Abstracts for the MAA Undergraduate Student Poster Session

"Research in Motion"

MAA MathFest 2024

Indianapolis, IN

August 9, 2024

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MATHEMATICAL ASSOCIATION OF AMERICA

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MAA Undergraduate Student Poster Session
“Research in Motion”

MAA MathFest 2024
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Organized by

Tom Langley
Rose-Hulman Institute of Technology

Amber Russell
Butler University

and

Peri Shereen
California State University, Monterey Bay

MAA

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 Digital Events Strategy Specialist), Olesia Romanova (MAA Meetings and Events Program Specialist), Beverly Ruedi (MAA Electronic Production and Publishing Manager), Bonnie Ponce (Managing Editor, MAA Journals), Annie Pettit (Editorial Assistant, Publications), and Brit Gourdine (Communities Team Member).

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

Tom Langley
Rose-Hulman Institute of Technology

Amber Russell
Butler University

Peri Shereen
California State University, Monterey Bay

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Titles, Authors, Advisors and Abstracts

1. Compositional Roots of Functions

Ruby Harris Taylor University
Mark Lee Taylor University
Daniel Bishop Taylor University
Advisor(s): Derek Thompson, Taylor University

In pre-calculus, students learn to compose two functions; in dynamical systems, the iteration of a function composed with itself is studied. But can you go backwards? Given $g(x)$, can we identify which functions $f(x)$ satisfy $f(f(x)) = g(x)$? Our work attempts to answer that question in some capacity. This work was funded by Taylor University's FMUS (Faculty Mentored Undergraduate Scholarship) program.

2. A Weaker Notion of the Finite Factorization Property

Hwisoo Kim Phillips Academy
Shihan Kanungo Henry M. Gunn High School
Henry Jiang Detroit Country Day School
Advisor(s): Felix Gotti, MIT

An (additive) commutative monoid is called atomic if every given non-invertible element can be written as a sum of atoms (i.e., irreducible elements), in which case, such a sum is called a factorization of the given element. The number of atoms (counting repetitions) in the corresponding sum is called the length of the factorization. Following Geroldinger and Zhong, we say that an atomic monoid M is a length-finite factorization monoid if each $b \in M$ has only finitely many factorizations of any prescribed length. An additive submonoid of $\mathbb{R}_{\geq 0}$ is called a positive monoid. Factorizations in positive monoids have been actively studied in recent years. The main purpose of this paper is to give a better understanding of the non-unique factorization phenomenon in positive monoids through the lens of the length-finite factorization property. To do so, we identify a large class of positive monoids which satisfy the length-finite factorization property. Then we compare the length-finite factorization property to the bounded and the finite factorization properties, which are two properties that have been systematically investigated for more than thirty years.

3. An Analysis of COVID-19 Social Vulnerability and Racial Disparity in the Mid-South Using Model Prediction and Machine Learning

Harrison Shao Mississippi School for Mathematics and Science
Advisor(s): Junmin Wang, University of Memphis

Increasing research shows that COVID-19 has disproportionately impacted racial minorities and people with low socioeconomic status (SES). By using statistical methods and machine learning data analysis, my study predicted how the interactions between community-level social vulnerability and individual-level factors affected COVID-19 infection, hospitalization, and in-hospital mortality in the Mid-South's tri-states (Arkansas, Mississippi, Tennessee). Risk-adjusted multivariate logistic regression models were used to assess the associations between risk factors and COVID-19 outcomes. Bootstrapping machine learning methods were used to improve model predictions. My findings showed that people living in communities with vulnerable household composition and a high percentage of minority residents were more likely to get infected. My findings showed the racial disparity and community-level social determinants of COVID-19 infection. My study contributed to the existing literature by showing the interactive relationships between community-level social vulnerability and race affecting COVID-19 infection in the understudied Mid-South.

4. Graph Theoretical Modeling of Self-Assembling DNA of the Double Cone Graph

Philiffe Tebalan Lewis University
Evan Burns Lewis University
Advisor(s): Amanda Harsy, Lewis University

Self-assembly is a term used to describe the process of a collection of components combining to form an organized structure without external direction. The unique properties of double-stranded DNA molecules make DNA a valuable

structural material with which to form nanostructures, and the field of DNA nanotechnology is largely based on this premise. By modeling nanostructures with discrete graphs, efficient DNA self-assembly becomes a mathematical puzzle. These nanostructures have wide-ranging applications, such as containers for the transport and release of nano-cargos, templates for the controlled growth of nano-objects, and in drug-delivery methods. This research project centers around exploring graph theoretical and combinatorial properties of DNA self-assembly to optimize the nanostructure construction for laboratories. This poster shares our results in determining optimal design strategies for graphs for the Double Cone Graph Family.

6. Evaluating the Effectiveness of Classification Algorithms to Predict the Presence of Breast Cancer

Sambhavi Lohani Rhodes College

Advisor(s): Chathurika Abeykoon, Rhodes College

This study aimed to predict the incidence of breast cancer using patient characteristics and routine blood analyses using a statistical model with regression techniques. We used a dataset available in UCL data repository which consisted of 64 women with breast cancers and 52 healthy controls recruited from the Gynecology Department of the University Hospital Centre of Coimbra (Portugal) between 2009 and 2013. Linear regression analysis was done and identified the significant variables. A Logistic regression model was modeled to indicate the presence of cancer using the variables age, BMI, fasting blood glucose, and resistin levels identified that higher fasting blood glucose levels were associated with increased odds of obesity-related cancer, with an odds ratio of 1.098 (95% CI: 1.052, 1.146). BMI and resistin levels showed significant associations with cancer risk, while age exhibited a negative association. Interaction effects between glucose level and age were explored, with statistically significant findings suggesting complex relationships between these variables. Finally explored the effectiveness of several classification algorithms in predicting the presence of cancer.

7. Assessing the Effectiveness of Real-World Application in School-Math Curriculum

Samantha Bucholtz Youngstown State University

Advisor(s): Alicia Prieto-Langarica, Youngstown State University

The purpose of this study is to assess the efficiency of using real-world applications to motivate mathematics learning and to gather perspectives from math educators concerning the relationship between real-world application and mathematical concepts taught in their classrooms. The questionnaire for educators calls for reflection within their classrooms, observation of student learning styles, and identification of the causes preventing the applications from being taught. With the results from the questionnaires, causes of this problem will be narrowed down and will present the first steps of change to the school-math curriculum. Analyzing the questionnaire results, the State of Ohio school-math curriculum will be examined to implement effective improvements for future students.

8. Thyronomality: Unraveling Thyroid Patterns with Support Vectors Machine and Decision Trees

Ronaii Walker Fayetteville State University

Advisor(s): Yufang Bao, Fayetteville State University

Thyroid disease remains a prevalent health concern affecting 20 million Americans annually, with a concerning 60% of cases undiagnosed. Our analysis involved categorizing data into three classes: hyperthyroidism, hypothyroidism, and normal thyroid function (Classes 1–3). We utilized R code to construct decision trees, revealing that the thyroid-stimulating hormone (TSH) emerged as the pivotal factor influencing thyroid disease occurrence for patients not on thyroxine. Class 3 accounts for more than 90% of instances with a TSH value less than 0.0061 nmol/L. Focusing on the remaining data, we employed the SVM to construct a prediction model assessing the likelihood of their class belongings. Our results indicate an encouraging accuracy rate of approximately 99.78% on training data, and an accuracy rate of approximately 98.60% on testing data, suggesting the potential efficacy of the developed model in predicting the three thyroid functional classes. This study contributes valuable insights into the factors influencing thyroid disease and showcasing the predictive capabilities of support vector machines together with decision trees in identifying at-risk individuals.

10. Graph Theoretic Approach to DNA Self-Assembly

Lucy Allen Youngstown State University
Advisor(s): Alexis Byers, Rochester Institute of Technology

Modeling self-assembling DNA structures is a rapidly growing area due to improvements in nanotechnology, and can be used to construct synthetic self-assembling DNA structures, which can in turn lead to more effective treatments and diagnosis of diseases. One way to model the DNA structure is with a graph structure. We can imagine strands of DNA as branches meeting at a single point called a node. These strands have sequences of the four bases attached to them, which determine which other branches they can bond to according to the Watson-Crick model for complementary pairings of the four bases. When the strands bond, they form an edge. Since these branched molecules are expensive and difficult to construct, the main problem is to minimize how they bond in a specified way and under increasingly restrictive constraints. Identifying patterns in different classes of graphs allows for the creation of a general formula for finding the minimum labeling of a given graph.

