Abstracts for the MAA Undergraduate Student Poster Session "Research in Motion"

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Organized by
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MATHEMATICAL ASSOCIATION OF AMERICA

Dear Students, Advisors, Judges and Colleagues,

As you walk around today, you will see posters and presenters representing a wide array of mathematical topics and ideas. These posters showcase the vibrant research being conducted as part of summer programs and during the academic year at colleges and universities from across the United States and beyond. It is so rewarding to see this session, which offers such a great opportunity for interaction between students and professional mathematicians, continue to grow.

The judges you see here today are professional mathematicians from institutions around the world. They are advisors, colleagues, new PhDs, and administrators. Many of the judges signed up when they registered for the conference, but there are also a number of judges here today who volunteered on-site. Their support is vital to the success of the session, and we thank them.

This session is one of many activities organized by the MAA Committee on Undergraduate Student Programming (CUSP), and we'd like to recognize their efforts. Committee members are listed on the next page.

If you're a faculty member who'd like to get involved in the undergraduate activities at MAA MathFest and beyond, please consider joining CUSP.

It takes a lot of work behind the scenes to make this day go smoothly, and we're grateful to the MAA staff for all their hard work: Cheryl Adams (Director, Meetings and Member Relations), Max O'Hern (MAA Senior Meetings Specialist), Olesia Romanova (MAA Meetings and Events Program Specialist), Bonnie Ponce (Publications Operations Manager), Annie Pettit (Editorial Coordinator, Publications), Brit Gourdine (Communities Specialist), and Jody Efron (Programs Assistant).

Thanks to all the students, judges, volunteers, and sponsors. We hope you have a wonderful experience at this year's poster session!

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Tom Langley
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Titles, Authors, Advisors and Abstracts

1. Characters of Lie Algebras

Evelina Gustafsson University of Alabama in Huntsville

Advisor(s): Alejandro Ginory, University of Alabama in Huntsville

There are several methods used to compute the characters of irreducible representations of Lie groups and algebras. For example, Weyl's character formula gives an algebraic method, and Littleman paths give a combinatorial approach. The purpose of the research was to find a simpler method to compute the characters of irreducible representations of A_3. In my work, I have found fundamental geometric patterns in the polytopes formed by the weights of irreducible representations that allow us to express an irreducible representation of A_3 as the sum of irreducible representations of A_2. Lie groups and their algebras play a crucial role in many areas. Although these objects were initially introduced to study the solutions of differential equations by taking advantage of their symmetry, Lie groups and algebras have wide-ranging applications in pure mathematics and physics. Therefore, understanding how Lie groups and algebras act on vector spaces, i.e., their representation theory, is of paramount importance.

2. Tolerant: A Non-Vanishing Discriminant for Repeated Roots

Swechchha Adhikari Brigham Young University

Advisor(s): Stephen McKean, Brigham Young University

We study a generalization of the discriminant of a polynomial, which we call the tolerant. The tolerant differs by a square from the duplicant, which was discovered in recent work on $\mathbb{P}^1$-loop spaces in motivic homotopy theory. We show that the tolerant is rational by deriving a formula in terms of discriminants. We also show that the tolerant satisfies many of the same properties as the discriminant. A notable difference between the two is that the discriminant is inversion invariant for all polynomials, whereas the tolerant is only inversion invariant on a proper multiplicative subset of polynomials.

3. Structure Constants for the Universal Enveloping Algebras of the Lie Algebras of Dimension Four and Smaller

Emmerson Taylor Park University

Advisor(s): Samuel Chamberlin, Park University

Given a Lie algebra, L, over $\mathbb{R}$ or $\mathbb{C}$, the universal enveloping algebra of L, $\mathbf{U}(L)$, encompasses all noncommutative polynomials with coefficients from the field, where the variables are the basis elements of L. $\mathbf{U}(L)$ is also equipped with the commutator bracket, that is the relation $xy = yx + [x, y]$, which gives us a way to "straighten" or reorder products of basis elements. The Poincaré-Birkhoff-Witt (PBW) Theorem implies that every element of $\mathbf{U}(L)$ can be written uniquely as a linear combination of products of elements of L in any fixed order. The coefficients of the resulting linear combination are referred to as the structure constants. The goal of our research was to derive straightening identities in $\mathbf{U}(L)$ where L has dimension four and smaller in order to find their structure constants. We formulated and proved closed formulas for the structure constants of many of these algebras.

4. Structures of Groups of Order 2^n Realized by Groups of Units

Avery Martin Texas Woman's University

Cadence McKinney Texas Woman's University

Advisor(s): Alexis Hardesty, Texas Woman's University

In this research, we investigate which structures of finite abelian groups of order 2^n are realized as groups of units. The groups of units of order 2^n can be generated using Fermat primes. For each value of n, we compute a metric on the variety of structures realized, analyzing how this metric changes based on a partition of n as distinct powers of 2.

5. Straightening Identities within the Universal Enveloping Algebra of the Witt Algebra

Stella Gulledge Park University

Ellie Miller Park University

Advisor(s): Samuel Chamberlin, Park University

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, combined with the commutator bracket, defined as $[d_m, d_n] = d_m d_n - d_n d_m$, are our tools for straightening products of the basis elements. Our research aims to derive a generals closed formula for straightening products of the form $d_m^r d_n^s, m, n, r, s \in \mathbb{N} : m > n$. We present straightening formulas for the products $d_m^r d_n$ and $d_m d_n^s$, proven by induction on r and s respectively. We are actively researching more formulas with specific r. Furthermore, $\mathfrak{sl}_2$ is the well-studied vector space of all 2×2 matrices with complex entries and trace 0. Fixing $m \in \mathbb{N}$, we derived a Lie algebra isomorphism $\phi : \mathfrak{sl}_2 \to \text{span}\{d_{-m}, d_0, d_m\}$, and several straightening formulas follow.

6. Visualizing the Fourier Transformation: Wrapping Functions Around Circles in The Complex Plane

Landon Jackman Norther Michigan University

Advisor(s): Joshua Thompson, Northern Michigan University

This project explores the Fourier transform, a fundamental concept in signal processing, through an intuitive visual representation. The Fourier transform decomposes a function of time (or space) into its constituent frequencies. The project is a visual approach to understanding just how the transformation works, wrapping functions around the origin in the complex plane to illustrate the underlying mathematical principles. By mapping functions onto circular paths, the transformation process becomes more understandable, revealing the relationships between the original function's characteristics and its frequency spectrum. This approach provides a dynamic and engaging way to understand how different frequencies contribute to the overall shape of a signal, offering insights for students and professionals in fields such as engineering, physics, and mathematics.

7. On a product rule for certain quantum metrics on matrices

Han Na Shin Scripps College

Advisor(s): Konrad Aguilar, Pomona College

Quantum metrics in the sense of Rieffel were developed to address some statements arising in the high energy physics literature. Quantum metrics are induced by certain seminorms that behave like the Lipschitz constant seminorm, which measures the absolute maximum value of the derivative. Therefore, these seminorms may have some form of product rule. Certain quantum metrics on matrices have been verified to have a version of the product rule, but it is unknown if this is the correct version. In this project, we provide computational evidence that suggests a better version exists.

8. Discrepancy Estimates for Liouville Irrationals and Applications to Quantum Dynamics of Quasi-Periodic Schrödinger Operators

Matthew Bradshaw University of Connecticut

Titus de Jong University of California, Irvine

Audrey Wang Rice University

Advisor(s): Wencai Liu, Texas A&M

We study the distribution of the sequence $\{n\alpha\}_{n=1}^{N}$ on the torus $\mathbb{T}^d$ when α is a Liouville irrational vector. Unlike the well-understood Diophantine case, such vectors exhibit irregular behavior. We establish upper bounds on the discrepancy of these sequences and apply our estimates to analyze quantum transport in quasi-periodic Schrödinger operators. This work was done as a part of the Texas A&M REU program.

9. Analyzing Systemic Inequities in Trespass Towing through Data-Driven Web Applications

Alexandra Veremeychik Montgomery College

Advisor(s): Rachel Saidi, Montgomery College

In this poster we explore the development of data-driven web applications designed to address potential systemic inequities in trespass towing within Montgomery County, Maryland. By analyzing towing data from July 2021 to June 2024 and integrating geographic, economic, and demographic datasets, we explored measures with the potential to track disparities. This included the development of a mathematical model to rank towing companies based on carefully chosen parameters and a GIS towing activity tracker incorporating over 100,000 data points.

