forward (the parameter ℓ_i) whenever it finds its preferred spot occupied. We focus on a special case where all of the parameters satisfy satisfy $k_i + \ell_i = 1$, and all parking functions that satisfy these conditions are called Binary Pullback Parking Function (BPF). Previous work has established that $(0, 1)$-PPFs, also known as Unit interval Parking Functions (UPFs), and they are counted by the Fubini numbers ($F_n = 1, 3, 13, 75, 541, \dots$). Since UPFs also satisfy that $k_i + \ell_i = 0 + 1 = 1$ for all i, they are a BPF. Our main result is that all BPFs are likewise enumerated by the Fubini numbers. To explain this, we construct a bijection that maps any BPF to another BPF in a structure-preserving way. We also describe a second bijection between weakly increasing-BPF and weakly decreasing-BPF.

Tegan Keen, Colorado State University
On the Identifiability of Leak Parameters in Linear Compartmental Models

In many applications, including in ecology and pharmacokinetics, linear compartmental models are used to model transfer between "compartments" which may represent populations, drug concentration, etc. Such models are represented by directed graphs in which the edges represent the transfers between compartments. An important feature of such models is the identifiability degree, which summarizes the extent to which it is possible to recover the transfer rates from noiseless experimental data. More precisely, the identifiability degree of a parameter is 1 if the transfer rate can be recovered uniquely, and is greater than 1 if the transfer rate can be recovered only up to a finite set (this size is equal to the degree). In this presentation, we investigate the effects of adding leaks (edges directed out of the model) on the identifiability degree. We show that in a model represented by a strongly connected graph, if exactly one leak is in the same compartment as an output, then that leak parameter is uniquely identifiable. We investigate improvements to this result, looking at the preservation of the identifiability degree of the non-leak parameters and the applicability to non-strongly connected graphs, like in the case of directed path models.

Sloane Kinley, Converse University
Mathematical Design of Tree-Shaped DNA Nanostructures

Deoxyribonucleic Acid (DNA) has been proven to be a valuable building block for constructing nanostructures capable of targeted drug delivery. DNA is also characterized as self-assembling; when a sticky end is introduced to complementary unbonded base pairs, they will hydrogen bond without any mechanical assistance. Graph theory can be implemented to model this phenomenon, and one such framework is referred to as the flexible tile model of DNA self-assembly. This model allows for symmetry and predicted bonding where it may not exist in the lab setting. We add to the flexible tile model in order to calculate the probability of self-assembly of certain graphs. This theoretical experiment explores the possibility and probability that the cohesive end types, in the flexible tile model, can bond to other end types when exposed to one another in the lab setting. Markov chains are used to calculate steady states of bond probabilities. This exploration specifically focuses on small tree graphs of orders three and four.

Madelyn Krueger, Hobart and William Smith Colleges
Mathematical Modeling of Bureaucracy and Corruption

In economic and political systems, regulation and bureaucracy are important mechanisms for ensuring a level playing field. However, these systems are vulnerable to corruption on small and large scales, especially when the bureaucratic system is inefficient. In this work, we use a compartmental mathematical model to explore the systemic costs of petty corruption, the relative strengths of different intervention strategies, and some counterintuitive special cases in which small amounts of corruption might increase the efficient operation of the system.

Reilly Lewis, John Carroll University
see **Annalise Caulfield**

Yihan Carmen Li, Carleton College
RD of $PSU(3, q)$

Resolvent degree (RD) is an invariant of finite groups in terms of the complexity of their algebraic actions. We address the problem of bounding $\mathrm{RD}(G)$ for all finite simple groups using established methods in terms of $\mathrm{RD}^{\leq d}_{\mathrm{Cb}}$-versality and special points. We give upper bounds on $\mathrm{RD}(\mathrm{PSU}(3, q))$ and $\mathrm{RD}(\mathrm{PSU}(2, q))$ in terms of classical invariant theory. In the $\mathrm{PSU}(3, q)$ case, stability of low-degree invariants permit an asymptotic bound on RD growing in q.

Sophie Meronek, Drake University
Realizing Graphs as Proper Power Graphs

Algebraic graph theory is the intersection between graph theory and algebra (linear and abstract). One area of interest in algebraic graph theory is power graphs, which are a way of visualizing groups and the relationships between elements and their powers. Our research looked into cataloging what graphs are proper power graphs of a finite group. Specifically, we are interested in what families of graphs can be recognized as proper power graphs. Some families include cycles, stars, and complete graphs.