11. Applications of Google's PageRank Algorithm: Predicting Tennis Outcomes

Natalie Dando Youngstown State University
Advisor(s): Natalie Dando, Youngstown State University

Google's PageRank is the algorithm developed by Larry Page and Sergey Brin to sort search results by relevance based upon the link structure of the Internet. The mathematical backbone of PageRank is Perron's Theorem, and the Power Method is used to implement the algorithm. While Google uses PageRank to rank its webpages, the foundations of PageRank can be used to rank anything. This project uses the algorithm to rank American men's tennis players. We discuss the mathematical background of the algorithm, how it was used to develop a model to rank tennis players, compares the model to existing tennis ranking systems, and tests various models in predicting tennis match outcomes. The novelties of this model include career head-to-head interactions between players, leading to more accurate win predictions than official rankings. This work was completed during the Youngstown State University Beginning Undergraduates Mathematical research Preparation (YSU-BUMP) summer research program (REU), supported by the National Science Foundation. The work was also supported by the Choose Ohio First Scholarship Program (COFSP).

12. Emergencies can't be predicted?

Joey Russler University of Southern Indiana
Ryan Eckels University of Southern Indiana
Advisor(s): Heather Cook, University of Southern Indiana

Fire department emergencies are typically treated as random events that are difficult to predict. Because of this, many previous studies focused on reducing the arrival time and optimizing resources for fire departments. Our study looks at this setting from another angle and attempts to answer two questions: (1) Do certain factors allow us to predict the number of calls in a single day? (2) Do certain factors allow us to predict the type of emergency? We employ multiple forms of regression and classification methods to analyze the effects of the time of an emergency call and weather-related variables on the type and number of calls. Are these emergencies predictable?

13. Cost Benefit Analysis of Yearly Mammograms: A Social Justice Approach to Individualized Protocols

DiAndra Tensley Youngstown State University
Advisor(s): Alicia Prieto-Langarica, Youngstown State University

False positive mammography results are rather common and can have a variety of negative effects. A patient with a positive mammography is usually required to undergo a biopsy. This procedure is financially costly, including lost labor, daycare bills, and other expenses. Furthermore, uninsured patients and patients of color bear a disproportionate share of these costs. In the United States, people are encouraged to have a mammography once a year after the age of 40. Our goal was to assess whether individuals over the age of 40 should receive mammograms annually or, as in other countries, based on their breast density, genetics, and other risk factors. We developed a data-driven mathematical model to better assess the danger that each patient faces based on many parameters. We are performing a cost-benefit analysis to establish the appropriate frequency for each patient, with a focus on patients of color, low-income, and uninsured. The Programs we were part of were YSU BUMP and Society for Industrial and Applied Mathematics (SIAM).

14. Prediction of a Fast-Changing Stochastic Process with Application to Short-Term Forecast of a Pandemic

Alan Cheng Memphis University School
Advisor(s): Guolian Kang, St Jude Children's Research Hospital

During a pandemic or epidemic, to effectively inform public health decision making in a local area (such as a county), it is important to have accurate short-term forecast of new disease cases or resource usage (such as the number of hospitalizations). The sharp increases and decreases of daily case count in the COVID-19 pandemic has posed an analytical challenge to forecasting accurately the disease levels or resource usage in a locality; conventional forecast methods such as time series models cannot capture the sharp peaks. We have developed a novel nonparametric method which combines one-sided moving average (1-WMA) and a multiplicative bias correction procedure. The 1-WMA is implemented by a one-sided discrete kernel with parameters controlling the distribution of the weights. Machine learning that minimizes the average prediction errors in the recent past is applied to determine the optimal weight distribution. Performance of this method is assessed by publicly available county-level daily new COVID-19 counts and a simulation study. The proposed method is able to adequately capture the sharp peaks and provide nearly unbiased short-term forecast.

15. Numerically Computed Double and Triple Bubbles in R^3 for Density r^p

Eve Parrott Livingston High School
Advisor(s): Frank Morgan, Williams College

Using Brakke's Evolver, we numerically verify conjectured optimal double bubbles in $\mathbb{R}^3$ with density r^p and provide conjectures for triple bubbles, extending many of the results of Collins from $\mathbb{R}^2$ to $\mathbb{R}^3$. Our computations support the conjecture of Hirsch et al. that the optimal double bubble is the standard double bubble with a singular circle passing through the origin. Further computations indicate that the optimal triple bubble resembles a standard triple bubble with one vertex at the origin.

16. Detecting Causality in 2+1 Dimension Spacetimes using Symplectic Quandles

Ayush Jain The Shri Ram School Arvali
Advisor(s): Vladimir Chernov, Dartmouth College

Spacetime is a Lorentzian manifold representing our universe based on the general relativity theory. Causally related points in this spacetime are points that a single light ray can traverse. Low's conjecture establishes that causality in $2+1$ dimension spacetime can be captured by 3D Knots (or links). Alexander-Conway polynomial is a commonly used invariant to distinguish such links from links of causally unrelated points. However, Allen and Swenberg identified an infinite series of potential sky-links that this polynomial cannot distinguish from the connected sum of Hopf, a link of causally unrelated points. This paper proves that a symplectic quandle can distinguish all links in Allen-Swenberg series from the connected sum of Hopf, demonstrating its capability to detect causality in conjunction with Alexander-Conway polynomial. A symplectic quandle due to its connectedness property offers additional information in the set of homomorphism from quandle to the knot; we also employ enhanced quandle counting that counts the cardinality of the image of each homomorphism to extract finer details. This result is important as affine Alexander Quandle is found to be insufficient.

17. Fighting Cancer with Spatial Mathematics: Comparing Euclidean and Fractal Approaches

Sarah Zhang The Waldorf School of Garden City
Yongjun Liu University of Washington
Advisor(s): Yongjun Liu, University of Washington

Traditional mathematical models of cancer face challenges because cancer does not conform to Euclidean geometry. Fractal geometry offers a promising alternative for understanding cancer's irregularity. We investigated the fractal characteristics of the erratic cancer cell spatial pattern and their correlation with cancer behavior. Images of 4 short- and 4 long-survival pancreatic adenocarcinoma were analyzed using artificial neural network to measure 13 Euclidean parameters (area, perimeter, circularity, eccentricity, solidity etc.). Fractal dimensions (FDs) of cancer cell spatial distribution were determined by Box-counting. We found the short and long survival groups exhibited similar tumor cell density and no significant difference in all 13 Euclidean parameters. In fractal analysis, the FDs of cancer cell spatial distribution were similar at a small spatial scale but were significantly higher in short-survival group at a large spatial scale. These findings indicate sole reliance on Euclidean geometric characteristics is not sufficient for predicting cancer behavior. Integrating fractal, topological and computational geometry approaches is crucial to model cancer holistically.

18. Symmetric Subcollection of the Modular Group

Lucas Saone Jacksonville State University
Jordan Hinton Jacksonville State University
Susanna Landis Jacksonville State University
Advisor(s): Jaedeok Kim, Jacksonville State University

Let $PSL_2(\mathbb{Z})$ be the set of 2×2 matrices with integer entries and determinant 1. This is then a modular group under matrix multiplication, and the matrices A and $-A$ are considered identical in the group. We will study the subcollection $SSL_2(\mathbb{Z})$ consisting of all symmetric matrices in $PSL_2(\mathbb{Z})$. A new group is formed by defining a binary operation on $SSL_2(\mathbb{Z})$. Many number theoretic properties of integers of the form $m^2 + n^2$, where m and n are relatively prime, can be determined by expressing these symmetric matrices in terms of the generators RL and LR where $R = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}$ and $L = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$. We investigate the related collection $SSL_2(\mathbb{Z}/p\mathbb{Z})$ for prime p and make a conjecture that $SSL_2(\mathbb{Z}/p\mathbb{Z})$ is a group if and only if $p \equiv 1 \pmod 4$.

19. Investigating Spatial Disorientation Related Aviation Mishaps Utilizing Machine Learning Keyword Extraction Models

Katherine Hoffsetz Embry-Riddle Aeronautical University
Advisor(s): Mihhail Berezovski, Embry-Riddle Aeronautical University

Spatial disorientation (SD) is a critical factor contributing to accidents in general aviation (GA), posing significant challenges to flight safety. This study conducts a comprehensive data analysis of general aviation crash reports to investigate the patterns and underlying factors associated with spatial disorientation. The dataset, derived from official reports from the National Transportation and Safety Board, has about 700 SD cases to study. Utilizing advanced statistical methods and machine learning algorithms, the textual data is analyzed to extract and categorize instances of spatial disorientation. The methodology involves natural language processing (NLP) techniques to systematically review and classify the narratives within the reports, focusing on keywords and phrases indicative of SD. This study contributes to the ongoing efforts to enhance general aviation flight safety by providing a data-driven understanding of spatial disorientation accidents.

20. Leveraging Adaptive Resonance Theory for Memory Data: An Autonomous Approach without Back Propagation

Charitie Martino University of South Florida
Advisor(s): Chad Dubé, University of South Florida

As a computational framework that models how biological systems adapt and learn from new information, Adaptive Resonance Theory (ART) uniquely meets the challenge of simultaneously harnessing stability and flexibility in its models. This allows for an alternative to back propagation for memory data applications via its autonomous learning characteristics. Continuous learning and adaptation are essential for real-time learning scenarios which are complemented by the inherent stability mechanisms in ART's models. Preventing catastrophic forgetting and maintaining robust memory representations over time, we will demonstrate the effectiveness of ART-based models for memory data tasks.