10. Explorations in Flow-Kick Dynamics - Part I

Agnes Boahen Carleton College

Angelina Kong Carleton College

Jasmin Fallin Carleton College

Advisor(s): Katherine (Kate) Meyer, Carleton College

What do wildfires, hurricanes, and drug doses have in common? One answer is that each of these events repeatedly knocks a system off its growth trajectory, whether that system is a forest, a coastal community, or a tumor. We will describe the flow-kick approach to modeling these dynamics using differential equations with discrete perturbations. Analyzing a flow-kick map allows us to consider questions like whether disturbance and recovery can balance one another and how changes to the amplitude and frequency of disturbances affect behavior of the system. We will share flow-kick insights in an application area we chose to explore in summer 2025.

11. Quantitative Analysis of Trading Strategies on MBT (Micro Bitcoin Futures)

Bijay Bhat William Paterson University

Unnur Chaulagain William Paterson University

Advisor(s): Von Dohlen , William Paterson University

Micro Bitcoin futures (MBT) provide retail traders with inexpensive exposure to cryptocurrency price action, yet naive limit-stop rules almost always lose money. We demonstrate how disciplined quantitative optimisation converts a negative-expectancy idea into a statistically robust trading engine. Using thinkorswim MBT day bars from January 2021 through April 2024, we generate 191,000 distinct limit/stop pairs and evaluate each with a walk-forward back-test that debits commission and slippage in real time. The selected parameters (entry limit 214.5 ticks, protective stop 9.5 ticks) earn US $5,200 net per contract and produce an equity curve with $R^2 = 0.99$. Although only 11% of trades finish positive, rare outsized gains dominate frequent small losses; the expectancy equation $E = p\mu_w - (1-p)\mu_l$ explains the edge. We illustrate the convex performance surface that guides parameter choice and contrast the raw model (slope-1.16, R^2 0.07) with the optimised curve (slope +5.52, R^2 0.9912). All code is written in Fortran for maximum speed and reproducibility.

12. Analysis of the effectiveness of insecticide control for dengue: A mathematical perspective

Victor Salcedo University of Puerto Rico-Mayaguez

Advisor(s): Luis Eduardo López-Montengro, Universidad de Cladas - Colombia

This article formulates a mathematical model that represents the transmission dynamics of the dengue virus in the human population, considering the population growth of the mosquito vector Aedes aegypti. Considering the equilibrium at which the mosquito population stabilizes, the model is simplified to a one-dimensional system. Subsequently, a local stability analysis is conducted on the equilibrium points of the simplified model based on the basic reproduction number of the disease. Since the basic reproduction number depends on a control parameter ε which represents the effectiveness of applying an insecticide to the mosquito population, constant control strategies are implemented to help reduce the number of infected individuals. Additionally, a cost functional is incorporated into the model to represent the direct and indirect costs of applying the control, and an optimal solution is obtained using Pontryagin's Maximum Principle. Finally, a piecewise constant control strategy based on the optimal solution is established, offering an additional alternative for health authorities responsible for implementing such control measures.

13. Cloudy with a Chance of Aspirin: Optimized drone delivery system for elderly and disabled people.

Inmaculada Felipe Delgado Wayland Baptist University

Dario Catalan Baguena Wayland Baptist University

Advisor(s): Charles Nelms, Wayland Baptist University

Life gets busy. Memory gets tricky. Medication delivery shouldn't be either — that's why we send drones. This project proposes a drone delivery system designed for elderly (65+) and disabled people in Hale County, Texas, to help deal with the increasing healthcare delivery challenges in rural areas. Medications would first be transported by truck to key towns across the county. Then, a set of drones would deliver the medication to individual homes, according to the needs of each individual. We developed a software solution capable of computing the most efficient delivery paths using optimization methods based upon the Traveling Salesman Problem and graph theory. Our program estimates the number of drones required per day and calculates the total delivery time based on distance and needs. The goal is to have a system capable of delivering the medication to the people in rural areas who have the least access.

14. A Reinforcement Learning Powered Dynamic Graph-Game Framework for Arctic Conservation

Ryka Chopra Mission San Jose High School

Advisor(s): Man Chiu (Sunny) Wong, University of Houston

Arctic cryosphere is vital to climate balance and biodiversity. CryoSat-2 data shows ice thickness declining 12.5% per decade, adding 29% atop the 1°C warming since 1880. Conserving Arctic ice is critical. Depletion stems from natural and anthropogenic stressors. However, existing physics-based and deep-learning models lack a unified framework, hindering long-term policy evaluation. We propose a dynamic graph-game framework unifying prediction and conservation research. The framework employs a double-graph structure that captures links between ice states and stakeholder networks, and establishes a circular feedback loop between ice evolution and human strategic behavior over iterative time periods. Reinforcement learning–based strategy updates integrate immediate impacts and long-run outcomes, enabling adaptive policy optimization. Embedded within an IceNet-inspired architecture, this model improves long-term forecast accuracy by 25.1% over IceNet. Under forward-looking learning rules, voluntary cooperation emerges as the dominant Nash equilibrium, reducing melt rates from 12.5% to 4.1% per decade. This approach achieves significant conservation gains without costly interventions.

15. Hammers for Hope: Improving Affordable Housing in Philadelphia

Jaylin Golar Rowan College at Burlington County

Chance Murray Rowan College at Burlington County

Julia Rosa Rowan College at Burlington County

Advisor(s): Jonathan Weisbrod, Rowan College at Burlington County

Within the United States, housing affordability continues to become a debilitating issue. As a result, several individuals lack access to safe and sustainable housing. In light of this issue, our group was tasked with developing a housing strategy for a city with at least 100,000 residents. To combat this issue in our chosen city of Philadelphia, our program focuses on creating more houses while providing employment for those facing housing insecurity. As a result of this program, a notable decrease in people living on the streets and utilizing shelter services would occur. Further, the average price of a house and rent would become more affordable, all while bringing in revenue for the city. This poster displays our team's solution to the 2025 AMATYC Student Research League Competition.

16. Modeling Complex Brain Dynamics Using Integral Operators

Saugat Acharya Idaho State University

Alice Giola Idaho State University

Andreas Kramer Idaho State University

Advisor(s): Emanuele Zappala, Idaho State University

Understanding complex temporal patterns in brain activity requires models that can capture both spatial and temporal dependencies over extended time scales. In this poster, we introduce a deep learning framework based on neural integral equations for analyzing and classifying fMRI stimuli. We outline the theoretical foundations of the operator learning problem and present a series of experiments to validate the effectiveness of our approach. Our results demonstrate that the proposed model can accurately classify neural stimuli from input data, reconstruct stimuli from fMRI recordings, and generate meaningful dynamical embeddings that reveal underlying brain activity patterns.

17. Investigating Tipping Points in the Budyko Climate Model

Demmi Ramos Lenoir-Rhyne University

Advisor(s): John Gemmer, Wake Forest University

The Budyko Climate Model is a dynamical system that represents the change in Earth's temperature as a function of latitude and time. Since dynamical systems can be used to make predictions about future behaviors, they are a powerful tool for analyzing climate forecasts. This model simplifies Earth's system by assuming it consists entirely of ocean and ice with no continents or freshwater bodies, includes no heat transport or advection, and treats the Northern and Southern Hemispheres as symmetrical. The model has three equilibrium states: stable ice, stable ocean, and a bistable state. To study stochastic transitions between these states, additive noise is introduced through a stochastic differential equation, which takes into consideration natural climate variability due to random fluctuations in weather. This poster explores noise-induced tipping points to identify when a shift from one equilibrium to another may occur. The project was done in collaboration with the Mathematics Climate Research Network.

18. Low-Dimension Feature Compression-Efficient MNIST Classification Using Haar Wavelet Transform

Nhu Y Nguyen Western State Connecticuit University

Advisor(s): Xiaodi Wang, Western State Connecticut University

This study proposes a mathematically-grounded dimensionality reduction method for image classification using the Haar wavelet transform. High-dimensional image data often imposes significant computational burdens, especially in resource-constrained environments like embedded systems. Wavelet transforms offer a principled approach to compression while preserving structural features. In this research, we apply a two-dimensional level-2 Haar wavelet transform to MNIST dataset images, reducing each 28×28 image (784 features) to a 7×7 approximation matrix (49 features). This process retains low-frequency coefficients and constitutes a linear transformation via orthonormal matrices. Logistic regression models trained on original and compressed features achieved 91.59% and 89.64% accuracy, respectively. The wavelet approach reduced dimensionality by 93.8% and yielded an 8.4× training speedup. Results demonstrate that wavelet preprocessing provides an effective speed-accuracy trade-off with minimal performance loss. This method offers an interpretable, efficient alternative to high-dimensional pixel models, making it highly suitable for low-power applications.

