Abstracts for the MAA Undergraduate Student Poster Session

"Research in Motion"

MAA MathFest 2023

Tampa, FL

August 4, 2023

MAA
MATHEMATICAL ASSOCIATION OF AMERICA

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

MAA MathFest 2023
Tampa, FL
August 4, 2023

Organized by

Emily Cilli-Turner
University of San Diego

Thomas Langley
Rose-Hulman Institute of Technology

Sara Malec
Hood College

and

Amber Russell
Butler University

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 Ph.D.s, 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 Students (CUS), and we'd like to recognize their efforts. Besides the session organizers, the other committee members are: Ximena Catepillan, Paul Fishback (PME Representative), Jason Hardin, Janine Janoski, Emille Davie Lawrence, Nancy Ann Neudauer, Peri Shereen (Chair), and John Snow (KME Representative). Also thanks to former poster session organizer and committee member Eric Ruggieri for his advice and support. If you're a faculty member who'd like to get involved in the undergraduate activities at MathFest and beyond, please consider joining CUS.

It takes a lot of work behind the scenes to make this day go smoothly, and we're grateful to all the MAA staff for all their hard work: Twila Cotter (MAA Communities Coordinator), Olesia Romanova (MAA Meetings and Events Program Specialist), Beverly Ruedi (MAA Electronic Production and Publishing Manager), and Max O'Hern (MAA Digital Events Strategy Specialist).

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

Emily Cilli-Turner
University of San Diego

Tom Langley
Rose-Hulman College

Sara Malec
Hood College

Amber Russell
Butler College

Sponsored by the MAA

Committee on Undergraduate
Student Programming

Titles, Authors, Advisors and Abstracts

1. Strong Homotopy Lie algebras and Hypergraphs

Samuel Bevins Virginia Commonwealth University
Advisor(s): Marco Aldi, Virginia Commonwealth University

We describe a procedure to attach a nilpotent strong homotopy Lie algebra to every simple hypergraph and prove that two hypergraphs are isomorphic if and only if the corresponding strong homotopy Lie algebras are isomorphic. We conclude with a combinatorial description of the cohomology of these strong homotopy Lie algebras in low degree.

2. Euclidean Distance Degree of Chemical Reaction Networks

Elise Farr Boston University
Galileo Fries Colorado College
Julian Hutchins Morehouse College
Vuong Nguyen Hoang Wingate University
Mark Curiel University of Hawai'i Manoa
Advisor(s): Luis David Garcia Puente, Colorado College

The study of chemical reaction networks forms a vital part of systems biology. In this project, we focus on chemical reaction networks with mass action kinetics for which the reaction dynamics are given by polynomial equations. This restriction allow us to apply methods from algebraic geometry to study several features of chemical reaction networks. In particular, we will analyze the algebraic complexity of the optimization problem which seeks to find the nearest point in the steady state algebraic variety to a given to a given data point. This work was completed during the 2023 Pomona Research in Mathematics Experience (DMS-2113782).

3. Constructing the Straightedge and Compass and the Origami Constructible Field Using Iterative Processes

Medha Ravi Saratoga High School
Advisor(s): Robert Geretschlager, Institute for Mathematics and Scientific Computing at the University of Graz

This paper explores the ancient Greek problems of doubling the cube and squaring the circle, specifically focusing on the construction of the cube root of 2 using straightedge and compass. We present a proof, without advanced field theory or notation, that it is impossible to construct the cube root of 2 using only the available set of intersections. Our proof uses a recursive approach based on a series of proofs that the cube root of 2 is not of any form that exists in the field of straightedge and compass constructible numbers. This provides a simplified approach to field theory problems and a way to construct the set of both straightedge and compass constructible numbers and origami constructible numbers without prior knowledge of field theory. Our findings make this problem more accessible to a wider audience.

4. Null Ideals of Certain Tri-diagonal Matrices Over a Ring R

Wiley Debs Montclair State University
Advisor(s): Aihua Li, Montclair State University

In this research, we study the null ideal of a polynomial ring $T(R)[x]$, where R is a commutative ring and $T(R)$ is the ring of 3 by 3 tri-diagonal matrices with entries from R. The null ideal consists of the polynomials $f(x)$ in $T(R)[x]$ such that $f(A) = 0$ for all $A \in T(R)$, which may or may not be a two sided ideal. Restricting $T(R)$ to a subset S, the null ideal of S. We give the structure of the null ideals of $T(R)$ and properties of the polynomials involved.

5. Trace Ideals in Semi-Group Rings

Akilah Goldson Sarah Lawrence College
Matilda LaFortune Scripps College
Eli Pregerson Harvey Mudd College
Erik Imathiu-Jones California Institute of Technology
Olivia Del Guercio Rice University
Advisor(s): Haydee Lindo, Harvey Mudd College

The well-known trace map on matrices can be generalized to a map on any module over a commutative ring. The image of such a map is a trace ideal. In particular, given a ring the trace ideal of a module is the ideal generated by the homomorphic images of that module in the ring. These trace ideals detect many salient properties of their modules. for example, the existence of free direct summands. There has been a recent uptick in the study of trace ideals within commutative algebra, often taking advantage of particular ring settings to aid in the calculations and applications of trace ideals. In this project we will investigate trace ideals in semigroup rings, highly structured rings with interesting number-theoretic and algebro-geometric properties. This work was conducted as part of the Pomona Research in Mathematics Experience (DMS-2113782)

6. Consecutive Integer Matrices and Their Properties

Kelsey DeAcosta Penn State University
Cole Hadley Penn State University
Ashhad Hanafi Penn State University
Trevor Wylezik Kutztown University
Advisor(s): Jonah Smith, Penn State University Berks Campus

We study square matrices of consecutive integers, i.e. $n \times n$ matrices where the ith row, jth column entry is $a_{ij} = k + (i-1)n + (j-1)$, $(k \in \mathbb{Z})$. For example,

$$A = \begin{bmatrix} k & k+1 & k+2 \\ k+3 & k+4 & k+5 \\ k+6 & k+7 & k+8 \end{bmatrix}.$$

We have discovered the general form of the characteristic polynomial for all sizes n and starting values k, and other properties such as the trace, determinant, and eigenvalues. Other variations and generalizations of consecutive integer matrices are discussed.