21. A Characterization of the Archimedean Solids

David Weed California State University Fullerton
Advisor(s): Tommy Murphy, California State University Fullerton

In studying any family of mathematical objects, a fundamental issue is to understand how one object can "sit inside" another object in the family, preserving the mathematical structure. We are concerned with convex uniform polyhedra.

Two famous families of polyhedra live in this class: the Platonic and Archimedean solids, as well as the prisms and antiprisms. Our main result geometrically characterizes the famed Archimedean solids among the convex uniform polyhedra by studying how they sit inside a regular tetrahedron.

22. Modeling the Oligomerization of Alzheimer's-Causing Toxins using Physics-Informed Machine Learning

Ayush Pal Mills E. Godwin High School
Joseph Pateras Virginia Commonwealth University
Advisor(s): Preetam Ghosh, Virginia Commonwealth University

Physics-informed AI is a powerful tool that can enhance learning algorithms in modeling complex physical systems. Training conventional machine learning models on sparse, noisy data from complex systems underperforms traditional mechanistic modeling. However, physics-informed machine learning leverages both approaches to alleviate the computational expenses associated with differentiation in traditional models, while enforcing their predictive abilities through typically unsupervised learning biases. This study uses the dynamics of Amyloid-β fibrils associated with the onset of Alzheimer's disease as a case study. The novelty of this work is to employ physics-informed machine learning for the parameter prediction of the ordinary differential equations that govern Amyloid-β aggregation. Hypergraph-structured models of A-β aggregation were analyzed, rate constants of which were found, and then sensitivity tests on the system were performed to optimize the model. It was found that discovered rate constants for a 10-species model were the most accurate at predicting future aggregation. Other potential applications of physics-informed AI to species-like models were also discussed.

24. Conducting a Network-Based Risk Analysis for Zebra & Quagga Mussel Invasion of Idaho Water Bodies Using Watercraft Traffic

Katie Theissen University of Idaho
Advisor(s): Jennifer, James Johnson-Leung, Nagler, University of Idaho

In 1988, zebra mussels (Dreissena polymorpha) were discovered for the first time in the Great Lakes of North America and the discovery of quagga mussels (Dreissena bugensis) followed swiftly in 1989. Due to the extreme environmental effects of these mussels and the near impossibility of removing them once established, predicting and subsequently impeding the future spread are at the forefront of the anti-zebra and quagga mussel efforts. Both mussel species have been gradually spreading westward across the US, primarily transferred on trailered boats. Using watercraft traffic data supplied by the Idaho State Department of Agriculture, network-based simulations of the potential zebra and quagga mussel invasion in Idaho have been developed. Such simulations provide a measure of risk of invasion. These results could help managers pinpoint Idaho water bodies for further monitoring, and additionally could be applied to other invasive species that spread through similar methods.

26. Numerical Methods for Assessing the Thermal Conductivity Performance of Aerogel Using the Boltzmann Transport Equation

Ethan Peters New York City College of Technology
Advisor(s): Yash Verma, India Institute of Technology Kharagpur

Space is a domain of temperature and radiation extremes, and to this end multi-layer insulation applications (MLI) are crucial for protecting vital components on satellites. Aerogel has emerged as an ideal material for insulation design due to its low thermal conductivity, therefore the effective modeling of aerogel conduction has been a key area of research. Aerogel is a nonporous structure that does not adhere to Fourier's Law of heat transfer. Instead, the Boltzmann transport equation (BTE) is essential to effectively model heat transfer. This project focused on developing a numerical method of solving the BTE to model the effects of aerogel in different MLI configurations. The Gaussian quadrature method was implemented to solve the BTE in different directions to account for the change in phonon energy density (Hamian, Yamada, Faghri, & Park, 2015).

27. Divisor Functions: Train-like Structure and Density Properties

Evelina Dubovski Staten Island Technical High School
Advisor(s): Lyubomir Boyadzhiev, Queensborough Community College, City University of New York

We explore divisor functions $f_s(n) = \dfrac{\sum_{d|n} d^s}{n^s}$ and extend the analysis from the already-proven density of $s = 1$ to $s \geq 0$. Wolke proved that $|f_1(n) - a| < \dfrac{1}{n^{0.6-\varepsilon}}$ has infinitely many solutions and conjectured that this estimate can be improved to $\dfrac{1}{n^{1-\varepsilon}}$. We establish that f_s is dense for $0 < s \leq 1$ and prove Wolke's conjecture for a from the range of f. This result slightly supports the hypothesis that there are infinitely many perfect numbers. Also, we extend Wolke's discovery to all $0 < s \leq 1$ and, thus, provide additional quantitative measures of density. We define the structure of f_s as the union of $trains$—specially organized collections of decreasing sequences. As parameter s increases, the *train* structures become more visible within chaos, forming ruptures at $s > 1$. At the threshold $s = 1$, the infinite product switches from divergence to convergence, leading to the loss of density. We also prove that if we treat $f_s(n)$ as a random variable, then its expectation is $\zeta(s + 1)$ and show that the variance drastically decreases with s.

28. Mathematical Optimization in Culinary Practices: Reducing Food Waste and Costs through Surface Integration, Euclidian Geometry, Fluid Dynamics, and Dilution Calculus

Bang Tam Ngo Lexington High School
Steven Yu Lexington High School
Advisor(s): Phuong Nguyen, Hanoi University

This paper explores the application of advanced mathematical techniques to culinary practices. We employ surface integration to precisely measure the volume and weight of ingredients, utilizing the formula: $\text{Surface Integral} = \int\int_S f(x, y)\, dS$ where $f(x, y)$ represents the volume density of the ingredient. Fluid Dynamics is utilized to model cooking times through differential equations, incorporating variables such as ingredient thickness and oven temperature, represented by: $\frac{dT}{dt} = k(T_{\text{oven}} - T_{\text{ingredient}})$ We apply principles of Euclidean geometry to create visually appealing and efficient food presentations. Furthermore, dilution calculus is employed to analyze diffusion, represented by Fick's second law of diffusion: $\frac{\partial C}{\partial t} = D\nabla^2 C$ where C is the concentration of flavor compounds and D is the diffusion coefficient. This enables a nuanced understanding of how acids, salts, and fats interact, contributing to the overall flavor profile. We present actionable strategies that culinary enthusiasts can adopt to enhance sustainability in food preparation and presentation.

29. On τ_n-Factorization and τ_n-Graphs

Jean García University of Puerto Rico - Mayaguez Campus
Advisor(s): Reyes Ortíz, University of Puerto Rico - Mayaguez Campus

The theory of τ_n-graphs or τ_n-irreducible τ_n-factor graphs has been study by Mooney with a paper in 2013, and Ortiz and his students since 2010. The τ_n-graph of a nonzero nonunit integer x is defined to be a graph in which every vertex represents a τ_n-irreducible τ_n-factor of x, up associates. An edge between two vertices v_1 and v_2 represent the existence of a τ_n-factorization for the τ_n-irreducibles τ_n-factors. In 2020, Lopez and Ortiz characterized a family of τ_n-graphs and properties to construct such graphs of nonzero nonunit integers. This ongoing problem is trying to answer the inverse problem. This is, given a graph, can we find nonzero nonunit integers such that the τ_n-graphs coincide with such graph? During the process we characterized a family of such graph. We present the idea and examples of this problem.

30. Data Augmentation Techniques for Real Tabular Data

Kate Huisinga Simpson College
Ellee Mortensen Simpson College
Advisor(s): Marilyn Vazquez, Simpson College

Scientists have developed powerful machine-learning techniques for data classification tasks. One of the issues with current classification approaches is that they require lots of data. However, collecting sufficient data to create reliable models is not always possible. For example, collecting more data from patients can be impossible if they no longer want to participate in the data collection. In Computer Vision, researchers get around the lack of data by applying data

augmentation, which refers to creating new data points without collecting more data. For example, new images are created by rotating or recoloring the original image set. This way, machine learning techniques have enough data to classify data accurately. We are continuing the work started by the 2022 Bryan Summer Research team. They built a foundation for data augmentation methods applied to real tabular data. We are developing and testing new methods to see how well our techniques keep the intrinsic patterns and if accuracy is improved. This project is a collaboration of the 2024 Bryan Summer Research Program in Mathematics team and the 2024 SIAM-Simons Undergraduate Research Program team.