Taylor Murrell, Virginia Polytechnic Institute and State University
LLM-Based Cryptographic Steganography: Methods for Undetectable Encrypted Communication

Steganography conceals existence; cryptography conceals content. We study LLM-based cryptographic steganography, embedding ciphertext in fluent LM output so a passive observer must first detect covert communication. Building on Gligoroski et al., we introduce balanced equivalence-class token selection for known-position resistance, reducing mean token rank at embedding positions from 12.71 to 5.22 ($\approx$ 59% reduction) and producing more natural token choices. Our tree-based constrained encoder backtracks over token paths and guarantees 100% message recovery in tested configurations. Example CPU runtimes: $\approx$ 6 s (GPT-2) and $\approx$ 39 min (Llama-3.2B). This work draws on cryptography, statistics, and information theory. Cryptographic encodings ensure recoverability and length preservation; statistical tools provide detectors and analytic approximations; information-theoretic measures quantify how closely embedded-token distributions match ordinary model output. For a simple known-position frequency attack inspecting 500 positions, our distinguisher correctly identifies embedded text $\approx$ 54.8% of the time – a marginal advantage over chance. Together, these techniques enable covert, recoverable messages that blend into public text, supporting private exchanges that do not appear as communication.

Noah Niederklein, Concordia University, Nebraska
see **Destiney Housley**

Camille Paradis, Skidmore College
Investigating the First Laurent Coefficient of the Hilbert Series for Symplectic Quotients by S_1 and SU_2

The first Laurent coefficient of the Hilbert series of regular functions on a symplectic quotient by S^1 and SU_2, referred to as γ_0, is a ratio of Schur polynomials. The goal of this project was to find if or when this number is the same for a symplectic quotient of S^1 and SU_2 of the same dimension through experimental checking. This was to find if γ_0 could be used to differentiate between symplectic quotients by the two groups. In addition, when studying the partial derivative of γ_0 for a symplectic quotient by S^1, the numerator is currently defined as a summation of skew Schur polynomials. It is known that this can be rewritten as a linear combination of Schur polynomials. The other part of the goal was to write this numerator explicitly in the terms of Schur polynomials. We will present progress made on these two goals.

Jasmine Pham, University of Nebraska–Lincoln
Analysis of a Intraguild Predation Model of Burmese Pythons and American Alligators in the Everglades

We discuss the application of differential equation predator-prey models to species in the Everglades area of Southern Florida. Burmese Pythons (Python molurus bivittatus) are invasive to Southern Florida and have established themselves as both an apex predator and an environmental threat. Since becoming established in the Everglades in 2000, small mammal populations have declined rapidly. While efforts have been made to reduce Python populations, controlling them has proven difficult. The natural apex predator in the Everglades is the American Alligator (Alligator mississippiensis). Interactions between Burmese Pythons and American Alligators include both preying on each other and competing for prey, a biological interaction known as intraguild predation. However, Burmese Pythons prey on American Alligators at a significantly higher rate, indicating asymmetric intraguild predation. The impact of Burmese Pythons on the Everglades ecosystem is a topic of great concern with dire ecological impacts. Thus, a three-dimensional predator-prey model incorporating American Alligators, Burmese Pythons, and a shared prey species may prove useful in understanding the effects of Burmese Python introduction in the Everglades ecosystem. This model may also help guide Burmese Python population reduction programs.

Devayani Pradhan, University of Michigan
Let Bigons be Bigons: Van Kampen Diagrams and Word Reduction

In this talk, we introduce Van Kampen diagrams as a way to analyze finitely presented groups. One essential problem in the study of such groups is the word problem, which asks if there is an algorithm to determine the equivalence of any two words. While such an algorithm may not exist in general, it does if words can be reduced to the identity without increasing word length. Following Wise, we will demonstrate how the geometry of Van Kampen diagrams can prove that such a reduction is possible. We will then discuss these techniques in the setting of the mapping class group of the five-times punctured sphere. In particular, we focus on understanding the curvature of minimal area Van Kampen diagrams for a certain presentation of this group.

Lucia Raciti, Saint Mary's College
Flying Through Change: The Red-Bellied Woodpecker's Shifting Body Size in Response to a Warming Climate

This study investigates how climate change, particularly rising temperatures, has affected the body size of Red-bellied Woodpeckers (Melanerpes carolinus) in the United States, with a focus on the period between 2000 and 2017 when climate changes became more pronounced globally. We apply a range of machine learning models to explore changes in body size using wing chord length as an indicator over time due to climate change. The data was categorized by regions, focusing on states with similar climates to identify patterns of bird size changes over time. Preliminary findings indicate a decline in body size in colder states between 2002 and 2012, coinciding with increasing temperatures, followed by a notable increase around 2014. These patterns suggest that temperature plays a role in size changes, though inconsistencies across regions point to additional ecological or behavioral influences, such as migratory shifts from warmer to colder states. These findings contribute to a better understanding of how species may respond to climate change and inform strategies for biodiversity conservation.