7. Singular genus two fibrations

Minjun Lee Lawrence University
Johnny Dahl Lawrence University
Fadila Louleid Lawrence University
Liu Scott Lawrence University
Advisor(s): Julie Rana, Lawrence University

Algebraic varieties are locally described by polynomials. We study algebraic varieties of dimension two, known as algebraic surfaces. Quotient singularities, which commonly appear on algebraic surfaces, have nice combinatorial constructions. We describe a database built to search for new surfaces with quotient singularities. Our surfaces arise from fibrations of genus 2 curves.

8. Essential Contributing and Predictive Factors of Bravery Through Advanced Data Analytics

Kylie Loftis Virginia Commonwealth University
Citlali Rocha-Ruiz Kansas State University
Advisor(s): Mihhail Berezovski, Embry-Riddle Aeronautical University

What makes a person brave? Brave Enterprises is a company that designs and implements dynamic training that enables people to recognize fear as a cue to take brave action. Part of the training sessions, requires participants to complete a pre-survey prior to the 2-hour session and a post-survey following the session. Embry-Riddle REU

students were given the opportunity to research and analyze various datasets provided by Brave. This analysis used more than a thousand matched surveys from various sessions done by Brave Enterprises since their founding in 2016. Our goal was to identify what factors lead to a person's sense of bravery. The advanced analysis performed included: feature importance, cross correlations that lead to high bravery scores, and efficiency of the program. It was expected that leadership style, choice of role model, and sense of purpose were strong indictors of one's bravery score. By understanding which factors are the most predictive, regarding bravery score, we can contribute and support Brave's mission of helping people tackle their obstacles, grow confidence, and be more brave.

9. An Inverse Condensation Test for the Convergence of a Monotone Infinite Series

Zubayir Kazi West Valley College
Advisor(s): William Breder, West Valley College

In this paper, we present a new technique for proving the convergence or divergence of a monotone infinite series. Our result also allows for estimating the partial sums of such a series. In particular, we prove that if $f : \mathbb{N} \longrightarrow \mathbb{R}$ is a strictly increasing function bounded above by 1, then: $\sum_{i\geq 0} \frac{1}{f(i)}$ converges if and only if $\sum_{n\geq 0} 2^{-n} f^{-1}(2^n)$ does where $f^{-1}(a) = \text{argmin}_{f(b)\geq a}\{b \in \mathbb{N}\}$. Moreover, the following bound holds for the partial sums: $\frac{1}{2}G(n+1) \leq \sum_{2^{n+1}\geq f(i)>1} \frac{1}{f(i)} \leq G(n+1)$. where $G(n+1) = 2^{-n} f^{-1}(2^{n+1}) + \sum_{n-1\geq k\geq 0} 2^{-k} f^{-1}(2^{k+1}) - f^{-1}(1)$. This allows us to elementarily reprove results such as: $\sum_{n\geq k>0} \frac{1}{k} \sim O(\log(n))$ and that $\sum_{k>0} \frac{1}{k^p}$ diverges iff $p > 1$. We further prove new results such as if $d \in \mathbb{R}$ is large enough such that $f(w) = \frac{w}{\log_2(w)^\kappa}$, $w \in [d, \infty)$ is monotone, then $\sum_{i>d} \frac{1}{f^{-1}(i)}$ diverges iff $\kappa > 1$.

10. Uncertainty Quantification of Segmentation in Computed Tomography

Ioannis Paraschos Embry-Riddle Aeronautical University
Ellie Kienast Georgia Institute of Technology
Hadley Santos-Del Villar State University of New York at Albany
Nathaniel Reimer Macalester College
Advisor(s): Mihhail Berezovski, Embry-Riddle Aeronautical University

Image processing and analysis are essential in materials science, manufacturing, and non-destructive testing. By processing computed tomography (CT) images, researchers can derive different physical attributes of an object. Pacific Northwest National Laboratory (PNNL) utilizes CT scans to study objects and materials efficiently and nondestructively. Partnering with PNNL, this Research Experience for Undergraduates project at Embry-Riddle Aeronautical University aims to quantify the uncertainty of segmentation methods applied to CT scans of machined objects. The uncertainty must be addressed to ensure the reliability and effectiveness of CT. The first phase in our research applies various edge detection methods to a dataset of 176 CT images of a test object provided by PNNL. Evaluation metrics are employed on each edge detection method to determine the accuracy. After selecting the most effective method using a generated ground truth, frameworks for quantifying error are investigated. Using the developed error models as a basis, the uncertainty of the CT scan segmentation can be quantified to generate a more robust and productive process to study materials in industry applications.