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32. Modified Burr III Odds Ratio-G Distribution and Applications

Ziyan He University of Wisconsin - Madison
Shusen Pu University of West Florida
Advisor(s): Shusen Pu, University of West Florida

In this study, we introduce the Modified Burr III Odds Ratio-G distribution, a novel statistical model that integrates the odds ratio concept with the foundational Burr III distribution. The spotlight of our investigation is cast on a key subclass within this innovative framework, designated as the Burr III Scaled Inverse Odds Ratio-G (B-SIOR-G) distribution. We delve into a thorough exploration of this distribution family's mathematical and statistical properties, spanning hazard rate functions, quantile functions, moments, and additional features. Through rigorous simulation, we affirm the robustness of the B-SIOR-G model. The flexibility and practicality of the B-SIOR- G model are demonstrated through its successful application to diverse datasets, highlighting its enhanced efficacy over several well-established distributions. These applications underscore the model's robustness as a versatile tool for statistical analysis in various scientific fields.

33. Solving the Bubble Path Problem

Maxwell Goskie Belmont University
Advisor(s): Adam Cartisano, Belmont University

In this presentation, we introduce the Bubble Path Problem, named for its resemblance to answer sheets on standardized tests. Let M be a $4 \times n$ binary matrix with exactly one nonzero entry per row. The Bubble Path Problem asks the probability $P(n)$ for a given matrix of length n that a path can be made passing through only entries of value 0 at orthogonal directions, connecting the top and bottom rows. We discuss a solution strategy that uses inductive reasoning and Markov chains to produce a transition matrix, where the eigen decomposition of this matrix leads to a form of $P(n)$. We then generalize to an arbitrary number of columns and take a new combinatorial approach, enumerating the number of binary matrix configurations which prevent the construction of a valid path. The number of unique solution classes of $m \times n$ binary matrices without a valid path is conjectured to be modellable using a linear recurrence formula with $m+1$ terms with constant coefficients, for some m. We discuss this problem's connection to these linear formulae by investigating combinatorial patterns present as both m and n vary.

34. Quasiperiodic Tilings of the Plane

Amar KC Howard University
Sunishchit Ghimire Howard university
Advisor(s): Roberto De Leo, Howard University

In a not well known short note published on Physica D in 1988, V.I. Arnold illustrated the relation between quasiperiodic functions and quasicrystals. Based on this relation, he suggested an elegant geometrical method to generate quasicrystals with any given number of distinct tiles. We recently implemented Arnold's method in Python. In this poster we present Arnold's construction and show several quasiperiodic tilings generated by our code. It is an NSF-funded "REU individual experience," that takes place at Howard University.

35. Sequential Failure Model of Carbon-Epoxy Composite Lamina in Type-IV Hydrogen Gas Storage Vessels

John Estrella New York City College of Technology
Advisor(s): Urmi Duttagupta, New York City College of Technology

My project is about the carbon-epoxy composite laminas for storage of compressed hydrogen in type-IV hydrogen vessels. My objective was to improve a computer program that finds out the first ply failure code to find the rest of plies that fail until the last one. The carbon fibers plies are unilateral and plies have different orientation and are stacked on top of eachother. We used the Tsai-wu failure criterion for testing the strength ratio of each lamina and determining the first ply for them. After this, we recalculate our values but now without the previous failed ply. After a lot of testing, based on the first time running the code, you can tell the sequence of the plies that are going to fail without needing to recalculate. This model since we are combining the power of computer and theory to simulate real physical experiments can save time and resources due to its reusability and can help determine the optimal orientation of laminas so that we get the most out of each lamina and have the most possible strength in the composite so it can handle the most amount of pressure

36. Spectral Simplicity in Quantum Graphs

Tyler Chamberlain Harvard
Advisor(s): Christopher Judge, Indiana University

Given a finite connected graph Γ with n edges, for what edge lengths $\overrightarrow{\ell} = (\ell_1, \ell_n)$ is the quantum graph $(\Gamma, \overrightarrow{\ell}, \Delta)$ spectrally simple? Leonid Friedlander, in his 2005 paper [4], proved for generic $\overrightarrow{\ell}$, a non-circle quantum graph is spectrally simple. Later, Yves Colin de Verdière in [3] established a relationship between degenerate eigenvalues of a quantum graphs and singularities of its corresponding secular manifold. He also posed the following question: *when does the secular manifold of a quantum graph admit a singular set of codimension at least two?*

Applying tools from algebraic geometry, we answer Colin de Vedière's codimension 2 question for star graphs in the affirmative; the secular manifold admits a singular set of codimension at least 2. We outline a method to answer the same question in arbitrary quantum graphs, given that they are loop-free and non-mandarin.

37. A Metabolomics Analysis of Pregnancy Complications

Zoe Winston United States Military Academy
Advisor(s): Andrew Lee, United States Military Academy

Hypertensive disorders of pregnancy (HDP) pose a significant risk to maternal health. While previous research has linked HDP to inflammation and endothelial damage, comprehensive understanding of predictive biomarkers are lacking. This study aims to identify key metabolic disturbances associated with HDP by using a statistical battery to increase the robustness of predictive models. Utilizing first-trimester serum specimens from 51 HDP cases and 109 controls obtained from the Global Alliance to Prevent Prematurity and Stillbirth repository, untargeted metabolomics data was acquired using liquid chromatography-mass spectrometry. We use a standard OPLS-DA in addition to penalized regressions in order to provide a more robust analysis of which metabolites are significant in a particular disease. Stepwise logistic regression with Ridge regression demonstrated the highest predictive capability, reducing the original 3122 signals to 15 significant variables. Vitamin D3, bile acid synthesis, steroid hormone, and Vitamin E pathways were identified as significant in HDP, with pathway disturbances observed in gestational hypertension and pre-eclampsia cases.

38. A Variation of the Game of Revolutionaries and Spies

Tarik Krestalica Southern New Hampshire University
Advisor(s): Melissa Newell, Southern New Hampshire University

Revolutionaries and Spies is a turn-based game played on a graph G with two teams, r revolutionaries and s spies. It was first introduced by Joszef Beck in the 1990s, about a decade after the introduction of Cops and Robbers. The revolutionaries' goal is to create a meeting of size m on a vertex with no spy at the end of the round; the spies seek to prevent this in perpetuity. We study a variation of the game with an additional parameter p. This represents the number of meetings of m a single spy can guard, which modifies the game in that one spy isn't enough to "fully" guard a vertex. We seek to optimize $\sigma(G, mr, p)$, the minimum number of spies needed to win the game on a graph

G. We will present a lower and upper bound for $\sigma(G, m, r, p)$ on a graph G and conjectures for trees, cycles, and unicyclic graphs.

39. Zeros of Fibonacci and Lucas Polynomials

Cuewon Kim Vestavia Hills High School
Advisor(s): Jaedeok Kim, Jacksonville State University

We study four families of polynomials generated by recurrence relations of the form $P_n(x) = xP_{n-1}(x) + P_{n-1}(x)$ or $P_n(x) = xP_{n-1}(x) - P_{n-1}(x)$. For example, the polynomials $F_n(x)$ generated by $F_n(x) = xF_{n-1}(x) + F_{n-2}(x)$, $F_0(x) = 0$, $F_1(x) = 1$ are called *Fibonacci polynomials*. We then present four families of $n \times n$ square matrices whose characteristic polynomials are equal to the sequences of polynomials. A complete description of the zeros of the polynomials will be given by identifying the eigenvalues and eigenvectors of the matrices.

40. Understanding the Geographical Concentration of Birth Rates of Individuals with Down Syndrome at the Municipality Level

Rachel Garcia Simpson College
Matthew Dietrich Simpson College
Caelynn Obleton Simpson College
Lanie Shettlesworth Simpson College
Advisor(s): Heidi Berger, Simpson College

This project focuses on better understanding the prevalence and distribution of the Down syndrome population in Mexico. We used spatial regressions to better to understand whether Down syndrome births are geographically concentrated and what spatial process are at play. Once we better understand where the need is, we can better understand how well resources for these individuals are poised to serve their need. This work was completed through the Dr. Albert H. & Greta A. Bryan Summer Research Program in Mathematics at Simpson College.

41. Classification up to Isomorphism of Groups of Order up to 15

Maggie Ha University of Houston Downtown
Advisor(s): Jean Nganou, University of Houston Downtown

While the results are known, our approach/organization to obtaining the results is different from the approach found in the literature. For the nontrivial orders, we repeatedly rely on the notorious construction of semidirect products. From orders 1 to 15, we grouped them into six nontrivial categories. (1) Groups of prime order; (2) Groups of prime power order; (3) Groups of doubled prime order; (3) Groups of order 15; (4) Groups of order 8; (6) Groups of order 12. We obtain that, up to isomorphism, (1) there exists a unique group of each of the orders 1, 2, 3, 5, 7, 11, 13, 15; (2) two groups of each of the orders 4, 6, 9, 10, 14. (3) five groups of each of the orders 8 and 12. That is altogether 28 groups of order up to 15. The number of groups used refers to the number of isomorphism classes of groups.