19. When Math Predicts Collapse: Evolutionary Game Theory Uncovers Social Strategy Failure in Dating Ecosystems

Triumph Kia Teh Dartmouth College

Advisor(s): Feng Fu, Dartmouth College

Emotionally charged environments characterize contemporary college dating cultures. We used evolutionary game theory to examine why, in spite of mathematical models that predict the predominance of AVOIDANT behavior, students are becoming more and more COMMITTERS. We simulated replicator dynamics on the 3-simplex and derived a four-strategy payoff matrix using a Dartmouth survey ($n = 81$). In order to resolve significant discrepancies between Nash, ESS, and actual results, our model identifies 15 fixed points, a critical 53% COMMITTER basin boundary, and a central repeller that represents a universal loss state. The majority of research on dating culture is qualitative in nature, but there are many strategic choices to be made on campuses, such as when to commit, avoid, explore, or pretend. Peer pressure, reputational risks, and emotional stakes are all present for students. In order to determine whether there is such a thing as an evolutionarily stable dating strategy and to observe what happens when dating behavior is viewed as a dynamic game, we wanted to apply mathematics. Can dedication endure? Is it possible for trust to change? Is it worth a try?

20. The winner and loser of the war of languages, and how to implement a “peace plan”

Maxwell Goskie Belmont University

Advisor(s): Zhujin Wu, Iowa State University

The war of languages, where languages compete for use in a population, has been going on for centuries and has worsened in recent decades. A few “world powers” of languages have expanded their massive grounds while thousands of other vulnerables have struggled for survival. As part of an REU at Iowa State University, we model the conflicts among the rivaled languages as a game and give a theoretical account on the nature of the war as the languages win or lose or agree upon a “peace plan” We show that the social status of a language and its preference among social groups influences its ability to compete against rivals in a society. We also show that societal interventions, for better or worse, may divert the course of the war, either declaring a winner or a loser of the war under certain language policies, or creating an equilibrium for multiple languages to co-exist in a society. We present the results and justifications from our analysis and simulation, all in a game theoretic setting.

21. Recurrent Variational Autoencoders for Multi-Lead ECG Classification

Shervin Tabatabai University of Central Oklahoma

Advisor(s): Emily Hendryx-Lyons, University of Central Oklahoma

The electrocardiogram (ECG) is a vital tool used by physicians to diagnose cardiac irregularities. ECGs can be recorded with a number of lead combinations, and the data can be transformed into various representations to gain greater insight.

This project studies arrhythmia detection using single- and 12-lead ECG data, as well as transformed vectorcardiogram (VCG) data. The goal is to classify beats as normal or anomalous according to clinical labels. Variational autoencoders (VAEs) using recurrent neural network layers are trained on each data representation to encode and recreate non-anomalous heartbeats. Since the VAE models are only trained on normal data, it is expected that the VAEs will not recreate anomalous data well, and discrepancies can be used to distinguish between different beat types. Classification of each beat type is performed using reconstruction error of recreated beats as well as encoded data extracted from the VAEs. Each classification method and data type combination is evaluated based on different metrics. The purpose of this research is to aid physicians in automated heartbeat classification to improve patient outcomes.

22. Oversampling Algorithms for Data Summarization

Auri Davis University of Central Oklahoma

Autumn Langer University of Central Oklahoma

Advisor(s): Emily Hendryx Lyons, University of Central Oklahoma

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 approximating the data with a subset of rows and/or columns from the original matrix. Several algorithms for this index selection problem, such as Leverage Scores, DEIM (Discrete Empirical Interpolation Method), and Q-DEIM, use the rank-k SVD to select at most k representative data points. Because computing the full SVD can be computationally expensive, "oversampling algorithms" that select k data points from a lower-rank SVD may offer a more practical alternative for subset selection. As some such algorithms have shown promise in prior studies, we adapt existing methods to produce several novel algorithms of this kind, examining their success in preserving archetypal data points.

23. New Heuristics for Optimal Team Selection for Pokemon GO PVP

Presley Wilson Bakersfield College

Gianna Nicomedes Bakersfield College

Elizabeth Camacho Bakersfield College

Advisor(s): Jonathan Brown, Bakersfield College

Pokemon GO player versus player combat has major international interest, and advise is a significant industry. However, they rely on full simulations for a few hand picked options, or rudimentary mathematical modeling. We present more developed mathematical models. We apply these to the entire dataset, and present and the implications for optimal team selection.

24. Mathematical Optimization of Investment Portfolios: Markowitzs Model and Modern Enhancements

Milan Rustagi Wake Forest University

Advisor(s): Stephen Robinson, Wake Forest University

In this project, I explore how an investor can optimize their expected return given a tolerance for risk, using Markowitz's Optimal Portfolio Theory as a starting point. Given a set of stocks, each with a known expected return and variance, find the portfolio (set of investment weights) which maximizes an investor's return for a given risk level (variance of the portfolio). Naturally, this results in a Lagrangian framework and the application of Karush-Kuhn-Tucker (KKT) conditions assuming non-negative weights. Learning this classical theory is the initial step in the process. Next, I might expand the model by substituting more contemporary risk metrics like Value-at-Risk (VaR) for variance. Further extensions involve examining the performance of the portfolio over several time periods, and allowing for options to

be traded. The overarching question at the heart of this project is: "How do we optimally incorporate options into an investment portfolio?".

25. Analysis of Rodent Behavior via Positional Data Using Machine Learning

Gabriel Bawden DeSales University

Alan Alexander DeSales University

Advisor(s): Carl Hammarsten, DeSales University

Based solely on human experience, it is difficult to attribute behaviors such as pain and anxiety to mice. This project addresses this difficulty through behavioral analysis of mice using machine learning and data science. This involves two main parts. The first takes data in the form of videos of mice and extracts positional data for multiple parts of a mouse using the machine learning program DeepLabCut. We then identify prominent features via persistent homology. These features are not physical positions or characteristics like a location in a cage or a foot, but rather abstract mathematical representations of key behaviors. We reduce this dataset to the most relevant features through Kernel Density Estimation. In the next part of the project, we create and train a machine learning algorithm using the reduced dataset. This produces a computational classifier capable of detecting the behavioral state (i.e., pain vs no pain, or stress vs no stress) in novel test subjects, thus opening up a new level of objectivity in, and potentially improving the quality of, rodent research.

26. Automated Microglial Phenotype Classification: A Comparison of Transformer-Based and Convolutional Vision Models

John Gerving California State Polytechnic University, Humboldt

Advisor(s): Kamila Larripa, California State Polytechnic University, Humboldt

Microglia are a specific immune cell of the central nervous system, and play an important role in brain health as well as neurodegeneration and pathologies such as Alzheimer's Disease. The identification and classification of microglia is an important task for biologists, but doing so on a large scale can be time-consuming. Microglia express multiple phenotypes, and automatically classifying instances of microglia as a given phenotype can provide insight on the overall health of the brain. Computer vision models can perform the task of object detection and classification, thereby significantly decreasing the time spent on this process. In this work, we compare transformer-based vision models to traditional object detection models on an established microglia image set. Transformers have risen in prevalence due to their competitiveness with convolutional neural networks and relative computational efficiency. We assess the accuracy and performance of multiple models in their ability to detect and classify the phenotype of microglia using a variety of metrics.

27. Mathematical Modeling of SARS-CoV-2 Reveals Immune Cell Dysfunction

Keopagnapech Ngoun Elon University

Advisor(s): Hwayeon Ryu, Elon University

In response to the impact of the SARS-CoV-2 pandemic, the scientific community has focused considerable research efforts to understand the spread of the virus. Despite a tremendous volume of research, the dynamics of the immune response to SARS-CoV-2 has been hampered due to limited analysis of the experimental information to date. Mathematical models that account for the interaction between SARS-CoV-2 and the human immune system will improve the scientific community's ability to analyze the amount of data available. We develop a mathematical model for the immune response to SARS-CoV-2 to investigate the role of various pathways in viral clearance and the key mechanisms responsible for its severity. These interactions are captured by a system of ordinary and delayed differential equations. We conduct parameter estimation based on experimental data. Our model demonstrates key aspects of the immune response to SARS-CoV-2 which might be responsible for disease severity. Specifically, Natural Killer Cell dysfunction

impairs its ability to eliminate infected cells effectively. This could be used to serve as a foundation for the development of therapeutic strategies.

28. Agentic AI Framework for Histopathological Breast Cancer Detection Using Wavelet Multi-View Learning and Spatial Transcriptomic

Nikita Karim Western Connecticut State University

Advisor(s): Xiaodi Wang, Western Connecticut State University

This study introduces an agentic artificial intelligence (AAI) framework for breast cancer subtyping and identifying potential treatment options. A foundation model-based approach integrates multi-view representations of histopathological images, wavelet-based decomposition, and spatial transcriptomics to improve malignancy classification. The pipeline processes 277,524 whole-slide image tiles using wavelet-enhanced convolutional neural networks to extract histological features such as nuclear pleomorphism and glandular architecture. Spatial gene expression profiles (including BRCA1, HER2, and PIK3CA) are aligned with tissue architecture and combined with imaging features through a multi-view learning strategy. The agentic system selects dominant modalities, resolves inter-modality conflicts, and estimates clinical outcomes such as surgical strategies or targeted therapies. This framework serves as a tool for classifying breast cancer subtypes, supporting pathologists by improving diagnostic accuracy, reducing review time, and highlighting regions for closer analysis.