11. Uncertainty Propagation in Image Deblurring

Thomas Pasfield Embry Riddle Aeronautical University
Madeline Gorman Embry Riddle Aeronautical University
Eleanor Sigel University of Southern California
Advisor(s): Mihhail Berezovski, Embry Riddle Aeronautical University

Within digital signal processing, noise resulting from motion, detector features, and source features contribute to blur, hindering interpretation of radiographic data. Various regularization methods, particularly Tikhonov (L2) and Total Variation (TV) Regularization, reframe deblurring as a linear inverse problem, simplifying various blurring factors into a single linear operator in order to estimate the degree of blur mapped onto an original signal as a Point Spread Function. However, estimates of the PSF are uncertain, rcompounding uncertainty during regularization. As such, supported by ERAU and the NSF REU Program, we have partnered with the NNSS to model the uncertainty propagated by TV and L2 Regularization. We will begin by applying these approaches to estimate blur, acknowledging uncertainty by estimating the error bounds for each method. Then, we quantify the uncertainty propagated by the yielded

estimates, beginning with 1-dimensional signals and extending to 2-dimensional images. These results will clarify the error associated with radiographic deblurring techniques and inform corresponding expectations of accuracy, improving predictions within signal processing.

12. Spatio-Temporal Analysis for Modeling and Forecasting High-Demand Events in European Private Aviation Travel

Noa Teed Embry-Riddle Aeronautical University
Michael Leitelt Stetson University
Talia Foley Grinnell College
Murphy John University of New Mexico
Samantha Mackley University of Missouri
Nicole Morgen Carroll College
Advisor(s): Mihhail Berezovski, Embry-Riddle Aeronautical University

Accurately predicting the demand for aviation is a complex problem that is essential for the success of the private aviation industries. Factors such as seasonality and location affect the demand for private flights, but high-demand events and holidays introduce additional and often unexpected influences on these services. Flexjet Inc., a renowned global provider of private aviation services, operates extensively in European destinations, where travel is heavily characterized by high-demand events and holidays. This research utilizes detailed characterization data provided by Flexjet Inc. containing over 1.1 million private flights between 2,016 locations from 2018 and 2019. Leveraging advanced data analysis techniques, this project constructs a spatio-temporal forecasting model to accurately predict the demand for private jet travel during high-demand events and holidays in European destinations. This research delivers valuable insights to providers of private aviation, enabling them to proactively respond to market fluctuations and optimize their operational strategies.

13. Is Access Improved? Geospatial Analyses of Virtual and In-Person Down Syndrome Specialty Programs

Jace Howard Simpson College
Kayla Jensen Simpson College
Paul Llamas Simpson College
Advisor(s): Heidi Berger, Simpson College

A Down syndrome (DS) specialty clinic can address many healthcare needs beyond those that are provided in primary care settings. Currently, there are 71 Down syndrome clinics in 34 states within the continental United States. To improve access to quality healthcare for individuals with DS, Down Syndrome Program was launched Down Syndrome Clinic to You (DSC2U) in 2020. This is a virtual, asynchronous DS specialty clinic that provides individualized care for people with DS. We used geospatial modeling techniques to understand the access to specialty care for people with DS in the United States. Using zip code level data, we determined if DSC2U improves this access to care. This work is conducted through support from Simpson College and the Hal & Greta Bryan Summer Research Program.

14. Mathematically Modeling a Nonlinear, Passive Acoustic Filter

Bjorn Ludwig Bowdoin College
Advisor(s): Christopher Chong, Bowdoin College

This project focuses on developing a mathematical model for a nonlinear, passive sound filter, which uses a drum-head-like membrane disc and magnets to dampen high-amplitude input signals while having little effect on low-amplitude input signals. Hypothetical applications of such a filter include installation in construction workers' headphones to allow them to hear each other speak while dampening dangerously loud noises from nearby machinery. The project has been ongoing since the summer of 2021, with a combination of analytical and numerical methods used to develop and test the model. The analytical methods of this project fall under the realm of differential equations. The project also included numerical comparisons on MATLAB and experimental testing using COMSOL Multiphysics, with a focus on refining the model and ensuring agreement between analytical and numerical data. Recent work entailed a visit to Universitat Politècnica de València to test the theoretical and numerical results on the physical apparatus.

15. Reintroducing Native Plants and Seabird Restoration on the Island of Kaho'olawe

Mandarine Chyba Rabeendran Colorado School of Mines
Advisor(s): Monique Chyba, University of Hawaii Manoa

The sacred island of Kaho'olawe located next to Maui in the Hawai'i Archipelago was turned into the Pacific's target range when the US military seized the entire island following the attack on Pearl Harbor. It was returned to the state of Hawai'i in 2003. Given proper restoration, Kaho'olawe has the phenomenal ability to become an exquisite habitat for many of the declining populations of seabirds and other endangered plants/animals native to Hawai'i. In this work, we model and analyze restoration efforts accounting for volunteer efforts as well as the dangers of forgotten unexploded ordnance.

16. Studying Robustness of Criminal Networks

Simon Zhang New York City College of Technology
Beck Bao New York City College of Technology
Katie Salas New York City College of Technology
Julia Burnside New York City College of Technology
Advisor(s): Urmi Duttagupta, New York City College of Technology

A drug trafficking network (DTN) can be represented by directed graphs through direct or indirect connections. Criminal networks are dynamic, meaning as players or their roles change over time, complexities, and attributes such as densities, centrality measures vary in each DTN and thus, the network evolves over time. Studying a DTN's robustness is vital to assess a network's viability with respect to the loss of actors (nodes) or links (edges), in the context of network modification due to a law enforcement interception. The robustness of a network can be studied by using connectance, which measures how a network is affected by a loss of some actors or links. Connectance specifies the degree to which the actors within a given DTN are connected to each other. Directed connectance, was one of the most robust measures for studying various network resolutions.We use normalized connectance for comparison of various DTNs and modify the expression to suit our purpose. This work could aid law enforcement personnel in evaluating which actors are most connected and who the key and strategic players are, and thus help in planning efficient disruption strategies.