43. Coffee Futures Forecasting with Transformers

John Hohman University of Pittsburgh
Advisor(s): Jeffery Wheeler, University of Pittsburgh

Forecasting financial markets is a byzantine task relying on understanding long-term and short-term trends. Transformer models are a relatively new technique for identifying these relations being developed by Google in 2017 for Natural Language Processing (NLP) purposes. Realizing that language is a sequential ordering of information with long-term and short-term dependencies, brings the possibility to use techniques traditionally reserved to NLP to time series forecasting. This presentation will demonstrate the prospect of using transformer models to forecast complex time series data, using coffee futures as a case study.

44. Multi-Dimensional Graphs Modeling Self-Assembling DNA Nanostructures

Katelyn Buck The University of Texas at Austin
Advisor(s): Amanda Harsy, Lewis University

Employing tools from graph theory and linear algebra, we model the biological process of the creation of nanostructures from self-assembling DNA complexes. We represent k-armed branch junction molecules with tiles which are vertices in a graph with half-edges. The half-edges depict the cohesive-end types of a DNA strand. We aim to determine the minimum number of tiles and cohesive-end types necessary to form the complete complex of a given multi-dimensional graph structure. The problem of modeling DNA self-assembly is particularly challenging when considering graph families which change in multiple dimensions. In this research, we present the minimum number of tiles and cohesive-end types necessary to create the stacked book graphs, the square lattice graphs, and the Mongolian tent graphs, under different laboratory constraints. This research was completed at the SummerICERM REU Program at Brown University in 2023, and it is an ongoing project.

45. Cyclic Permutations Avoiding Patterns in Both One-line and Cycle Forms

Ethan Borsh Allegheny College
Advisor(s): Kassie Archer, United States Naval Academy

A permutation is said to avoid a given pattern if there is no subsequence of the permutation in the same relative order as that pattern. This notion of pattern avoidance has several applications, including applications to computer science, algebraic combinatorics, and dynamical systems. We investigate cyclic permutations that avoid a pattern $\boldsymbol{\sigma}$ in its one-line notation and another pattern $\boldsymbol{\tau}$ in its cycle notation. In this, we will prove a bijective mapping from previous permutations to those of the desired n by using recursive sequences. The student authors of this research, Ethan Borsh, Jensen Bridges, and Millie Jeske, were funded as part of an REU at the University of Texas at Tyler sponsored by the NSF Grant DMS-2149921.

46. The Game of Cycles on Maximal Plane Graphs

Aakash Gurung LaGuardia Community College
Advisor(s): Malgorzata Marciniak, LaGuardia Community College

We investigate the properties of specific maximal plane graph which we define as IO maximal plane graph and how the game of cycles introduced by Su in “Mathematics for Human Flourishing” is played on such maximal plane graphs. Our approach involves analyzing the invariant properties of these graphs and the associated matrices to establish winning strategies in a two-player mode. This research was funded by CUNY Research Scholars Program.

47. Quantum Connect 4

Michael Edge Sewanee: The University of the South
George Thomas Alexander Sewanee: The University of the South
Advisor(s): Shuler Hopkins, Sewanee: The University of the South

Key concepts when exploring the fundamentals of quantum computing include the ideas of superposition and entanglement. These ideas, seemingly daunting at first, can be made intuitive when incorporated into a familiar game such as Connect 4. In a perfectly played game of Connect 4, player 1 will always win; this result was first shown by Victor Allis in 1988. In this project, we developed a quantum version of this game hoping to give player 2 a chance. We will discuss the existence of winning strategies under various conditions for this quantum version. Furthermore, we explored different strategies for developing an AI opponent.

48. Graphs in Polynomial Parameter Space

Forrest Hilton University of Alabama at Birmingham
Advisor(s): John Mayer, University of Alabama at Birmingham

A lamination is a closed set of chords of the unit disk such that no two chords intersect in the open disk. Laminations are often used as a model of the Julia set of a degree d polynomial. A lamination that models a polynomial is d to 1 invariant under the degree d covering map $\sigma_d : S \to S$. The chords of the lamination are mapped by the covering map according to their end points. A polynomial will have an infinite lamination, but it is possible to contemplate the set of polynomials which share a finite lamination as a subset of their lamination. For this purpose, we define a class of laminations which we call Finite Dynamic Laminations or FDL, and we arrange these laminations into a tree called the pullback tree. Any polynomial matching an FDL must match at least one of its children in a pullback tree. We take all the FDL from one level of the pullback tree as the vertices of a graph, and form connections when the set of polynomials matching each vertex touch (have intersecting closures). In this ongoing research project supported by the UAB Presidential Honors Fellowship, we develop both software and theorems to better understand polynomial parameter space.

49. Mathematical Modeling of Immune Response to SARS-CoV-2

Ayesh Awad Elon University
Advisor(s): Hwayeon Ryu, Elon University

In response to the profound impact the COVID-19 pandemic, the scientific community has focused considerable research efforts to understand the spread of the virus. Despite a tremendous volume of research in this area, how the human immune system responds to SARS-CoV-2 has not been yet fully understood due to limited analysis of the experimental or clinical 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 successful viral clearance and the key mechanisms responsible for disease severity. These interactions are formulated in a system of ordinary and delayed differential equations. We conduct parameter estimation based on experimental data and investigate model behaviors via computational simulations. Our model demonstrates key aspects of the immune response to SARS-CoV-2 which might be responsible for disease severity. This could be used to serve as a foundation for the development of therapeutic strategies.

50. Optimal Tile-Based Self-Assembly of DNA Using Graph Theory

Rawdah Abdullah Dominican University
Advisor(s): Amanda Harsy, Lewis University

One recent application of graph theory and linear algebra is the theoretical analysis of self-assembling DNA nanostructures. In a laboratory setting, using technology pioneered by Seeman's laboratory in the 1980s, branched junction molecules of DNA can self-assemble into targeted geometric structures. By employing tools from graph theory and linear algebra, theoretical efficiency of this process can be improved by mathematically modeling the biological process of creating nanostructures from self-assembling DNA complexes. In this model, we represent k-armed branch junction molecules with tiles as vertices in a graph with half-edges. The half-edges depict the cohesive-end types of a DNA strand. We aim to determine the minimum number of tiles and cohesive-end types necessary to form the complete complex of a given target graph structure. The problem of modeling DNA self-assembly is particularly challenging when considering graph families that change in multiple dimensions. This research shares our results in determining optimal design strategies for graphs with multiple growth patterns like the Kayak Paddle Graphs, Fan Graphs, and Sunlet Graphs.

51. The Effect of Sound and Spatial Structure on Animal Signaling

Asma Hasan Elmhurst University
Mikala Marcussen-Abuharb Elmhurst University
Advisor(s): Rohan Mehta, Elmhurst University

Animals frequently use sound to communicate with each other across a variety of circumstances. These situations include alarm calls to avoid predators, breeding calls to find mates, and foraging/predation calls to find food. In all of these cases, communication allows animals to behave as a collective despite the individual nature of the behavior. However, sonic communication depends very strongly on the medium of communication. Sound declines in intensity by distance very fast in air and much more slowly in water, for instance. In this project, we incorporate the mathematics of sound propagation in concert with the environment of the organisms to create a flexible, agent-based model of the effectiveness of sonic communication for a specified biological task. In particular, we study alarm calls and foraging calls and provide predictions given environmental variables for when such behaviors should be evolutionarily favorable.

53. The Hunt for New Number Sequences in the Union of Path and Cycle Graphs

Bridget Rozema Grand Valley State University
Advisor(s): Feryal Alayont, Grand Valley State University

This study focuses on the sequence of numbers formed by counting the edge covers of specific graph families. An edge cover is a subset of a graph where each vertex is adjacent to at least one edge. Using the known sequences derived from the path and cycle graphs (Fibonacci and Lucas, respectively), we examine how combining these two graph families together at certain vertices lead to new number sequences. We will employ various methods to find the sequences

that arise from these combinations of path and cycle graphs, such as rocket and bolo tie graphs, and determine their properties.

54. Number Sequences Generated by Edge Covers of Fan Graphs

Marshall Nicholson Grand Valley State University
Advisor(s): Feryal Alayont, Grand Valley State University

In an effort to discover new integer sequences, we examined the number of edge covers of fan graphs. An edge cover of a graph is a subset of the edges such that every vertex is the endpoint of at least one edge. A fan graph is obtained from a path graph by adding new vertices adjacent to each vertex of the path graph. In this poster, we will present our research on the edge cover sequences and edge cover polynomials of fan graphs, beginning with the cases obtained from a path graph of length two and extrapolating to larger fan graph cases.