Alana Ray, Truman State University
Isomorphism Classes of Maximal Chain Descent Orders of the Lattice of Flats of a Graph

We study the structure of a finite graph G by investigating certain partial orders on the maximal chains in the lattice of flats of G. These partial orders on maximal chains are called maximal chain decent orders (MCDOs), which were introduced by Lacina for any finite, bounded poset that has something called an EL-labeling. Each total order on the edges of G gives rise to an EL labeling of its lattice of flats, which gives rise to an MCDO. We ask the question: when do different total orders on the edges of G result in isomorphic MCDOs? We give partial answers to this question. In particular, when G is a forest or cycle, the MCDOs of G are isomorphic no matter the total order on its edges. When G is two cycles that share an edge, we give an explicit description of the MCDO induced by a total order on its edges. This explicit description allows us to partially answer our question for G. Namely, it shows when the MCDOs induced by certain total orders on its edges are not isomorphic. Some parts of this explicit description also apply to constructing MCDOs of the lattice of flats of a general matroid.

Lily Rippeteau, University of Nebraska–Lincoln
The Road to Efficient Graph Comparison: Assessing the DIWECT's Graph Retrieval Success and Speed

A common problem in mathematics is comparing two graphs to each other. For example, a city planner might want to know how similar one road intersection (represented as a graph) is to another intersection. There are several commonly used graph distances such as the Huasdorff and Frechet distances. However, commonly used graph distances can be unfeasible to use on large amounts of data due to their computation time. A way to reduce computation time is to reduce each graph from a $n \times n$ matrix to a one-dimensional vector that captures the essential information of the graph. This can be done using a topological descriptor called the directionally integrated weighted Euler characteristic transform (DIWECT). This work investigates the use of the DIWECT to assess graph similarity between road network data from California. It confirms the retrieval of graphs from a dataset that are most topologically similar to a given test graph, and shows the extreme speed with which this can be done.

Bella Roberge, Skidmore College
Computing the Hilbert Measure for non-Coregular Representations of the Special Orthogonal Group.

The elements of the Lie group $\mathrm{SO}(m)$ rotate points in the m-dimensional space $\mathbb{R}^m$. Given a collection of k vectors in $\mathbb{R}^m$, the invariant polynomials are generated by the dot products and determinants of these vectors. If we want to integrate a function of these k vectors that is invariant under the $\mathrm{SO}(m)$-action, we can take advantage of these invariants to simplify our integral. Specifically, we can change to these invariants to reduce the number of variables we're integrating over. In order to do this we need a function called the Hilbert measure that connects the integral in terms of the original coordinates to the integral in terms of the invariants. We will present computations of the Hilbert measure for the non-coregular cases of k points $\mathbb{R}^m$.

Micaela Roth, Wellesley College
Understanding Networks Through Balanced Colorings

A red-blue coloring of a graph is an assignment of a color (red or blue) to each vertex, and a neighborhood balanced coloring of a graph is a red-blue coloring for which each vertex has an equal number of red and blue vertices in its open neighborhood. Since not all graphs have a neighborhood balanced coloring, my work explores a generalization of this idea. A graph is k-balanced if it has a red-blue coloring so that for each vertex, the difference between the number of red and blue vertices in its open neighborhood is at most k. In this talk, we will discuss the balance number of a graph, which is the minimum k for which the graph is k-balanced. I will present results from different graph families, and also explore the closed neighborhood version of the problem. A k-balanced coloring can be used to model a network of employees with two desirable skills so that the set of coworkers that each person interacts with has an optimal balance of these skills.

Mark Sandey, University of California, Riverside
Configuration Spaces of Composite Open Kinematic Systems Using A Categorical Framework

Due to work by Baez et al., it is known open systems in classical mechanics can be represented in such a way that they can be composed along shared information, such as shared interactions or actors. In particular, forthcoming work due to Abeje-Stine and Weisbart proposes such a compositional framework by constructing a category whose objects are the configuration spaces of open systems and whose morphisms are inclusions into configuration spaces of larger open systems consisting of additional actors or constraints. In this presentation, we compute the configuration spaces of several classical mechanical systems which have yet to be addressed using this framework in the literature.