29. Modeling the Long-Term Spread of Chornic Wasting Disease in Iowa Whitetail Deer Using Agent Based Simulation

Aidan Jones Simpson College

David Lochner Simpson College

Eric Reines-Schmidt Simpson College

Advisor(s): Adam Brustkern, Simpson College

Chronic Wasting Disease (CWD) is a fatal neurological disease, arising from a misfolded prion that affects cervids, such as whitetail deer. This disease poses a significant threat to cervid populations, hunting economies, and ecological balances. Because the whitetail deer population in Iowa is indispensable for the ecological and fiscal health of the state, mathematical modeling is essential to predict the spread of the disease. This research presents an agent-based model (ABM) to forecast the spread of CWD in Iowa. An ABM is a computational approach in which each individual entity, in this case deer, holds their own behaviors, conditions, characteristics, and calculations according to the defined rules of the model. Using the ABM, this project will evaluate the factors that influence the spread of CWD, including direct and environmental transition pathways. Validating the model through a performance evaluation using a preexisting dataset, we will develop a predictive framework to simulate the future spread of the disease. By adjusting model variables including hunting strategies and environmental factors, we can predict their influence on the spread of CWD over the next 50 years.

30. Can neurocognitive test scores predict ACL injury risk? A transition from MATLAB to Python and a regression analysis

Ethan Drake Simpson College

Eli Fox Simpson College

Jack Howard Simpson College

Advisor(s): Shekoofe Saadat, Simpson College

Anterior Cruciate Ligament (ACL) injuries are highly common among young athletes playing team sports (Chia et al, 2022). Previous studies have shown that individuals with previous ACL tears have slower reaction time compared to

healthy individuals (Jiménez-Martínez et al, 2025). The goals of this project were twofold. Our first objective was to transfer an existing MATLAB code into Python and validate the Python scripts. While MATLAB offers a user-friendly interface and extensive built-in functions, its licensing costs have led to a growing interest in transferring motion analysis programs to Python, an open-source language with a large set of scientific computing libraries. Our second objective was to investigate the relationship between neurocognitive test scores and ACL injury risk factors in healthy individuals during a series of jump landing movements. We used a multiple linear regression model to better understand how test scores can predict landing mechanics associated with higher injury risk.

31. Taxman game's optimal second move

Jose Colchado St. Edward's University

Advisor(s): Jason Callahan, St. Edward's University

The taxman game begins with a list of integers from 1 to some integer N. The player may only select a number with proper divisors left on the list, which the taxman then collects. When no numbers with proper divisors left on the list remain, the taxman collects all remaining numbers, and whoever has the largest sum of numbers wins. Previous research shows that the player's optimal first move is the largest prime on the list, and their optimal second move is the largest square of a prime on the list if $N \leq 1000$ except for $N = 8, 20$, and 120. We show that this is the optimal second move for all $N > 120$. We then analyze the algorithm of the aforementioned previous research to explore subsequent optimal moves.

32. On the Smallest Partition Associated to a Numerical Semigroup

Kaylee Kim University of California, Irvine

Advisor(s): Nathan Kaplan, University of California, Irvine

The set of hook lengths of an integer partition λ is the complement of some numerical semigroup S. There has been recent interest in studying the number of partitions with a given set of hook lengths. Very little is known about the distribution of sizes of this finite set of partitions. We focus on the problem of determining the size of the smallest size of a partition with set of hook lengths equal to $\mathbb{N} \setminus S$. (This work was completed as an undergraduate research program at the University of California, Irvine during Summer 2024.)

34. Cycle Diagrams of Permutations and Hopf Links

Efosa Owie Towson University

Advisor(s): Nathan McNew, Towson University

The cycle diagrams of permutations resemble grid diagrams used to depict knots and links in topology. By drawing the cycle diagram of a permutation and then considering that diagram to be a grid diagram instead, we can associate a knot to any permutation. Previous work has enumerated permutations that correspond to unknots (or unlinks). We investigate permutations whose cycle diagrams correspond to Hopf links and trefoil knots. It suffices to characterize those permutations which are derangement ($\sigma(i) \neq i$ for any i) and have no points on the off diagonal ($|\sigma(i) - i| \neq 1$ for all i, $\sigma(1) \neq n$ and $\sigma(n) \neq 1$). Using ideas motivated by Seifert's algorithm in topology, a method to obtain the boundary of a connected, oriented surface by smoothing crossings and connecting the resulting loops with bands, we are able to characterize all the permutations that are associated to a Hopf link.

35. Solution to the sum 15 game, and its relation to other tic-tac-toe variants using combinatorial game theory

Travis Mickle Cal State University of Monterey Bay

Advisor(s): Alison Lynch, Cal State University of Monterey Bay

The 15 sum game is a popular children's puzzle game used to practice arithmetic. Two students face off with three rings on a peg board with pegs 1-9 trying to make their three numbers add up to 15. The game may end in three moves or last forever. If the board is rearranged so the numbers form a magic square, it becomes obvious that it is equivalent to tic-tac-toe where players are limited to three markers and can change the position of one after their third turn. Unlike other similar variants which are well known and date back thousands of years, the 15 sum game is not a first player win, but a draw with optimal play. We will show the method of proving this fact, and how optimal play will result in looped gameplay.

36. A Disproof of Two Conjectures by Defant and Kravitz

Olivia Chen Boston Latin School

Jerry Zhang South Pasadena High School

Michael Luo Minnetonka High School

Advisor(s): Yunseo Choi, Harvard University

When generalizing West's stack-sorting map on permutation to words, a natural question is whether identical characters should be allowed to sit on top of each other in the stack. As a result, Defant and Kravitz introduced two distinct maps, tortoise and hare: while tortoise does not allow identical characters to sit on top of themselves, hare does. For a word w, let $\langle w\rangle_{\text{tortoise}}$ and $\langle w\rangle_{\text{hare}}$ be the number of iterations of tortoise and hare required to sort w, respectively. For a word of length $|w|$, Defant and Kravitz conjectured

$$\langle w\rangle_{\text{hare}} - \langle w\rangle_{\text{tortoise}} \leq \frac{|w|-5}{2} \quad \text{and} \quad \langle w\rangle_{\text{hare}} \leq 2\langle w\rangle_{\text{tortoise}} - 2.$$

We disprove both conjectures. Our results imply $\langle w\rangle_{\text{hare}}/\langle w\rangle_{\text{tortoise}}$ may be arbitrarily large.

37. Direct Isomer Enumeration of Cycloalkenes, Cycloalkadienes, and Cycloalkatrienes

Rishabh Mahale Okemos High School

Advisor(s): Rajesh Kulkarni, Michigan State University

The enumeration of isomers has been a topic of interest for chemists and mathematicians alike for centuries. This paper aims to directly enumerate the number of isomers for cycloalkenes, cycloalkadienes, and cycloalkatrienes. Chemical graphs are used to represent the 3D structure of these molecules. In a spirit similar to Nemba's enumeration of cycloalkanes, Polya's theorem will be employed on these chemical graphs to develop the algorithms that will produce closed-form formulas representing the upper bound of isomers for the class of molecules of interest, polyhomosubstituted monocyclic cycloalkenes. Partial integer sequences are derived from the closed-form formulas. The technique used to develop the algorithm for cycloalkatrienes potentially implies a way to extend the enumeration past 3 double bonds, making the process less tedious. Many complex, practical molecules involve rings and interactions other than single bonds, and these algorithms may one day be built up to enumerate them.

38. Spectral Radii and Critical Groups of Arithmetical Structures

Sebastian Ramirez-Gonzalez University of Puerto Rico, Rio Piedras

Jedward Melendez University of Puerto Rico, Rio Piedras

Paul McGinley Villanova University

Advisor(s): Alexander Diaz-Lopez, Villanova University

An arithmetical structure on a graph is an integer labeling on the vertices of the graph such that the label at each vertex divides the sum of the labels of its neighbors and the gcd of the labels is 1. Dino Lorenzini originally defined them in order to answer some questions in algebraic geometry, but more recently, they have been studied on their own,

particularly with a combinatorics and algebraic lens. In this talk, we will discuss results about the spectral radius of some matrices associated to these structures and results about the critical group (a generalization of the sandpile group) for these structures.

39. Counting Arithmetical Structures on Cycles with a Multi Edge

Nesty Dogbatse Villanova University

Bryan Busby University of Puerto Rico, Mayaguez

Peter Palma Villanova University

Advisor(s): Alexander Diaz-Lopez, Villanova University

An arithmetical structure on a graph is an integer labeling on the vertices of the graph such that the label at each vertex divides the sum of the labels of its neighbors and the gcd of the labels is 1. Dino Lorenzini originally defined them in order to answer some questions in algebraic geometry, but more recently, they have been studied on their own, particularly with a combinatorics and algebraic lens. In this presentation, we will discuss recent enumerative results related to arithmetical structures on cycles with a multi edge.