55. Going Bananas: A Procedure for Organizing Ship Deliveries into a Warehouse for Efficient Perishable Product Departures

Julia Rosa Rowan College at Burlington County
Emily Hewitt Rowan College at Burlington County
Laura Van den Heuvel Rowan College at Burlington County
Micaela Lyons Rowan College at Burlington County
Advisor(s): Jonathan Weisbrod, Rowan College at Burlington County

The distribution process from producer to end consumer often involves transitions from ship to warehouse and warehouse to delivery vehicle. The motivation of this project is to minimize the cost of the distribution of pallets from two arriving ships to the recipient vehicles following temporary storage in a warehouse. Two ship manifests, a warehouse layout description, and a listing of related lot orders were analyzed to develop a procedure to unload ship contents into a warehouse to minimize running costs and costs related to rearranging pallets in the warehouse. Our results include mathematical models that compute the overall cost of the process in terms of monetary expenses and labor. This project was sponsored by PIC Math. PIC Math is a program of the Mathematical Association of America (MAA) and the Society for Industrial and Applied Mathematics (SIAM). Support is provided by the National Science Foundation (NSF grant DMS-1722275).

56. Mathematically Modeling Recurrent *C. difficile* Infections in Long-Term Care Facilities

Zachary Campbell Lewis University
Advisor(s): Cara Sulyok, Lewis University

Clostridioides difficile (*C. difficile*) is one of the most frequently identified healthcare-acquired infections in the United States. Individuals shed *C. difficile* endospores that can survive for long periods on surfaces outside the host and are resistant to many commonly-used disinfectants. Numerous mathematical models have been developed to understand and quantify *C. difficile* spread in hospital settings, but little work has been done considering disease spread in long-term care facilities (LTCFs). In LTCFs, residents are generally over the age of 84, making them more susceptible to a *C. difficile* infection, with a 10–35% chance of recurrent infection. This project focuses on the spread of *C. difficile* throughout LTCFs by modeling interactions between residents, healthcare workers, and surfaces, with an emphasis on recurrent infections. The model utilizes a system of ordinary differential equations to simulate the interactions and exposure of residents and identify strategies to reduce incidence rates in LTCFs.

57. Edge Covers of Joined Tadpole Graphs

Jarrett Gadziemski Grand Valley State University
Advisor(s): Brian Drake, Grand Valley State University

We investigate number sequences that arise from counting edge covers. An edge cover is a subgraph that includes all of the original vertices, such that every vertex has degree of at least one. A tadpole graph is a cycle and a path joined at an end vertex. The edge covers of tadpoles are known to satisfy nice properties like Fibonacci recurrences. In this project we study sequences of tadpoles joined head to tail. We use the Carlitz-Scoville-Vaughan theorem to find the recurrence relation for the number of edge covers.

58. Counting Edge Covers Of Chain Graphs

Ethan Woudwyk Grand Valley State University
Advisor(s): Brian Drake, Grand Valley State University

In this project we study the sequences formed by counting edge covers of graph families. An edge cover of a simple graph is a subset of edges that cover every vertex. For example, the number of edge covers for the cycle graph family follow the Lucas numbers. We consider the number of edge covers for a new family of graphs, the chain graphs. A chain is obtained by joining copies of a graph at distinct edges. We count edge covers for the chain graphs using the transfer-matrix method and investigate their recurrence relation properties.

59. Determining the Effect of Curvature in a Mathematical Model of Cell Migration

Jianda Du University of Florida
Advisor(s): Tracy Stepien, University of Florida

Cell migration is critical in tissue development, wound healing, and cancer metastasis. For example, gastrulation is an early phase of embryonic development in which cell migration plays a large role in forming the germ layers of the embryo (which eventually give rise to tissues and organs). We extend a previously developed continuum mechanical cell migration model by incorporating curvature as a key variable. Sensitivity analysis and data fitting were conducted to determine the most appropriate form of curvature dependence. We analyze the extent of cell migration dependence on curvature for spreading embryonic tissues of two species, aquatic frog Xenopus laevis and axolotl salamander Ambystoma mexicanum, using experiments with different initial tissue shapes.

60. Development of Agent-Based Models for Evaluation of Precision Nutrition Interventions through a Socioeconomic Lens

Chuckie Gentile Lewis University
Nuvia Hernandez Lewis University
Emilio Vilchis Lewis University
Mackenzie Welsh Lewis University
Advisor(s): Brittany Stephenson, Lewis University

An individual's overall health is dependent upon characteristics such as age, demographics, physical activity, body-mass index, underlying health conditions, and socioeconomic status. To date, many guidelines to promote healthier eating have targeted the total population rather than focusing on the individual level. This work investigates the role of an individual's socioeconomic status on both their overall health and the total population health through agent-based models (ABMs) of two Chicagoland villages: Broadview and Clarendon Hills. Our ABMs will track individual characteristics, decision-making, and daily behaviors in order to determine an overall health score for each individual. We developed a graphical user interface of Broadview using Google Maps that includes detailed information about the village, including houses, schools, restaurants, and grocery stores. We incorporated residents with individual characteristics to simulate their daily routine of interacting with both others and their surroundings, such as grocery stores and restaurants (or lack thereof), in order to assess how an individual's social network and resources affect their overall health score.

61. Intervals in the Weak Order on 132 and 312 Pattern Avoiding Permutations

Evan Calderon Yale University
Advisor(s): Brian Drake, Grand Valley State University

This poster examines the weak order posets on permutations that avoid the patterns 132 and 312. These posets have nice recursive structures and are isomorphic to the shifted shape lattices, whose elements are Young diagrams above a staircase. We count the intervals of different types, including linear and Boolean intervals.

62. Winnability of Threshold Graphs in the Lights Out! Game

Troy Conlay Grand Valley State University
Advisor(s): Darren Parker, Grand Valley State University

"Lights Out!" is a game that can be played on graphs where toggling a vertex changes the state of the vertex and its neighbors. The objective is to turn off all the lights on a given graph. This research, funded by the McNair Scholar's Program, investigates under what conditions the game can be won when applied to threshold graphs. Threshold graphs

are a special class of graphs characterized by a binary string where each '1' represents a vertex connected to all subsequent vertices.

64. A Finitely Ramified Cell Structure and Resistance Form on the $2-$nacci Word Fractal

James Opre McDaniel College
Advisor(s): Benjamin Steinhurst, McDaniel College

We present a finitely ramified cell structure on the 2−nacci Word Fractal. This is not the natural cell structure given by the iterated function system because the IFS cell structure has an inevitable, uncountable overlap between cells. The finitely ramified cell structure has the property that the cells only overlap at finitely many points. Using this cell structure we construct a resistance form and associated Laplacian on the fractal. Approximations to eigenvalues and eigenfunctions for the Laplacian are also given.

65. Anti-van der Waerden Numbers of Tadpole Graphs and their Products

John Caceres Quinnipiac University
Jeremiah Ellis Kutztown University
Edgar Yak-De Padua California State University, Los Angeles
Advisor(s): Zhanar Berikkyzy, Fairfield University

A k-term arithmetic progression $(k-AP)$ in a graph G is a list of vertices such that each consecutive pair of vertices is the same distance apart. A $k-AP$ is called rainbow under a coloring c, if each vertex in $k-AP$ is colored distinctly. The anti-van der Waerden number of a graph with respect to k is the least positive integer r such that every surjective r-coloring of vertices of G has a rainbow $k-AP$. In this research project, we focus on tadpole graphs, they are created by joining a cycle with a path using an edge. We determine the anti-van der Waerden number for $3-AP$s in tadpole graphs, as well as their products with path graphs.

66. Conjugate Flow Analysis for Traveling Waves in a Multilayer Fluid System

Annie Wang University of Pittsburgh
Advisor(s): Ming Chen, University of Pittsburgh

Ocean waves are not confined to the surface. Stratification, caused by factors like salinity and solar heating, leads to the formation of pycnoclines. This results in large-amplitude waves propagating through the fluid's interior while the surface remains undisturbed, known as internal waves. In this project, we aim to mathematically study the physical conditions for the formation of a two-dimensional steady internal bore in the ocean. We have three conservation equations (mass, energy, and momentum) and extra conditions based on the physical setting. We want to find solutions to the conjugate flow equations that would give necessary conditions for the existence of internal waves. Dias and Il'ichev did an explicit conjugate analysis and obtained solutions for internal waves numerically for a two-layer fluid with a flat bottom and a rigid lid. We propose to push matters further by incorporating more interfaces into the system, specifically, (1) a two-layer fluid with a flat bottom and a free interface, and (2) a three-layer fluid with a flat bottom and a rigid lid. This is funded by University of Pittsburgh's Summer Undergraduate Research Award.

67. Realizing Group Structures for Order 2^n via Groups of Units

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

The Fundamental Theorem of Finite Abelian Groups describes the possible structures of finite abelian groups of a certain order. In this research, we investigate which structures of abelian groups of order 2^n are realized as groups of units. For each value of n, we calculate what percent of structures are realized as groups of units, analyzing how the percentage changes as n increases.

68. An Evaluation of Monotonic Voting Methods Using Ranked Choice Voting Data in the United States

Benjamin Bruyns Austin Peay State University
Advisor(s): Brad Fox, Austin Peay State University

The standard voting methods in the U.S. of plurality and ranked-choice (or instant-runoff) voting can both exhibit major voting failures. These flaws can include majoritarian and Condorcet failures as well as monotonicity paradoxes.