Sam Schaich, Furman University
Breaking Codes Using Integer Programming

Integer programming has been used for decades to solve logistical problems in fields such as operations research and supply chain management. This technique utilizes an objective, such as maximizing value or minimizing costs, and constraints, such as meeting supply or demand requirements, to inform the model of a solution space and how to navigate through it. In our research, we applied this integer programming technique to decrypt monoalphabetic substitutions ciphers (MASCs). In historical cryptography, MASCs were used to encrypt or obscure a message by replacing one letter with another for the entire text, essentially creating a one-to-one mapping of the alphabet to a permutation of the alphabet. Our integer programming model takes in a text that was encrypted by an MASC and decides whether to decrypt letter x as letter y under constraints provided both by the patterns in the cipher text and a distribution of letter usage in the English language. Preliminary results show high accuracy for long text samples and demonstrate the potential of this method for decoding MASC-encrypted messages.

Eric Shao, The Pennsylvania State University
Hybrid Low-Rank and Frequency-Domain Method for Image Compression

We explore a hybrid approach to image compression that combines two advanced mathematical techniques: Randomized Singular Value Decomposition (RSVD) and the Fast Fourier Transform (FFT). While RSVD captures global structure through low-rank approximation in the spatial domain, FFT emphasizes frequency-domain sparsity by discarding high-frequency components. Our hybrid method first applies FFT-based filtering to remove negligible frequency content, followed by RSVD to compress the spatially smoothed image. Using a test image (my selfie) in MATLAB, we evaluate this pipeline against standalone RSVD and FFT methods using quantitative metrics including Frobenius norm error, Peak Signal-to-Noise Ratio, and Structural Similarity Index. The results suggest that the hybrid approach offers improved trade-offs between compression ratio and reconstruction quality while maintaining high runtime efficiency, particularly for images with mixed spatial and frequency complexity.

Gabriella Stewart, Northern Arizona University
Cover Pebbling Numbers of Directed Graphs

The cover pebbling number of a graph is the minimum number of pebbles needed so that from any initial arrangement of the pebbles, after a series of pebbling moves, there is at least one pebble on every vertex. We will present new results on the cover pebbling numbers of various families of directed graphs.

Deja Story, Tennessee State University
Symbolic Rees Algebras of Space Monomial Curves with Multiplicity Five

Determining when a symbolic Rees algebra is Noetherian remains challenging in the study of prime ideals defining space monomial curves. We will focus on the multiplicity 5 case and aim to show that $R_s(p)$ is Noetherian for all such curves. This research investigates all cases for multiplicity 5 using Huneke's 1987 theorem and computational methods in Macaulay to search for elements f, g satisfying the length condition $\lambda(A/(f,g,x)) = \lambda(A/(p,x)) \cdot k \cdot l$.

Shiqi Sun, Carleton College
Do Machines Count? AI-Powered Exploration of the Tree Unimodality Conjecture

The independence sequence of a graph encodes the numbers of independent sets of fixed sizes. Over 30 years ago, Erdös and coauthors conjectured that the independence sequence for any tree is unimodal. Redcliffe later verified a stronger condition, log-concavity, for all trees with up to 25 vertices using an algorithm developed due to Yosef and coauthors. However, in 2023 Kadrawi, Levit, Yosef, and Mirzrachi developed a dynamic programming algorithm and discovered exactly two counterexamples on 26 vertices. Building on this and the machine learning architecture PatternBoost, we trained a machine to find counterexamples to the log-concavity conjecture. In this presentation, I will highlight the successes of the method, including new counterexamples on larger trees, as well as some striking failures that emerged along the way. This presentation is based on research conducted at the NYC Discrete Math REU under the supervision of Professor Eric Ramos (Stevens Institute of Technology).

Ella Theoharis, Skidmore College

Uniqueness of the First Laurent Coefficient of the Hilbert Series of SU_2-Symplectic Quotients

Symplectic quotients are geometric objects formed from a representation of a group. One way of studying symplectic quotients is through the Hilbert series, a power series that counts functions on the symplectic quotient of each degree. The Laurent expansion of the Hilbert series at $t = 1$ has coefficients that are important invariants of the symplectic quotient. When the group is SU_2, the first of these Laurent coefficients $\gamma_0^{SU_2}$ can be expressed using Schur polynomials, which are a specific kind of symmetric polynomial. We will discuss the first Laurent coefficient of the Hilbert series of a symplectic quotient and its expression in terms of Schur polynomials. We will present progress on the question of whether, in a given symplectic quotient dimension, the first Laurent coefficients of the Hilbert series of the symplectic quotient associated with the SU_2-representation $\gamma_0^{SU_2}$ are unique. This question explores whether one can use the first Laurent coefficient to distinguish between SU_2-symplectic quotients.