17. Demographic Diversity and Political Districting

Jason Bruder McDaniel College
Advisor(s): Jonathan Epstein, McDaniel College

Demographic variation among political districts and biological diversity among a collection of associated subcommunities share a common mathematical framework: both can be thought of as partitioning a set in two ways. By establishing this parallel, we are able to use the robust set of tools that have been developed to understand and quantify biodiversity to study the structure of demographic variation among political districts. The tools include Rényi entropy, Hill numbers, and α-, β-, and γ-diversities. We also show how special cases of some of these measures are related to well-known measures of segregation.

18. Mathematical Modeling for Honeybee Colony Populations

Iris Xue Mississippi School for Math and Science
David Johnson Mississippi School for Math and Science
Georgia Gibson Mississippi School for Math and Science
Advisor(s): Fatima Hilali, Mississippi State University

Honeybees, of the scientific species Apis, play a vital role in agriculture, pollination, and human existence. However, honeybee hives and colonies worldwide have experienced a concerning phenomenon Colony Collapse Disorder (CCD). The objective of this project was to develop a deterministic mathematical model to simulate the population dynamics of honeybees over time and predict annual population variations. By identifying the key variables influencing honeybee populations and making necessary assumptions to simplify the model, a deterministic population model was created. This model incorporated variable amounts for each season into one combined equation. The model uses main variables, including growth rate, foraging attrition, temperature death, and the rate of swarming, to determine the colony population of the Western Honeybees. The model was then tested, and sensitivity analysis was conducted to determine the variables that most affect the predicted population. An infographic was created to provide an overview

of the model and research project. This project will help beekeepers to take better precautions to prevent a tremendous population decline.

19. Will They Pass or Run? Predicting Whether an NFL Team Will Run or Pass the Ball Using Play-by-Play Data.

Josh Dunham Wentworth Institute of Technology
Lev Sukherman Wentworth Institute of Technology
Advisor(s): Barry Husowitz, Wentworth Institute of Technology

There are many complex factors that go into a coaches offensive and defensive play-calling decisions. They must decide in real time what will give their team the best chances for success while considering the players on both sides as well as the current situation of the game. We achieved this goal by employing a variety of machine learning techniques on play-by-play data that documents every play between 2009 and 2018 for the NFL. We investigated key variables such as score difference, time remaining, down, yards until first down, field position, and others to determine their importance in whether a play is going to be a run or a pass. We explored methods such as logistic regression, neural networks, and support vector machines to compare their effectiveness for predicting whether the play will be a run or pass.

20. A Sentiment Analysis of Texts Published Before and During the Covid-19 Pandemic

Emily Musgrove Ursinus College
Advisor(s): Hugo Montesinos-Yufa, Ursinus College

This research will examine the statistical significance of the change in connotative language use before and during the Covid-19 pandemic. By analyzing news articles from several major US newspapers, preliminary analyses indicate a statistically significant correlation between the sentiment of the text and the publication period. This implies a shift in societal attitudes associated with the pain and stress that many suffered during the pandemic. Our results showcase an important relationship between a high-stress event such as the Covid-19 pandemic, the sentiment reflected from the use of language, and potential long-term mental health implications for the population.

21. A Mathematical Model for Housing Security

Ana Chacon Drake University
Jessica Avianeda Drake University
Cristina Baez Drake University
Advisor(s): Terrance Pendleton, Drake University

The availability and affordability of safe and stable housing are essential for the well-being and quality of life of individuals. In this project, we propose a mathematical model for housing security that can provide valuable insights into understanding and addressing housing security challenges. In particular, we use mathematical modeling approaches such as differential equations and monte carlo simulations to analyze housing security, focusing on the factors that contribute to housing insecurity and the potential interventions to mitigate it. The model incorporates various variables such as housing prices, income levels, housing subsidies, and population growth to capture the complex dynamics of housing security.

22. Studying the Impact Forces Experienced By A Player's Head During Different Types of Collisions

Savannah Ming Drake University
Brooklyn Lowry Drake University
Brandon Manogura Drake University
Tre' Montague Drake University
Advisor(s): Terrance Pendleton, Drake University

In the realm of sports, concerns regarding player safety have gained significant attention in recent years. One crucial aspect of player safety is understanding and mitigating the impact forces experienced by a player's head during collisions. In this project, we explore the application of mathematical modeling to analyze and quantify the impact forces

on a player's head during various types of collisions. To this extent, we develop a system of difference equations that consider factors such as collision velocity, player mass, and impact angle to simulate different collision scenarios which allows for a comprehensive evaluation of the effects of varying parameters on head impacts.

23. A Mathematical Journey of the Immune System's Effect on COVID-19 Replication

Isaak Mouring Drake University
Advisor(s): Terrance Pendleton, Drake University

The immune system protects against viruses and diseases and produces antibodies to kill pathogens. It is well known that once the virus enters the body, it usually finds itself in cells that line your nose, sinus cavity, and throat. While the immune system could potentially respond to different parts of the virus, it's the spike proteins that get the most attention. Immune cells recognize the spike proteins as a foreign substance and begin producing antibodies in response. Our research project attempts to address the following questions:

- How does the immune system affect the growth of COVID-19 cells in the body?
- To what extent does age, gender and size affect the immune system's ability to suppress and/or eradicate COVID-19 from the body?
- What effects do preventative and/or therapeutic measures have on the immune system's ability to suppress and/or eradicate COVID-19 from the body?