We investigate alternative forms of ranked-choice voting using variations the points-based Borda Count Method that satisfy the monotonity property. In particular, we empirically studied 458 U.S. elections conducted from 2004 to 2022 to determine how often voting failures occur using the Borda variations.

71. Comparing Methods and Optimizations of Opportunistic Risk-Limiting Audits

Rohith Raghavan Sharon High School through MIT PRIMES
Eric Chen Acton Boxborough Regional High School through MIT PRIMES
Advisor(s): Mayuri Sridhar, MIT

Auditing elections is an important part of preserving faith in the electoral system and verifying the accuracy of the reported results of an election. Conventional election audits involve taking a set number or percentage of ballots and checking if the samples match the reported winner. However, these methods are unreliable for close races and excessive for races with a wide margin. Risk-limiting audits use statistical tests in order to assign a certain risk limit, the maximum probability that the results are incorrect, by sampling ballots one at a time until the risk limit is achieved. Our research explores opportunistic auditing, the ability to audit multiple races simultaneously, and attempts to determine what strategies are most effective for opportunistic auditing. We examine complex multi-state and strata races that are audited using the ALPHA (Stark) supermartingale and test different bet-size and sampling strategies to answer the core question: how can existing auditing tests/martingales provide useful risk guarantees over multiple races at the same time? This research was done through the support of the MIT PRIMES program.

72. The Truncated Octahedral Conjecture

Lark Song University of Pittsburgh
Advisor(s): Thomas Hales, University of Pittsburgh

One of the most difficult problems in geometry, the Kelvin problem, seeks the surface-minimizing partition of three-dimensional Euclidean space into cells of equal volume. Bezdek (2005) named a weak form of the Kelvin problem the Truncated Octahedral Conjecture, which requires the cell to be a parallelohedron and asserts that no parallelohedron can have a smaller surface area than the truncated octahedral Voronoi cell of the body-centered cubic lattice for a given volume. Parallelohedra are of particular interest in research both within and outside of mathematics because they are the only convex polyhedra capable of translational tiling. Although this conjecture is more approachable than the notorious Kelvin problem, it remains challenging to prove. We investigate this conjecture using a decomposition method inspired by Hales's proof of the Kepler conjecture, ultimately working with 144-variable linear programming certificates with computer assisted verifications. We are confident that our approach has the potential to fully address the conjecture. This project is supported by the University of Pittsburgh through a Chancellor's Undergraduate Research Fellowship.

73. Acyclic Matchings on Quivers of Arrows

Andrew Hale University of Minnesota
Advisor(s): David Favero, University of Minnesota

Finding minimal resolutions of toric modules is useful in homological mirror symmetry, which ties together two string theory models. Favero and Hanlon discovered combinatorial algorithms to produce resolutions of these modules. However, the resolutions obtained from these algorithms were only sometimes minimal. Our objective was to find a combinatorial algorithm to find minimal resolutions for these modules. We did this using discrete morse the quiver associated with the toric module. We found a new "tesselation model" for generating resolutions based on the fan data. The model first determines a set of characteristic cubes from the fan data, and then projects the cubes to form a "tessellation" of the module. We conjecture that the module resolution data can be read off directly from the tessellation and that the resolution is always minimal. Future directions for this research could be to prove this conjecture and classify the toric modules that can be resolved this way.

74. Optimizing Transport Predictive Modeling with Simulation-Based Statistical Inference

Quyen Tran DePauw University
Advisor(s): Mamunur Rashid, DePauw University

Simulation-based statistical inference (SBI) leverages computer simulations to help scientists understand and analyze complex data. This project explores how SBI techniques can be used to analyze transportation data. We use modern

computational methods, including machine learning models, to improve the accuracy of predictions and decision-making in transportation planning. Our study focuses on applying two SBI methods, Approximate Bayesian Computation - Markov Chain Monte Carlo and Synthetic Likelihood, to create synthetic data for training machine learning models. These models show the potential of SBI to handle uncertain data. It also highlights the practical benefits of SBI in making predictions and decisions for transportation systems.

75. On the Expected Number of Rolls before Obtaining Consecutive Results

Arthur Xu Naperville Central High School
Advisor(s): Jie Yang, University of Illinois at Chicago

This study presents a novel, simple solution to find the expected number of flips of a coin before obtaining h consecutive heads or t consecutive tails, namely, $\frac{1}{\frac{1}{2^{h+1}-2}+\frac{1}{2^{t+1}-2}}$. I proved this new solution by using the linearity of expectation on independent events. The same formula, albeit with some modifications, also applies to dependent events. Meanwhile, I also compared it with numerous other methods, such as states, recursion, and generating functions. Lastly, I expanded the findings to apply to rolling die and relate them to sequences and martingales.

77. Complexity of the Canonical Form of Convex Codes

Parker Abed Creighton University
Advisor(s): Alexander B. Kunin, Creighton University

An animal navigating an environment develops hippocampal place fields, regions in the environment where certain corresponding neurons will fire. The binary representation of the neurons that fire in a given location is called the codeword. The set of all codewords corresponding to locations in an environment is the code of the place fields. The canonical form is a different representation of the code using polynomials to represent the cover of a space by place fields. The canonical form of a code is comprised of polynomials of various forms, which describe the intersection and containment relationships between place fields. Additionally, the canonical form is helpful by serving as a potential tool for measuring the complexity of a code. We have observed that, when generating the code from convex place fields, the canonical form tends to be smaller than the canonical form of a set of random codewords tends towards a larger canonical form. We study this phenomenon and propose a new method to quantify the complexity of the codeword's binary data.

78. Polynomial Consensus Networks Using Geometric Calculus

James Yoho Grove City College
Advisor(s): Remi Drai, Grove City College

Linear consensus theory is widely used in the analysis and design of network systems across various scientific and engineering disciplines. The mathematics of linear consensus theory involves graph theory, linear algebra, and classical linear differential equations. However, many interesting network systems are intrinsically nonlinear. We demonstrate how some of these nonlinear networks can be naturally and fruitfully studied within the framework of geometric calculus. In particular, the proposed approach can handle entropic systems driven by the geometric mean of the state components instead of the usual arithmetic mean. The main results are illustrated using Python simulations.

79. The Local-Global Conjecture for Apollonian Circle Packings is False

Clyde Kertzer CU Boulder
Advisor(s): Kate Stange, CU Boulder

In a primitive integral Apollonian circle packing, the curvatures that appear must fall into one of six or eight residue classes modulo 24. The local-global conjecture states that every sufficiently large integer in one of these residue classes will appear as a curvature in the packing. We prove that this conjecture is false for many packings, by proving that certain quadratic and quartic families are missed. The new obstructions are a property of the thin Apollonian group (and not its Zariski closure), and are a result of quadratic and quartic reciprocity, reminiscent of a Brauer-Manin obstruction. Based on computational evidence, we formulate a new conjecture.

81. Monotonicity of Preimages in Functions Mapping to Totally Nonnegative Spaces

Ben Casica-Patton Wabash College
Advisor(s): Alison Rosenblum, Wabash College

Given a finite string of numbers representing an element in the symmetric group S_n, a function **f** can be defined using those numbers to map from $\mathbb{R}^n$ to upper triangles matrices with ones on the diagonal. The resulting matrix can then be used to plot a subset of $\mathbb{R}^n$. The subsets of $\mathbb{R}^n$ corresponding to the various elements of the symmetric group form a cell complex. If the matrices corresponding to these cells all have nonnegative minors, the cell complex is said to be in a totally nonnegative space. This project examines the preimages of these functions to totally nonnegative spaces and determines whether certain preimages are cells homeomorphic to the open ball of dimension m.

82. Constraining Random Graph Models for Improved Scalability.

Nick Forbes Creighton University
Advisor(s): Alexander B. Kunin, Creighton University

Random graph models are valuable tools for analyzing complex networks, providing insights into their structural and statistical properties. While Exponential Random Graph Models (ERGMs) are theoretically robust, they often encounter practical issues such as degeneracy and poor scalability. This study introduces a framework using "scaffolding" to address these challenges. An ERGM can be considered as a probability distribution over graphs, which can be represented as a joint distribution over the edges. A scaffold, in this context, discards irrelevant interactions between edges, streamlining the model for better performance. Our primary objective is to evaluate the impact of scaffolding on ERGMs, focusing on mitigating degeneracy and enhancing scalability for applications in biological networks.