40. On the sum of 1st column hooksets of integer partitions with a focus on numerical semigroups

Nicholas (Nick) Rosa CSU East Bay

Advisor(s): Simone Sisneros-Thiry, CSU East Bay

We present various patterns on the sum of 1st column hooksets of integer partitions with focus on numerical semigroups. For every integer partition, there is a unique Ferrers diagram that encodes useful information about its corresponding numerical set. The 1st column of the diagram is equivalent to the complement of its numerical set. A type of numerical set is one with closure under addition, called a numerical semigroup. We showcase the structured nature of the sum of the 1st column for integer partitions, given size and genus. Additionally, we present a generalization of the complements of numerical semigroups whose multiplicity is 2 or 3. This project works toward enumerating numerical semigroups whose corresponding partition has a 1st column hookset that sums to n.

41. On The Resolution of Torus Knot Shadows

Brian Beveridge CSU Monterey Bay

Ignacio Maravilla CSU Monterey Bay

Advisor(s): Gabriel Chavez, CSU Monterey Bay

In knot theory, a shadow is a projection of a knot diagram in which all crossing information is omitted. Each shadow corresponds to a collection of full knot diagrams, or resolutions, obtained by assigning over- and under-crossings in all possible ways. In this paper, we investigate the structure and resolution counts of shadows associated with (p, q)-torus knots. Using a combinatorial approach, we prove that among all 2^q possible resolutions of a $(2, q)$-torus knot shadow, exactly $2\binom{q}{\lfloor q/2 \rfloor}$ correspond to unknotted diagrams. Moreover, for the knotted resolutions, we establish a closed-form expression that counts the number of resolutions corresponding to each distinct prime knot type contained within the shadow's resolution space. We generalize our combinatorial framework to other torus knots with $p > 2$.

42. Permutations of Initial Terms and Integer Frequencies in Riffle Transforms of Positive Integer Sequences

Aashrith Muppalla George Walton Comprehensive High School, Research is being completed at Georgia Southern University

Advisor(s): Dennis Stewart, GHP @ Georgia Southern University

We investigate the riffle transformation, which maps a sequence $\langle a_n \rangle$ to a new sequence $\langle a'_n \rangle$ using a recursive formula. Our study addresses two key questions: (1) Does there exist an integer $N > 1$ such that the first N terms of both $\langle a_n \rangle$ and $\langle a'_n \rangle$ are permutations of $\{1, 2, \ldots, N\}$, and if so, what are all such N? (2) For a given $\langle a_n \rangle$, which positive integers never appear, occur only finitely often, or recur infinitely often in $\langle a'_n \rangle$? We use computational methods, including Python simulations and iterative data analysis, to automate riffle operations over a large N. This allows us to identify patterns, test conjectures, and detect emergent behavior. Possible applications include algorithmic shuffling, stream ciphers, randomized data structures, and sequence-based hashing. Our results may suggest broader questions about sequence stability and recurrence under structured transformations. We acknowledge the 2015 ARML contest for inspiration in the above questions.

43. Sequences and Structures That Avoid or Produce Quads

Nahian Nawar Smith College

Fida Bijin Smith College

Sabzara Ali Smith College

Advisor(s): Ileana Vasu, Smith College

EvenQuads is a mathematical card game designed by Dr. Lauren Rose, developed in collaboration with the American Mathematical Society (AMS) and the Association for Women in Mathematics (AWM), to explore mathematical structure, combinatorics, and geometry in an engaging, playful way. In this project we explore combinatorial and geometric structure of quads—sets of four binary vectors in F_2^n whose sum is zero. These structures appear naturally in affine geometry, combinatorics, and mathematical games like Quad 64. We explore both the construction of quad-free sets—those that avoid forming quads—and quad-rich sets and sequences—those that maximize the number of quads. Using a combination of combinatorics, geometry, and computational tools, we explore both quad-free configurations and quad-generating ones. We examine questions like: What is the longest sequence without a quad? What is the probability of getting a quad in a k card layout in n dimensions for $n \geq 6$? What types of patterns produce the most quads? How do random sequences or well-known recursive sequences (like Fibonacci, Thue–Morse) behave in this context?

44. A Fourier Analysis Approach to Comparing Film Music Scores from Hans Zimmer and John Williams

Daniel Hyun Portola High School

Advisor(s): Shelley Godett, Portola High School

While musicologists have studied harmonic elements of film scores, this research introduces Fourier analysis to compare the spectral properties of iconic film compositions. In this study, a selection of film music was analyzed using Fast Fourier Transform to extract frequency spectra from audio waveforms. Preprocessing steps included normalization, time alignment, and signal segmentation. The resulting frequency-domain representations were then compared using cosine similarity. Moreover, frequency plots were used for visual comprehension. The samples used for the analysis include three scores each from Hans Zimmer and John Williams. The cosine similarity and Frequency Spectrum Comparison were retrieved from a pair of scores. Scores coming from the same composer exhibited high cosine similarity with an average of 0.547. In exceptional cases, despite coming from different composers, the scores demonstrated a high level of similarity: Interstellar v. Superman – 0.5951. This work demonstrates that mathematical tools can uncover latent structures within music, complementing traditional music theory. The implications extend to fields such as genre prediction and computational musicology.

45. AI-Driven Micro-Wildfire Prediction and Evacuation Planning Using Multi-Modal Data Fusion

Rhea Ghosal Westlake High School

Advisor(s): Manisha Banerjee, Gogte Institue of technology

Micro-wildfires are often overlooked,which can be incredibly dangerous to ecosystems, infrastructure, and public safety. Systems are designed for larger wildfires and tend to ignore faster-growing outbreaks, with little focus placed on smaller yet more advanced breakthroughs. The goal of this study is to develop an algorithm for estimating micro-wildfires based on data fusion from satellite imagery, weather forecasts, and automated ground sensor systems. LSTM networks achieved 89% accuracy, outperforming CNN classifiers with 92% accuracy and AUC score of 0.94. Random Forest and XGBoost were tested to assess their vulnerability to small sample sizes. With demographic parity, fairness metrics calculated via Equalized Odds showed a reduction from 0.21 to 0.05. The hybrid edge-cloud architecture of the system was validated with Californian, Australian, and Mediterranean datasets. Confidence in model trust was attained from statistical cross-validation and analysis based on the ROC curve. This work adapts machine learning for early detection to optimize wildfire response through a multi-parameter approach, integrating fairness-driven, rational probabilistic frameworks for reasoning.

46. A Comparative Review of Topic Modeling Methods in the Analysis of Open-Ended Survey Results

Hannah Van Cise United States Coast Guard Academy

Jacob Hardy United States Coast Guard Academy

Advisor(s): Jillian McLeod, United States Coast Guard Academy

Organizations collect valuable feedback through open-ended survey comments where users can respond with any amount of detail they deem suitable. When such surveys are completed en masse, the analysis of these unstructured responses can be challenging and tedious. Human-centric coding and analysis of this unstructured data is common to extract themes, but this approach is resource intensive and subjective. Alternatively, a variety of text analytics techniques exist that can provide structure and automation to unstructured text analysis. Topic modeling is a type of Natural Language Processing that seeks to cluster unstructured text documents into latent topics based on word co-occurrence within the text documents. Our research delves into how mathematical concepts presented at the undergraduate level can be harnessed to perform a comparative analysis of various topic modeling methods in the analysis of survey results. The topic modeling methods selected include Latent Dirichlet Allocation, Non-Negative Matrix Factorization, and BERTopic. Essential to the comparison of topic modeling methods is the selection of quantitative metrics that can be universally applied to all methods.

47. Progress on the Andrews-Curtis Conjecture

Jonathan Liu Princeton University

Advisor(s): Sebastian Seung, Princeton University

The Andrews-Curtis conjecture asserts that any balanced presentation of the trivial group can be transformed into a standard form using conjugation and concatenation moves. We employ Proximal Policy Optimization (PPO) to find solutions for the Miller-Schupp series, a set of potential counterexamples. We find that the quality of PPO solutions exceed those from a greedy search, reducing solution lengths by an average of 1.96 moves across 533 generated presentations. We identify 161 equivalent subsequences spanning up to 400 moves, revealing structural redundancies. A contrastive learning approach additionally improves sample efficiency by 25%. A 27,000-presentation dataset of near-minimal solutions supports future scalable critic training.