To address the research questions above, we develop a system of differential equations which tracks the growth of COVID-19 cells in a human body and the number of antibodies being produced by an immune system.

24. Predicting physician actions for prescribing antibiotics in sepsis: a discussing using logistic regression and gradient boosting machines

Devang Sharma University of Minnesota
Advisor(s): Gyorgy Simon, University of Minnesota

Machine learning physician action prediction models are becoming increasingly popular due to their benefits in assisting physicians with patient diagnosis and treatment plans. These models have been adapted for specific diseases, i.e., heart disease, cancer, and diabetes; however, there is not a model of this type developed for sepsis yet. The goal of this study is to utilize logistic regression and gradient boosting machine (GBM) models to predict weather a physician will prescribe antibiotics to potential sepsis patients within 1 or 3 hours. A total of 4 models were built: a logistic regression and GBM for 1 and 3 hours. The best model achieved an AUC of 0.78 suggesting that there is scope for utilizing machine learning models to help physicians prescribe antibiotics to patients in a short time after hospitalization.

25. Machine Learning in Finances

Elma Kastrat CUNY New York City College of Technology
Akinyemi Apampa CUNY New York City College of Technology
Advisor(s): Satyanand Singh, CUNY New York City College of Technology

In our study we work on an optimization of an appropriate stock portfolio base on available information. Our work takes into consideration the average return and any associated risk. We produce an investment strategy that predictively allows a portfolio to grow with high yields. We look at the stocks relatively stable over a period. Our goal here is not to show you how to win at the stock market, but rather to show how, with stock quotes and some statistics, you can figure out the average rate of return on investment and the risk of investing. We will use Lagrange multipliers to construct an optimal investment portfolio based on these estimates.

26. A dynamical study of a mating system with sex-biased predation for invasive species control

Margaret Cathcart University of South Carolina
Charles Ohanian Muhlenberg College
Nihal Kumar Pennsylvania State University
Advisor(s): Eric Takyi, Ursinus College

Invasive species are nonnative species capable of causing economic and environmental harm and are very difficult and costly to eradicate. There are several control methods utilized to regulate them, one of which is biocontrol, which

involves the introduction of natural enemies (predators). In this work, we propose a mathematical model to control invasive species via the introduction of predators wherein the predation is sex biased. We will study the impact of sex-biased predation and provide numerical simulations to support our theoretical results and discuss any ecological implications. This work is funded by the NSF grant number #1851948 and was conducted through an REU program at Ursinus College.

27. Predicting tropical cyclone paths through learning from existing methods

Dannie Dong Memphis University School
Advisor(s): Ching-Chi Yang, University of Memphis

Accurately predicting the trajectory of tropical cyclones is critical for effective hurricane preparedness and minimizing the risk of associated damages. While numerous techniques have been developed to track and forecast hurricane paths, concerns persist regarding prediction precision and consistency. Recent research has highlighted the potential of ensemble methods in improving hurricane track forecasting. However, individual techniques undergo continuous refinement, and the list of top-performing methods can change over time. In this project, we propose a real-time approach that leverages existing methods to enhance prediction accuracy. Our methodology involves averaging predicted locations from a selected number of high-performing approaches, determined based on their prediction errors. By employing optimization techniques, we determine the optimal number of top methods that minimize errors. For our case study, we utilize data provided by the National Hurricane Center on Atlantic hurricanes. By evaluating prediction errors across a range of two to twenty methods, our results demonstrate that averaging across the top fifteen techniques yields the lowest overall prediction error.

28. Patterns in Political Polarization

Emma Conran Carthage College
Elena Knebel Carthage College
Brett VanDeWostine Carthage College
Landon Gauthier Carthage College
Advisor(s): Haley Yaple, Carthage College

The present political climate of the United States suggests that political partisanship has reached an all-time high. How can this be quantified? We investigate polarization in the U.S. Senate with methods previously used to study the U.S. House of Representatives. By measuring agreements both within and between members of political parties, we create a network structure defined by voting records. These networks display the range of senator behaviors, allowing us to track changes in partisanship on both an individual and a party level. We observe shifts in behavior over decades of voting history, highlighting trends and outlier events. Some of our findings may contradict what you hear on the news! This work was completed as part of the Carthage College Summer Undergraduate Research Experience.

29. Comparing Maximizations of Weighted Criterion and Individual Criteria in Core Selection

Kyra Batarse California State University, Monterey Bay
Advisor(s): Steven Kim, California State University, Monterey Bay

Genetic datasets typically have thousands of markers which are overwhelming for researchers to work with. Researchers want to work with a smaller subset of the entire dataset, which is referred to as a core. In this project, we focus on three criteria for core selection: coverage (C1), Shannon diversity index (C2), and modified Roger's distance (C3). We consider two methods to increase all C1, C2, and C3. Method 1 is to maximize the weighted average of C1, C2, and C3 at each iteration of the core selection. Method 2 is to maximize C1, C2, then C3 sequentially. We expect that Method 2 results in a lower value of the weighted average of C1, C2, and C3, but it will be substantially more efficient than Method 1 in terms of computation time. We use an original genetic dataset of wheat which consists of 556 markers and 14,099 samples. Due to the size of genetic datasets constantly increasing, being able to obtain a similar value for the weighted criterion at a faster computation time will be practically valuable for core selection. (This project is supported by the NREUP at CSU Monterey Bay.)