83. Game Theoretic Strategies to Optimize Global Healthcare Resource Allocation during Pandemics

Zachary Nunez University of Alabama in Huntsville
Satyaki Roy University of Alabama in Huntsville
Advisor(s): Satyaki Roy, University of Alabama in Huntsville

Inequities associated with the international distribution of life-saving medical resources during the former COVID-19 pandemic have illustrated the need for sound incentives for cooperation. In this project, we model the sharing and consumption of healthcare resources by governments as a multi-agent, continuous-time control problem amongst a finite number of player countries, where each country seeks to control its own state vector governed by the SIRD equations using an affine linear control, where the extent of control is constrained by limited resources. In the model, countries are able to exchange resources at a time-varying rate in response to the actions and states of other countries, introducing the potential for both competitive and cooperative behavior. Using tools from optimal control theory, differential game theory, and machine learning, we derive theoretical and numerical results, we characterize optimal play within this game, particularly in the 1-player, 2-player, and N-player games. We then utilize numerical experiments to predict the extent of emergent cooperation under a variety of starting conditions and possible outside interventions.

84. A Statistical Learning Model for Risk Management of Remote Work

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

The COVID-19 pandemic prompted a widespread shift to remote work for many companies, revealing significant gaps in existing risk management frameworks. Traditional risk management has not kept pace with this transition, leaving businesses vulnerable to new and unaddressed risks. In this research, we will introduce a novel statistical model designed to integrate these risks into Business Continuity Planning (BCP). This model will utilize probabilistic risk assessment and logic to provide a comprehensive approach to managing the complexities of remote work. By adapting risk management strategies we'll be able to decide what to include, or remove in a remote work environment, so that businesses can enhance their resilience and ensure continuity in an increasingly digital and distributed work environment.

85. Monoid Representations of Upho Posets and Total Positivity

Yuchong Zhang University of Michigan
Advisor(s): Yibo Gao, Peking University

In this paper, we establish a bijection between locally finite colored upho posets and left-cancellative invertible-free monoids. Additionally, this bijection maps $\mathbb{N}$-graded colored upho posets to left-cancellative homogeneous monoids. Furthermore, we use this bijection and the new concept of semi-upho posets to prove that every totally positive power series is the rank-generating function of some upho poset, resolving a conjecture of Gao et al. This research was conducted as part of the PACE program during the summer of 2023 at Peking University, Beijing.

86. Hyperbolicity of the Curve Graph of the n-Punctured Sphere

Ava Ostrem Rutgers University - New Brunswick
Mandy Unterhalter University of Virginia
Advisor(s): Dan Margalit, Vanderbilt University

The curve graph is an important object in the study of surfaces. Hensel, Przytycki, and Webb proved that the curve graph is hyperbolic in the sense of Gromov. In this project, we aim to quantify the degree of hyperbolicity for various types of surfaces. In particular, we aim to study the hyperbolicity of the curve graph of the n-punctured sphere. This is joint work with Ryan Dickmann as part of the CUBE REU at Vanderbilt University.

87. Evaluating the Exam Leak Impact on the Integrity of the 2023 American Math Competition (AMC) 12A

Rockwell Li Ocean Lakes High School
Advisor(s): Heng Fu, Tidewater Community College

The American Math Competition (AMC) 12 is a test that selects students for the United States International Math Olympiad Team. The 2023 AMC 12A was reported to have an exam leak which could have affected student scores. As high school students who took the 2023 AMC 12A, we were interested in assessing if it had an abnormal score distribution that may have been linked to the exam leak. To study this, we used the available data of the past AMC 12 score distributions from 2009 to 2023. We compared the 2023 AMC 12A score distribution to past AMC 12 score distributions using Z-score analysis. After converting the Z-scores to p values and analyzing the graphs of both quantities across past AMC tests, we found that the contest score distributions for the 2023 AMC 12A had an abnormally large proportion of students receiving top scores (120 - 150 out of 150). Our results suggested that there was a significant correlation between the leak and this abnormal distribution.

88. Lower Bound for Non-cyclic Quotients in Virtual Braid Groups

Isaiah Williams Vanderbilt University
Jerry Gao Vanderbilt University
Alberto Magana Vanderbilt University
Advisor(s): Dan Margalit, Vanderbilt University

Just as the study of the classical braid group is important for understanding classical knot theory, virtual braids reveal the structure of virtual knots. In studying the braid groups, collapsing sets have been found to be a useful tool. Following Kolay, who used collapsing sets to show that the smallest finite non-cyclic quotients of the braid groups are symmetric groups, our goal is to generalize this method to the virtual braid groups. Specifically, we aim to refine Scherich-Verberne's lower bound of the size of finite non-cyclic quotients of the virtual braid group on n strands given to n!, attained by the symmetric groups. This is joint work with Jacob Guynee, Jerry Gao, Alberto Magana as part of the CUBE REU at Vanderbilt University.

89. On the Genus of Right-Angled Artin Groups

Jack Moffatt Yale University
Simon Rosenblum New York University
Advisor(s): Dan Margalit, Vanderbilt University

Right-angled Artin Groups (RAAGs) are a family of groups that interpolate between free groups and free Abelian groups. We can associate any collection of curves on a surface with a RAAG via their intersections. We introduce a

notion of genus for RAAGs as the minimal genus of surface which can realize this construction, and study it for a large family of RAAGs to better understand this association. This is a joint work completed during the CUBE REU at Vanderbilt University.

90. Homomorphisms between Fundamental Groups and RAGGs

Qianqian Wu Grinnell College
Stephanie Huang Harvey Mudd College
Advisor(s): Abdoul Karim Sane, Vanderbilt University

Crisp and Wiest provided a geometric construction of a homomorphism from the fundamental group of a surface, S, to a right-angled Artin group (RAAG). This RAAG can be defined by a collection of curves on S. In this project, we aim to characterize homomorphisms obtained by Crisp and Wiest's construction among all abstract homomorphisms. This project is part of the CUBE REU at Vanderbilt University.

91. From Equations to Evolution: The Mathematics of Genomic Transformations

Nafisa Raisa Fordham University
Advisor(s): Poly Hannah da Silva, Columbia University

While genomes may prioritize parsimony in the short term, their evolutionary paths diverge from the most parsimonious routes over longer periods. Considering a stochastic model of genome evolution under DCJ-indel operators, we study the fluctuation of evolutionary paths and their escape from parsimony. For any given set of parameters p_{dcj}, p_{ins}, p_{del} in $[0, 1]$ with $p_{dcj} + p_{ins} + p_{del} = 1$, and positive integers l_{ins}, l_{del}, we assume that the evolution starts at an arbitrary signed multi-chromosomal genome with n genes or markers. At each step with probability p_{dcj}, we pick a DCJ operator at random from the set of all possible DCJ operators to change the current state of the genome. Similarly, with probability p_{ins} (p_{del}, respectively) we let an insertion (deletion) of length at most l_{ins} (l_{del}, respectively) operate on the current state of the genome. As n tends to infinity, we show that there exists a real number $c := c(p_{dcj}, p_{ins}, p_{del}) > 0$, depending on the operator weights p_{dcj}, p_{ins}, p_{del}, such that evolution binds to parsimony up to time cn, while escaping from parsimony after this time. We study the divergence time cn for different choices of parameters.

92. Examining the Influence of UAB Data Pre-Training on BioBERT for Predicting Opioid Use Disorder Entity Modifiers

Andrew Trotter University of Alabama at Birmingham (UAB)
Advisor(s): John Osborne, UAB

Advancements in machine learning and text analysis are driving progress in clinical data science and precision medicine. This study investigates the impact of additional UAB clinical document pre-training on BioBERT for predicting entity modifiers in Opioid Use Disorder (OUD) and evaluates the influence of synthetic substitution methods on model performance. Comparing BioBERT and UABBioBERT across synthetic datasets generated by BRATSynthetic, this study measures accuracy, macro-F1 score, and micro-F1 score for key entity modifiers: "negation," "DocTime," "subject," and "uncertainty." Results indicate slight improvements in the "negation" and "DocTime" modifiers with additional pre-training, but UABBioBERT performs consistently worse for the "subject" modifier, with no difference observed for the "uncertainty" modifier. Synthetic substitution methods exhibit no significant impact on model performance across all datasets and modifiers. Further research should explore reasons for the limited improvement in certain modifiers and to investigate alternative methods for enhancing language models in predicting OUD entity modifiers.

93. Cohomology and Independence of Lie Algebras Associated with Graphs

Kyle Kelley Kenyon College
Advisor(s): Marco Aldi, Virginia Commonwealth University

In 2005, Dani and Mainkar introduced a method for constructing a 2-step nilpotent Lie algebra from a simple graph G. We investigate the relationship between the dimensions of the basic cohomology of such Lie algebras and the independence polynomial of the graph, $I(G)$. Additionally, we explore the dimensions of basic cohomologies of metabelian Lie algebras derived from finite simple graphs with edge colorings (as described by DeCoste, DeMeyer,

Mainkar, and Ray) and independent sets of such graphs. Our findings provide deeper insight into the algebraic structures linked to graph-theoretic properties. This research is being done through Virginia Commonwealth University's Research Experience for Undergraduates and is funded by the National Science Foundation.

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