49. A Comparison of Mathematical Modeling Techniques Describing Disease Spread in Healthcare Settings

Erik Schutte Lewis University

Advisor(s): Cara Sulyok, Lewis University

Clostridioides difficile (C. difficile) is one of the most frequently identified healthcare-acquired infections in United States hospitals and is the leading cause of infectious diarrhea. Colonized patients, both symptomatic and asymptomatic, shed C. difficile endospores that can survive for long periods on surfaces outside the host and are resistant to most commonly-used disinfectants. Transmission often occurs through direct contact with both healthcare workers and fomites, surfaces on which endospores lay dormant. This work uses mathematical modeling to quantify how interactions with healthcare workers and environmental pathways affect disease transmission in a hospital. A system of ordinary differential equations describing these interactions is used to simulate the impact of fomites, healthcare workers, and doctors on patient colonization. Specifically, the effectiveness of these control measures are compared with strategies of previously-developed models to determine whether the predicted control strategies are sensitive to the model structure.

50. Harmonic Content of String Networks: A Physical Application of Quantum Graphs

Miriam Abecasis Monmouth University

Advisor(s): Torrey Gallagher, Monmouth University

It is well known that the harmonics of an idealized vibrating string take the form

$$k = \frac{n\pi}{L}$$

where k represents the harmonics, n is an integer, and L is the string length. We considered two concatenated strings and using quantum graph theory we found the harmonics are of the form

$$k = \frac{n\pi}{\ell_1 + \ell_2}$$

meaning a two-string system abiding by our boundary conditions produces the same harmonic spectrum as a single string of length $L = \ell_1 + \ell_2$. We then built a physical apparatus to allow us to test our theoretical findings. We attached tuning pegs and guitar string to a board, and used the one-string case to establish a baseline error for our two-string case. We then had to develop a way to concatenate two strings without disrupting the system's integrity. Our method of concatenation, analysis including software development, and results will be discussed.

52. 2D and High Dimensional Fractals Inside a Regular Polygon and Polyhedron and Their Projections

Corina Huang Georgia Southern University

Advisor(s): Yan Wu, Georgia Southern University

Fractals can be generated in various ways, including nonlinear dynamical systems in continuous time or their discrete analogues known as iterative maps. One such method is the Chaos Game, a discrete dynamical system that generates fractals by iteratively plotting points at a fixed proportion between the current point and randomly selected vertices of a shape. Starting with a random point inside a polygon, this process produces intricate fractal structures with the right proportional parameter and sufficient iterations. In this project, we extend the Chaos Game beyond the classical 2D setting to generate fractals within regular polygons (2D), polyhedra (3D), and polychora (4D). By introducing constrained vertex selection rules and optimized parameters, we efficiently produce novel and complex fractal forms. To analyze and visualize their structure, we project these high-dimensional fractals into lower-dimensional spaces, such as rendering 4D fractals in 3D, and onto curved surfaces like spheres. This work demonstrates how the Chaos Game can be adapted as a flexible and powerful tool for exploring fractal behavior across multiple dimensions.

53. The Orthocentric System of Every Triangle is the Projection of a Regular Tetrahedron.

Elena Ruiz Belmont University

Chase Pittman Belmont University

Advisor(s): Adam Cartisano, Belmont University

The orthocentric system of a triangle ΔABC is the set $S = \{A, B, C, H\}$, where H is the orthocenter of ΔABC. In this project, we prove S can be lifted to a regular tetrahedron via an oblique projection $\pi : \mathbb{R}^3 :\to \mathbb{R}^2$. We also investigate some consequences, including that the axes of symmetry of the tetrahedron project onto the Euler lines of the triangles formed by the three-element subsets of S.

54. A Solution to a Problem Posed by Caro, Davila, Hennings, and Pepper Concerning d-regular Claw-free Graphs

Maggie Ha University of Houston Downtown

Advisor(s): Ryan Pepper, University of Houston Downtown

For a d-regular, claw-free graph G with the domination number γ and the independence number α, it was established by Caro-Davila-Henning-Pepper in 2024 that $\alpha \leq \frac{2\gamma(d+1)}{d+2}$, and the bound is sharp for $d \in \{2, 3, 4\}$. The question is that whether the equality is achieved when $d \geq 5$. The authors showed this bound was sharp for $d \in \{2, 3, 4\}$ and left as an open problem whether the bound was also sharp when $d \geq 5$. In this paper, we solve this open problem constructively by providing families of graphs achieving equality for all values of $d \geq 5$.

55. Spanning Tree Enumerator of Descendants of Complete Graphs

Sheng-Chang Chen California State University, Sacramento

Shivjyot Brar California State University, Sacramento

Advisor(s): Santosh Kandel, California State University, Sacramento

Graphs appear in many practical applications. A graph is a mathematical structure that models relationships between objects using vertices and edges. One can assign a weight to each edge in the graph, for example, a weight can be the cost to travel along the road that connects two cities. A graph with weights attached to each edge is called a weighted graph. A spanning tree is a subgraph that traverses through all the vertices without repeating a vertex. By taking the product of all the weights in a spanning tree, we can encode information about the cost of that route. If we consider the sum of all the products of the weights in each spanning tree, then it is the total cost it takes to traverse all possible spanning trees of the transportation network. Such a quantity is called a Kirchhoff polynomial or a spanning tree enumerator. In this poster, we discuss an explicit formula for the spanning tree enumerator of a certain class of graphs. Our main result extends previous studies of the number of spanning trees of unweighted graphs, called generalized Weinberg's formula, to the weighted case.

56. NBA Player Rank: A new way to rank players

Elijah Shepherd North Carolia Agricultural and Technical State University

Advisor(s): Laurie Zack, North Carolina Agricultural and Technical State University

NBA player rankings often rely on stats, media polls, and awards. This study proposes a new ranking system using a modified PageRank algorithm, capturing both direct and indirect contributions. The algorithm models players as nodes in a network, with links based on statistical interactions (assists, on-court impact, win shares, net/offensive/defensive rating, and box plus-minus). The algorithm rewards players who perform well against strong competition or contribute to team success. Data was sourced from Basketball Reference. The hypothesis was that the model would correctly rank elite and underrated players. Results show PageRank's potential to offer a more objective, data-driven evaluation.

Future work may refine input metrics and account for roles or team dynamics. This approach could impact how players are assessed, awarded, and valued in contracts

57. Numerical Results of New and Modified Heuristics for the Vertex Coloring Problem

Elliot Hanson University of Minnesota: Morris

Advisor(s): Peh Ng, University of Minnesota: Morris

The *chromatic number*, $\chi(G)$ of an undirected graph $G = (V, E)$ is the minimum number of colors required to color its vertices so that no two adjacent vertices have the same color. Given a graph, G, finding its chromatic number is useful for solving scheduling problems and other combinatorial optimization problems. However, determining the chromatic number of a connected graph is NP-Hard, meaning there is no known polynomial time algorithm which solves it. Thus, we are interested in heuristic solutions which give approximations for the chromatic number in polynomial time. There are well-known heuristics for finding $\chi(G)$ for any graph G. In this project, we introduced modifications to the Welsh-Powell and the sequential heuristics. Specifically, for each vertex, we find its degree in the subgraph induced by the uncolored vertices, rather than using the whole graph throughout. We use numerical results to compare the efficiencies of these heuristics with their predecessors and other, non-iterative, constructive heuristics. We compare heuristics' runtimes and their average results, and we show the classes of graphs on which each of these heuristics is most effective.

58. Optimal Pebbling of Lollipop, Spider, and Tadpole Graphs

Nathaniel Hall University of Southern California

Advisor(s): Matthew Gherman, California Institute of Technology

Graph pebbling involves assigning a non-negative integer to every vertex of a connected graph. Each integer represents the number of "pebbles" on that vertex. A pebbling move redistributes one pebble from a vertex to a neighboring vertex and removes another pebble from the starting vertex. The constraints were developed to prove specific conjectures in number theory. In our work, we focus on a specific variation in which we optimize the pebbling of various types of graphs. We compute the optimal pebbling number of lollipop and tadpole graphs and verify the optimal pebbling of spider graphs.

59. Graham's Conjecture for Novel Graph Products

Mitchell Agris California Institute of Technology

Grace To California Institute of Technology

Advisor(s): Matthew Gherman, California Institute of Technology

Graham's Conjecture states that the pebbling number of the Cartesian product of two graphs is at most the product of the pebbling numbers of the graphs. Graham's Conjecture is the most significant open problem in the theory of graph pebbling. We prove Graham's Conjecture for the lexicographical product of two graphs and provide an example to show that Graham's Conjecture does not always hold for the rooted product of two graphs. We then determine a sharp upper bound for the pebbling number of a rooted product of two graphs in terms of their respective pebbling numbers.

60. Generating Symmetric Crosswords Grids for the New York Times Mini Puzzle

Kirsten Balgord University of Wisconsin-Eau Claire

Advisor(s): Chloe Lewis, University of Wisconsin-Eau Claire

A standard crossword puzzle grid contains words of at least three letters, has no completely black rows or columns, and is symmetric. These grids are combinatorial in nature, making them an interesting object of mathematical study.