30. A Mathematical Approach for Optimizing Linguistically-Induced Analgesia

Ryka Chopra Mission San Jose High School
Advisor(s): Suparna Chakraborty, University of San Francisco

A fundamental challenge in computational neuroscience is to build tractable models to understand how external stimuli affect human responses. This is particularly important in translational medicine where current focus is on finding alternatives to opioid-based analgesia. This study develops a theory of music-induced-analgesia where music acts as a somatosensory stimulus that impacts pain. To this end, I build a lifetime-utility-maximizing model of pain management and show how linguistic cues embedded in the lyrics of a song delivers pain relief by manipulating the nucleus accumbens to release dopamine through initiating a positive affective-motivational state via lowered future discount rate. I derive conditions under which linguistic cues have the largest impact. A model-based computational linguistic algorithm built using NLP and ML principles reports an 18.3% increase in pain tolerance and 11.6% reduction in pain intensity, along with significant cardiovascular benefits when patients are exposed to cortically simple positive lyrics. My project aims to provide a tractable model that can be used to improve efficacy of pain and drug rehabilitation therapies for optimal relief.

31. An Agent-Based SVIRS Model for the Spread of a Disease between Two Regions with Different Population Densities

Daniel Jin Ed W Clark High School
Advisor(s): Timothy Comar, Benedictine University

We consider an agent-based model (ABM) for a the spread of a disease with vaccination between two regions, one of which is a central city with high population density and the other of which is a rural region with significantly less population density. We study the how the disease mitigation strategies of vaccination and travel restrictions impact the spread of the disease. We determine conditions for which the disease can be eliminated and conditions for which the disease will persist. We perform sensitivity analysis to determine which of the these strategies has the greatest impact on the spread of the disease.

32. A Model for Integrated Pest Management with Pest Migration Between Two Regions

Aashima Singh Sisodia Illinois Mathematics and Science Academy
Advisor(s): Timothy Comar, Benedictine University

We consider a model for integrated pest management (IPM) using impulsive differential equations in which pest species move between two types of regions. In one of these regions, the pest species primarily consumes an agricultural crop, and in the other region, the pest species primarily reproduces and takes refuge from the management strategies. Impulsive behaviors in this model include migration between the regions, application of pesticide, and augmentation of the predator species. The management strategies include a predator species and the application of pesticide. We study the dynamics of this model and provide conditions for which there is pest eradication and conditions for which the pest species persists and remains under control.

33. An Agent-Based Model for Integrated Pest Management with Refuge for the Pest Species.

Calvin Zheng La Salle College Preparatory High School, Pasadena
Advisor(s): Timothy Comar, Benedictine University

We consider an agent-based model (ABM) for integrated pest management (IPM) with refuge for the pest species. The model incorporates stage structure for the pest and predator species. The control strategies of augmentation of the predator species and pesticide application and the pest births occur periodically at possibly different frequencies. Moreover, the amount of augmentation depends on the ratio of the population densities of the pests and predators. We determine conditions under which pest eradication occurs and under which both species persist. We will also consider how the location of the refuge areas with respect to the location of the crops can impact the control strategies. We also perform sensitivity analysis to understand which of the parameters have the greatest impact on the control of the pest species.

34. Asymptotic Behavior of Stem Cells in Healthy and Cancerous Bone Marrow Niches

Maxyn Hallare Warwick High School
Hally Hallare Homeschool
Advisor(s): Maila Hallare, United States Air Force Academy

Stem cells are of particular interest in the field of microbiology because of their characteristics of plasticity and self-renewal. Recently, oncologists have hypothesized that cancers are supported by a subpopulation of Cancer Stem Cells with properties similar to healthy stem cells. We consider a simple mathematical model, based on principles from mathematical ecology, that looks at the dynamics of hematopoietic stem cells, hematopoietic progenitor cells, hematopoietic differentiated cells, leukemic stem cells, and leukemic differentiated cells. We apply equilibrium and stability analysis techniques to find parameter regimes where desirable steady states are stable. Desirable steady states are defined by those states where the leukemia stem cell population and leukemia differentiated cell population are zero, and the hematopoietic cell populations are not zero. Matlab numerical simulations are used to support theoretical computations. Preliminary results include that the high transition from leukemia stem cells to leukemia differentiated cells result in a faster death rate for differentiated cancer cells, with an earlier peak time.

35. Regression methods for constructing species distribution models for eagle use in the continental United States.

Justine Fretz Lafayette College
Annaliese Chen Swarthmore College
Eugene Monforte Cal Poly Pomona
Advisor(s): Leslie New, Ursinus College

Species distribution models (SDMs) are a statistical approach that uses species abundance and environmental data to predict species' distribution across an area of interest. An SDM can take the form of a generalized linear model, generalized additive model, or kernel density estimation. Our research focuses on using existing SDM frameworks to model and analyze eagle distribution across the continental United States. We will use an SDM to better predict eagle minutes at wind facilities in the United States. Our SDM will allow for the extrapolation of existing data to predict the distribution of golden and bald eagles at any proposed wind facility site prior to its construction. These predictions can be used in partnership with US Fish and Wildlife Service to inform take permit decisions for wind farms. Eagle take permits are required for wind farms to operate due to fatal collisions of bald and golden eagles with wind turbines. Our research seeks to understand the relationship between eagles and wind farm locations while minimizing the time and funding resources associated with the data collection required. This work was completed as part of the NSF REU 1851948 at Ursinus College.