Sam Thiel, Oberlin College

Costello Division: Exploration of a Comedic Division Algorithm

In the 1940's, comedian and amateur mathematician Lou Costello proved erroneously on film that 7 times 13 equals 28. He does this with three methods, including long division of 28 by 7, getting 13 as a quotient. Costello's mistakes grant us an insight into an alternate world of mathematics. We first analyze Costello's proof and focus on Costello's long division mistakes. Then, we use our analysis to define a new operation that extends Costello's example into a consistent algorithm for any dividend and sufficiently small divisors. We name this algorithm Costello division, and then prove the surprising fact that any remainders under Costello division are equal to those under standard division.

Quella Wang, Northeastern University

Connection between Math & Music: Topological Patterns in Beethoven's Symphony

We ask: how do the chords in Beethoven's Symphony¬†relate over time? Each chord is represented as a point in a geometric space where "distance" measures how many and how far voices would need to move to get from one chord to another. This lets harmony become a shape we can study. Using tools from Topological Data Analysis (TDA), we apply the Mapper to build a network that sketches the landscape of the data: regions group similar chords, and bridges show smooth voice-leading paths. Persistent homology looks across many "zoom levels" and records features that persist–like connected regions and loops–so we can separate stable musical structure from noise. We find clear harmonic neighborhoods (tonal areas), predictable corridors used for modulation, and recurrent loops linked to cadential patterns and thematic returns. Pivot chords appear as hubs connecting regions. This project shows how topology captures large-scale harmonic design. The approach is robust to performance choices, complements traditional analysis of music theory, and points to future comparisons across works and styles.

Joan West, University of Tennessee–Martin
Radio Graceful Cartesian Products of Circulant Graphs

Radio labeling is an active field of graph theory connected to $L(2,1)$-labeling and vertex coloring, among others. A radio labeling of a simple, connected graph G is a vertex labeling $f : V_G \to \mathbb{Z}^+$ satisfying

$$|f(u) - f(v)| \geq \mathrm{diam}(G) + 1 - d(u, v)$$

for all distinct $u, v \in V_G$. Optimal radio labelings of a given graph G minimize the span of the labeling. Since f is injective, the minimal possible span of a radio labeling is $|V_G|$. Graphs for which this span is achievable are called radio graceful, and examples of such graphs are sought. The conditions G must satisfy to be radio graceful become more restrictive as $\mathrm{diam}(G)$ increases, so high diameter examples are particularly valuable. We will discuss the results of an undergraduate research project in which we discovered a new infinite family of radio graceful graphs of arbitrarily large diameter from Cartesian products of certain circulant graphs.

Sidney Wright, Hope College
Artificial Intelligence Agent Training Across a Family of Combinatorial Games

This talk explores how various reinforcement learning applications can be applied to train artificial intelligence (AI) agents in developing strategies for combinatorial games. Specifically, we study a family of 2-player combinatorial games played on m-by-n grids, where players alternate placing their pieces until the grid is full. Once complete, sequences of pieces are scored based on length and a scoring mechanism. The variety of methods of reinforcement learning used during this research includes tabular learning and genetic algorithms involving artificial neural networks. We train these AI agents using a variety of non-learning agents and evaluate their performance against both non-learning agents and one another to assess the effectiveness of their decision-making. In addition to experimental work, we explore theoretical aspects of this family of games, identifying optimal strategies in many smaller cases.

Xizhi Zhou, Mount Holyoke College
Uniform-in-Time Limiting Behavior of Ergodic Markov Chain

Ergodic theorems for Markov chains (MCs) are classical and elementary topics. However, the nature of limit theorems for perturbed MCs X_n^ε, even in finite state spaces, is not well documented. The existing classical metastability results characterize $\mathbb{P}(X_n^\varepsilon \in \cdot)$ as $\varepsilon \downarrow 0$ on specific time scales $n = n(\varepsilon)$. In this work, we instead aim to seek *uniform-in-time* descriptions: conditions under which the distribution of X_n^ε converges to a limit simultaneously for all n in a broad range. We have been successful in writing theorems for some degenerate cases, while some other cases still remain open.