We present code that generates all possible 5×5 crossword grids under specific symmetry constraints, inspired by the format of The New York Times Mini crosswords. Our work builds on existing research by Cote and Merrill (2021) which gave a representation of crossword grids as bipartite graphs with a node for each word and an edge connecting any intersecting words. We construct crossword graphs for all 5×5 grids with various symmetries and study their graph theoretic features. This project contributes new results to the mathematical study of crossword puzzles by exploring non-traditional symmetries in puzzle grids (diagonal, horizontal, vertical) which have not previously been studied.

62. Taking Advantage of Advanced Placement (AP) Statistics for College Admission: A Study of High School Students in the Houston Area

Thomas Duong University of Houston-Downtown

Advisor(s): Timothy Redl, University of Houston-Downtown

This project explores the Advanced Placement (AP) Statistics test scores of high school students across various districts in the Houston area. It compares them to local colleges' minimum score requirements for college admission and course equivalency. Through this analysis, the study highlights trends and differences in how colleges accept AP Statistics scores for credit. Based on the findings, the project provides recommendations to the University of Houston-Downtown (UHD) regarding appropriate minimum AP Statistics scores for college credits and course equivalency. These recommendations aim to help UHD establish clearer policies that better align AP credit with the expectations of college-level courses, benefiting both students and the institution.

63. Supporting Algebra-Intensive Courses for STEM Majors

Mya Freeman Towson University

Brooke McConnell Towson University

Amanda Wisoky Towson University

Advisor(s): Diana Cheng, Towson University

A team of mathematics faculty and mathematics education secondary pre-service teachers are supporting Towson University undergraduate students enrolled in the MATH 102: Intermediate Algebra course. MATH 102 is a prerequisite course for College Algebra, Trigonometry, PreCalculus, and Calculus; these courses are all gateways for STEM majors. As undergraduate learning assistants, we provided tutoring in facilitated study groups in a half-semester intervention for students earning a C or lower on the first exam. The intended impact is to help the students enrolled in MATH 102 to pass so that they can make progress in their STEM coursework. In Fall 2024, 33 students enrolled in the facilitated study groups and achieved an 88% pass rate in the course; in comparison, 525 students enrolled in MATH 102 and had a 73% pass rate. Based on a two-sample t-test, there was a significantly higher passing rate for those receiving the intervention.

64. Representations of Derivatives for Teaching Calculus: Extending Beyond Traditional Frameworks

Hannah Freund Cal Poly San Luis Obispo

Chris Liu Cal Poly San Luis Obispo

Advisor(s): Saba Gerami, Cal Poly San Luis Obispo

The teaching of derivatives often extends beyond the widely used representational framework by Zandieh (2000), which emphasizes graphical, symbolic, verbal, and physical ideas. Our prior research analyzing eight calculus instructors' introductory derivative tasks found that many instructors incorporate additional representations, particularly through infinitesimal-based reasoning. Motivated by these findings, we developed the Representations of Derivative (RoD) framework, which expands the language used to analyze how instructors utilize multiple representations in their

teaching. This framework aims to provide a more comprehensive perspective on the cognitive processes that different representations engage students with.

65. From Snakes to Squares: Measuring Area with a Twist

James Tokunaga Sacramento State

Advisor(s): Sayonita Ghosh Hajra, Sacramento State

Area is a two-dimensional measurement that represents the amount of space a surface occupies. This project examines how a hands-on, exploratory task can support prospective elementary teachers in developing a conceptual understanding of area and the construction of area units. Using a flexible “fidget snake” toy, participants investigated area through non-standard units by identifying both maximum and minimum coverage of a defined surface. Our qualitative analysis of participants’ written work indicates that the task encouraged meaningful reasoning about unit iteration, spatial structure, and the nature of area measurement. These findings highlight how carefully designed exploratory tasks can foster deeper mathematical thinking and support future teachers in developing foundational measurement concepts.

66. Scaffolded Graphing Tasks Reveal Developmental Stages in Students’ Covariational Reasoning

Audrey Gianelle Towson University

Advisor(s): Kristin Frank, Towson University

This study investigates how scaffolded graphing tasks support the development of Calculus I students’ covariational reasoning. This poster explores how one student’s thinking evolved over the course of a six-question task based clinical interview. In Meg’s early reasoning she constructed graphs by tracking one quantity over experiential time but her reasoning developed throughout the interview as she came to understand the graph as coordinating quantities’ magnitudes at specific moments. The shifts in her thinking happened in distinct stages in response to the structure and design of the tasks rather than instructional moves by the interviewer. The findings suggest that well-designed and sequenced graphing tasks can support meaningful development in covariational reasoning.

67. Authority in Data Science: Increasing Participation through Pair Programming in Introductory Data Science

Noah Kan California State University Monterey Bay

Ian Abrash California State University Monterey Bay

Erica Lopez California State University Monterey Bay

Advisor(s): Judith Canner, California State University Monterey Bay

Pair programming is a recommended pedagogical tool for enhancing students’ learning, sense of belonging, and increasing retention in computing-based programs. However, researchers have found that pair programming can also be subject to inequitable interactions, and diminish some students’ opportunities to learn and develop discipline-based identities. Through our research, we hope to outline curricular and pedagogical practices related to pair programming which increase participation for every student within the data science classroom. We will compare student attitudes and experiences after participating in an introductory data science class that uses paired programming throughout the course. We will explore how varied levels of prior programming experience, student class level, and other demographics impact student attitudes towards data science and their perceived experiences of pair programming through the evaluation of survey responses. Our results will be used to evaluate if the piloted pair programming practices impacted students’ sense of belonging within the data science class and will provide evidence to support continued improvement of pair programming pedagogy.

68. Centering Belonging, Identity and Self-Efficacy in Introductory Calculus

Sabzara Ali Smith College

Fida Fatima Bijin Smith College

Advisor(s): Ileana Vasu, Smith College

For many students entering college, Calculus remains more of a filter than a pump. This research presents a case study of a reformed, inclusive, student-centered Calculus program at a women's liberal arts institution that employs ambitious educational methods. Grounded in the Mathematical Association of America's (MAA) Seven Characteristics of Successful Calculus Programs, the Calculus program integrates active learning, coordination, revision, reflection, and innovative assessments, and has shown strong positive outcomes from students. We describe key instructional characteristics and provide a mixed-method analysis of students' affective experiences, with focus on students from traditionally marginalized groups. In particular, we examine constructs such as math identity, sense of belonging, and self-efficacy, highlighting how instructional practices influence students outcomes Our findings reveal diverse student experiences shaped by identity and background, and highlight the importance of intentional practices and support structures in creating more equitable and affirming calculus classrooms.

69. Evaluating the Impact of Peer-Led Study Groups on Student Success in Lower-Division Mathematics and Statistics Courses

Navid Amarlou California State University, Monterey Bay

Advisor(s): Gabriel Chavez, California State University Monterey Bay

The Math and Stats Café (MSC) at California State University, Monterey Bay is a peer-led tutoring program designed to foster collaborative learning in introductory mathematics and statistics courses. Objective: To evaluate the MSC's impact on students' academic performance, self-efficacy, and motivation. Methods: Employing a mixed-methods design, we compared regular MSC attendees ($\geq$ 5 sessions per semester) with non-attending peers using quantitative measures (attendance logs, course grades, validated self-efficacy surveys) and qualitative insights from semi-structured interviews. Quantitative analyses will assess performance and confidence differentials, while thematic coding of interview data will identify factors influencing engagement and learning strategies. Implications: Results will inform best practices for scalable, peer-led academic support interventions in STEM education.

70. On Modular Prime Bias in Exponential Prime-Generating Functions

Arnold Spantzel Brigham Young University

Advisor(s): Arnold Spantzel, Brigham Young University

Prime numbers play a crucial role in number theory, cryptography, and computational mathematics. This paper presents a computational analysis of modular biases in prime-generating functions of the form:

$$f(a,b,x,c) = \frac{a^x + b}{c}$$

where a, b, c are integers, x is a positive integer exponent, and $f(a,b,x,c)$ is tested for primality. Through large-scale numerical experiments, a significant bias is observed when $b \equiv 0 \mod 15$, suggesting an underlying structure in modular arithmetic that influences prime density. The study leverages computational methods to validate the pattern, with potential applications in algorithmic number theory, prime-search heuristics, and cryptographic key generation. Future work includes formalizing the theoretical foundation behind the observed bias and optimizing computational models for prime prediction.