36. Understanding people's behavior during the COVID-19 pandemic from epidemic and mobility data

Amira Gbagba Stony Brook University
Sofia Iturbides SUNY New Paltz
Advisor(s): Anca Radulescu, SUNY New Paltz

In our study, we used data from the public domain to understand the bidirectional relationship between the timeline of the Covid 19 epidemic outbreak and human response to this timeline (as reflected in adherence to travel, social distancing and vaccination protocols). We used New York State Health Department data to access county-wise epidemic information on the daily number of cases and tests throughout the course of the pandemic. We then investigated to what extent the overall case incidence in each county was correlated with its population mobility patterns (as accessed from Apple and Google mobility reports). Both epidemic and mobility timelines showed some common patterns across all counties. However, we found that counties with different demographic profiles (e.g., population density, household income, political affiliation) showed differences in the coupling between the epidemic and the mobility timelines, potentially underlying their different long-term outcomes. Understanding this coupling can help us generate hypotheses regarding the effects of people's social behavior during the Covid 19 epidemic and more generally, evaluate the actions of society in crisis. This work is supported by the MAA's National REU Program.

37. Using a SIR-type mathematical model to understand human behavior in epidemic dynamics

Angelique Santiago SUNY New Paltz
Jasmin Nunuvero SUNY New Paltz
Advisor(s): Anca Radulescu, SUNY New Paltz

Susceptible-Infectious-Recovered (SIR) models have been used for decades to understand epidemic outbreak dynamics. We will present an SIR-type system specifically informed by Covid 19 epidemic data and literature, and we will illustrate how we used this model to study the effects of the human response along the evolving viral timeline of the Covid 19 outbreak. Through a collection of parameters, our model includes contributing factors such as population birth, death, infection, recovery and vaccination rates as well as limited immunity. This allows us to account for the virus consecutive mutations as changes in the infectiousness parameter, and to efficiently capture the human response to the epidemic timeline. We show how premature relaxation of safety protocols at the extinguishing of an epidemic wave can result in a temporarily increased infection rate at a time where it may cause additional epidemic waves. We also show how population vaccination behaviors can contribute to controlling the epidemic. Our results can be used to better understand the patterns observed throughout the Covid 19 pandemic, and to increase our behavioral preparedness for any future epidemic outbreaks. This work is supported by the MAA's National REU Program.

38. Mathematically Modeling the Immune Response of Celiac Disease

Olivia Adamic Lewis University
Advisor(s): Cara Sulyok, Lewis University

Celiac disease is a hereditary autoimmune disease that affects approximately one in 133 Americans. It is caused by a reaction to the protein gluten found in wheat, rye, and barley. After ingesting gluten, a patient with celiac disease may experience a range of unpleasant symptoms while small intestinal villi, essential to nutrient absorption, are destroyed in an immune-mediated process. The only known treatment for this disease is a lifelong gluten-free diet and there is currently no drug treatment. This work uses a system of ordinary differential equations to track changes in small intestinal cell densities. The model can be used to investigate and analyze the immune response by focusing on understanding the dynamics of the small intestine in situations mirroring healthy function and celiac disease. By doing so, we can investigate potential therapies to mitigate the negative effects of celiac disease.

39. A Mathematical Model of Disease Spread Incorporating the Environment and Interactions in Healthcare Settings

Kristen Ess Lewis University
Advisor(s): Cara Sulyok, Lewis University

Clostridioides difficile (*C. difficile*) has been the leading cause of infectious diarrhea and one of the most commonly-obtained infections in United States hospitals. Those infected could have contracted *C. difficile* due to interactions with a surface or person harboring the spores spread by the disease. Patients that are infected with *C. difficile* spread these endospores which have proven to be difficult to remove from the hospital environment. The mathematical model developed uses a system of differential equations including different transmission routes such as healthcare workers, doctors, and low- and high-touch frequency fomites, objects likely to carry infection. The results from this model can be applied by those in the healthcare field into their practice in order to lessen the spread of *C. difficile* in healthcare settings.

40. An Agent-Based Model of *C. difficile* Transmission in a Multi-Ward Hospital

Austin Kind Lewis University
Ethan Jakubowski Lewis University
Matthew Senese Lewis University
Laila Mahrat Lewis University
Brittany Stephenson Lewis University
Advisor(s): Cara Sulyok, Lewis University

This project investigates the impact of environmental pathways to *Clostridioides difficile* (*C. difficile*) transmission in healthcare settings. *C. difficile* is one of the most frequently identified healthcare-acquired infections in United States hospitals. Colonized patients shed *C. difficile* endospores that can survive for long periods on surfaces outside the host

and are resistant to many commonly-used disinfectants. In this work, we formulate an agent-based model (ABM) of *C. difficile* transmission in a hospital, with disease spread occurring both within and among wards, while focusing on frequently-touched surfaces in each hospital room and ward. Different hospital wards operate under different cleaning procedures and healthcare worker-patient interactions. Developing an ABM replicating a real-world hospital with the distinction of multiple wards operating under individualized protocols will allow us to examine the role that different types of healthcare workers and surfaces with varying touch frequencies play in patient colonization and determine effective control strategies to mitigate the spread of *C. difficile* in healthcare settings.