71. Obstructions to Classifying PPQuads Using Q-Points of S2

Cara Admiraal Belmont University

Advisor(s): Adam Cartisano, Belmont University

Euclid wrote down a formula for Pythagorean triples $\varphi(m,n) = (2mn, m^2 - n^2, m^2 + n^2)$ which can be realized as the stereographic projection of the Q-points of S^1. One generalization identifies Pythagorean *quadruples* as the stereographic projection of the Q-points of S^2. The formula becomes

$$(m_1, m_2, n) \mapsto (2m_1n, 2m_2n, m_1^2 + m_2^2 - n^2, m_1^2 + m_2^2 + n^2).$$

In this project, we investigate the conditions under which the resulting PQuads fail to be primitive.

72. Generating Radical Magic Diamonds

Russell Martinez California Institute of Technology

Advisor(s): Matthew Gherman, California Institute of Technology

The magic squares of squares problem is an open problem in recreational mathematics that asks whether a 3×3 magic square can contain nine distinct square entries. Using elementary mathematics, we exploit a series of magic square invariants to develop a single equation whose primitive solutions are in a bijective correspondence with the collection of radical magic diamonds (RMDs), i.e., magic squares with six distinct square entries in a particular configuration. We then impose a second condition to create a system of equations whose solution, if it exists, would yield a non-Bremner magic square of seven distinct square entries; a lack of solution, however, would prove the nonexistence of a magic square of squares.

73. From Statistics to Scores: Predicting Winners in Male and Female Professional Soccer Matches

Dominic Petruzzelli Neumann University

Advisor(s): Ryan Savitz, Neumann University

This work uses data from the last six years of professional men's and women's soccer matches to determine which, if any factors, help to predict the winner of a match. In order to do this, we separated the data out by gender and used separate correlation and regression analyses. Upon finding the statistically significant variables for each gender, we compared those two sets of variables. We then found that the sets of predictors for the two gender's match outcomes were different from one another. In the poster we give details of these analyses and compare and contrast the gender's predictors.

74. Mathematically Modeling Disease Transmission Between Hospitals and Long-Term Care Facilities

Zack Littell Lewis University

Advisor(s): Brittany Stephenson, Lewis University

Clostridioides difficile (C. difficile) remains one of the most common causes of healthcare-associated infections in the United States. Many mathematical models have been developed to understand C. difficile transmission in singular healthcare settings, but there is a noticeable absence of models of C. difficile transmission across multiple facilities, especially with a focus on what could lead to a C. difficile infection (CDI) outbreak. This project investigates the effects of both hospital and long-term care facility (LTCF) transmission of C. difficile, particularly patient/resident transfers, using an agent-based model to simulate interactions between patients and residents, healthcare workers, and surfaces. Simulations help identify the primary drivers of CDI outbreaks within hospitals and LTCFs as well as the role that

patient/resident transfers play in transmission. Our model also aids in identifying strategies to reduce or eliminate the potential spread of the bacteria across this interconnected healthcare setting.

75. The Kumaraswamy Exponentiated Odds Ratio Family: Mathematical Insights and Practical Applications

Sean Fang University of West Florida

Chenling Fang Shenzhen College of International Education

Advisor(s): Shusen Pu, University of West Florida

We propose the Kumaraswamy Exponentiated Odds Ratio Family of Distributions, an innovative statistical framework integrating the odds ratio structure with the foundational Kumaraswamy distribution. We thoroughly investigate critical mathematical and statistical properties such as hazard rate functions, quantile functions, moments, entropy, and order statistics. Through rigorous simulation studies including Maximum Likelihood, Least Squares, Weighted Least Squares, Maximum Product Spacing, Cramér–von Mises, and Anderson–Darling estimation methods, we confirm the robustness and efficiency of our proposed model. Real-world datasets further highlight the flexibility, adaptability, and superior performance of the Kumaraswamy Exponentiated Odds Ratio Family compared to traditional distributions.

76. The Asymptotics of Localizing Entanglement

Long-Yo Lee University of Illinois Urbana-Champaign

Advisor(s): Jacob Beckey, University of Illinois Urbana-Champaign

An entanglement source is essential for most quantum information-processing tasks. By performing local operations on a part of the source state, we can transform multipartite states from an entanglement source into a suitable form. In our project, we define a value (τ) indicating how entangled a state is. Given τ and a state $|\Psi\rangle_{AB}$ shared between systems A and B, let $L^{\tau}_{\text{global}}(|\Psi\rangle_{AB})$ be the maximal average post-measurement entanglement over all possible projective measurements that eliminate the A-qubits and $L^{\tau}(|\Psi\rangle_{AB})$ the similar but with operators having a tensor product form with respect to the qubits in system A (thus localizable). According to previous works, we can establish an exponential bound on $L^{\tau}_{\text{global}}(|\Psi\rangle_{AB})$, where $|\Psi\rangle_{AB}$ is sampled uniformly according to Haar measure. Our results show that $L^{\tau}(|\Psi\rangle_{AB})$ concentrates around 0 exponentially as the dimension of B approaches infinity, and the next step is to rigorously prove the fact.

77. Analysis of Home Team Advantage for National Collegiate Men's Volleyball

Tony Kochev Lewis University

Luke Pekol Lewis University

Zach Pekol Lewis University

Advisor(s): Amanda Harsy and Adam Schultze, Lewis University

In this research, we explore the role of home team advantage in National Collegiate Men's Volleyball. Other research has explored the impact of home team advantage in various sports and in professional volleyball, but not at the college level. We investigate its impact on various statistics like attacking efficiency, serving error percentage, and game outcomes. Additionally, we explore whether incorporating home court advantage is useful in predicting end-of-season rankings and outcomes.

78. Slice Genus Bounds of Knots Using Grid Diagrams

Christopher Qiu Harvard University

Advisor(s): Yonghwan Kim, Massachusetts Institute of Technology

The smooth sliceness of a knot is an important property with connections to longstanding problems in topology such as the smooth four-dimensional Poincare Conjecture (4SPC) and the Slice-Ribbon Conjecture. Existing methods to determine the smooth sliceness of a knot use sophisticated algebraic tools such as knot homology and the Rasmussen s-invariant. We present a novel combinatorial methodology to lower bound the slice genus of a knot by studying its relationship with the grid index and the Thurston-Bennequin number and provide a heuristic for which types of knots yield slice genus bounds high enough to guarantee smooth sliceness. Additionally, we give a recursive construction for an infinite sequence of knots with slice genus approaching infinity. We identify a base knot 16n196836 that makes all knots in this sequence topologically slice. This concrete sequence of topologically but not smoothly slice knots is useful because potential counterexamples to 4SPC involve conditions on the sliceness of a knot that can be satisfied by the knots in this construction. This research was conducted at the Research Science Institute.

79. Standard modules of the Temperley-Lieb algebra at zero

Eddy Li The Nueva School

Advisor(s): Kenta Suzuki, Massachusetts Institute of Technology

For any $\beta, q \in$ such that $\beta = q^{1/2} + q^{-1/2}$, the Hecke algebra $\mathcal{H}_n(q)$ surjects onto the Temperley-Lieb algebra $\mathsf{TL}_n(\beta)$. When q is not a root of unity, the irreducible modules of $\mathsf{TL}_n(\beta)$ are exactly the standard modules W^n_ℓ. However, the standard modules cease to be irreducible when q is a root of unity, most notably when $\beta = 0$. In this paper, we demonstrate the connection between the category of representations of $\mathsf{TL}_n(0)$ for even n and the category of perverse sheaves on $\mathbb{P}^{n/2+1}$. This motivates the existence of a long exact sequence on the standard modules. Indeed, we construct explicit homomorphisms between adjacent modules and demonstrate their exactness. Our work extends a result of Ridout and Saint-Aubin. The surjection from the Hecke algebra also implies the existence of a long exact sequence among the Specht modules on base field $\mathbb{F}_2$. We end by observing the applications of our results with the task of computing the Jones polynomial of a link at $t = -1$.

80. Improving Transparent Communication About Lower Division Mathematics Courses Through Guided Self-Placement With ACT UP Math

Gabriel Lee California State University, East Bay

Sagar Shah California State University, East Bay

Allie Hurley California State University, East Bay

Advisor(s): Simone Sisneros-Thiry, California State University, East Bay

ACT UP (Achieving Critical Transformations in Undergraduate Programs) Math was a multi-institution, NSF-funded project that supported teams of students and faculty making data-informed decisions to improve student experiences. At CSUEB, we focused on improving lower-division STEM course placement. This action was motivated by data collected about misplacement of students and inspired by self-placement practices at other institutions. In Summer 2023, we ran a pilot for a small group of first-year STEM students. In 2024, we scaled the program, inviting participation from nearly all incoming first-year STEM students. The program includes a questionnaire for students to reflect on their confidence in specific math concepts and prior math course experiences followed by an optional interview with a team member, resulting in a placement decision. In Fall 2023, 7 out of 133 students enrolled in Calculus I were freshmen. The next year, freshmen enrollment jumped by 10 times, to 70 out of 175.

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