41. Modeling Disease Transmission and Control in Long-Term Care Facilities

Lizbeth Leon Dominican University
Brittany Stephenson Lewis University
Harold Arriaga Lewis University
Advisor(s): Cara Sulyok, Lewis University

This project focuses on studying the transmission of *Clostridioides difficile* (*C. difficile*) within long-term care facilities by employing a system of ordinary differential equations to identify strategies for mitigating the spread of this bacterium. *C. difficile* is a healthcare-acquired infection frequently encountered in long-term care facilities, and its transmission can occur through direct contact with infected individuals or exposure to *C. difficile* endospores on contaminated surfaces. Mathematical models offer a unique opportunity to analyze complex dynamics and interactions that are challenging to study directly in real-world settings. By developing a mathematical model specific to long-term care facilities, this project aims to understand the primary routes of *C. difficile* transmission and identify effective control strategies to reduce incidence rates within long-term care facilities.

42. Mathematically Modeling the Interactions of Community- and Hospital-Acquired *C. difficile* Infections

Edmonde Olongo Dominican University
Sara Gongora
Advisor(s): Cara Sulyok, Elmhurst University

Clostridioides difficile (*C. difficile*) is an infection-causing bacterium commonly contracted by patients in medical institutions in the United States. *C. difficile* creates endospores which can survive in harsh conditions for long periods. This bacteria can be spread either through contact from person-to-person or with surfaces hosting the endospores. Patients who are currently on or have recently taken an antibiotic are susceptible to contracting *C. difficile* as certain bacteria in the stomach become weaker, creating an ideal environment for *C. difficile* to grow as its spores spread faster without competition. This study quantifies the spread of the *C. difficile*, differentiating between community- and hospital-acquired infections. Using a system of ordinary differential equations distinguishing between individuals in the local community and hospital as well as varying environmental surfaces, results can be used by local communities to predict and limit potential outbreaks of *C. difficile*.

43. Modeling the Effects of Temperature on Within-Mosquito Malaria Parasite Transitions and Sporozoite Load

Alexander Diefes Duke University
Advisor(s): Miranda Teboh-Ewungkem, Lehigh University

Malaria is caused by Plasmodium parasites and is transmitted via Anopheles mosquitoes from one human to another. Temperature is known to affect within-mosquito parasite forms and dynamics; we incorporate these effects into the first mathematical model of within-mosquito parasite dynamics. We integrate experimental data associated with transition rates of the sporogonic phase, which includes processes from gamete fertilization to sporozoite formation. Using constructed cubic splines, we incorporate regional average monthly temperature from selected African regions by mapping experimental temperature-dependent sporogonic traits to time-varying model parameters; we embed these converted temperature-to-time varying parameters into the mathematical model, yielding a non-autonomous system of differential equations. This system is used to study the impact of temperature on the sporogonic malaria cycle. We also propose appropriate approximations for these constructed spline functions and investigate how the overall timeline of the sporogonic process is influenced by temperature. We conclude by discussing broader implications of rising global temperatures on malaria transmission dynamics.

44. Almost all wreath product character values are divisible by given primes

Hannah Graff Creighton University
Lola Vescovo Macalester College
Brandon Dong Carnegie Mellon University
Skye Rothstein Bard College
Joshua Mundinger University of Chicago
Advisor(s): Nate Harman, Michigan University

We sketch the current landscape of character tables and introduce a new theorem about the prime divisibility of wreath product character values. We explore this new theorem through partitions, Young diagrams, and the symmetric group to understand previous research in the area. This generalizes the work of Peluse and Soundararajan on the character table of the symmetric group.

45. Impartial Geodetic Games on Graphs

Laila Mahrat Lewis University
Advisor(s): Marie Meyer, Lewis University

An impartial game is a 2-player game that consists of a finite set of positions in which the possible moves are the same for each player at any position. Nim is an example of an impartial game since both players remove stones from any pile, whereas chess is not impartial since each player can only move a piece of their own color. In this research, we explore winning strategies for a new variation on the geodetic achievement and avoidance games played on various families of connected graphs as originally defined by Buckley and Harary. The games are played such that players take turns selecting previously unselected vertices of the graph until the set of selected vertices satisfies our geodetic conditions. To win the achievement game, a player must choose a vertex such that the selected vertex set generates all vertices of the graph. As for the avoidance game, the players must avoid choosing the vertex that generates the set of all vertices of a graph; the player that chooses that vertex loses the avoidance game.

46. Uniquely Completable and Critical Subsets of Infinite Latin Squares

Emma Hasson Bard College at Simon's Rock
Kenneth Callahan Brown University
Matt Ollis Emerson College
Yolanda Zhu Bard College at Simon's Rock
Advisor(s): Kaethe Minden, Bard College at Simon's Rock

Much work has been done on Latin squares in the finite case, including the study of uniquely completable and critical subsets. A partial Latin Square is said to be uniquely completable if it has exactly one possible completion. A critical subset is a uniquely completable partial Latin Square with the property that if any one entry is removed, the partial Latin square is no longer uniquely completable. In this research we examine two main examples of infinite Latin squares- the integer square $L_{\mathbb{Z}}$ and the set of Fractal squares- and the unique implications of their infinite structure. Our discussion will focus on critical sets which we have found on these squares and their properties, such as density and diversity. We will also discuss our further attempts to construct critical sets on these squares.

47. Action Graphs for Catalan Sequences

Alison Cochran Indiana University Kokomo
Sarah Klanderman Marian University
Advisor(s): Amelia Tebbe, Indiana University Kokomo

The Catalan numbers are a well-known sequence of positive integers that appear in a variety of settings related to combinatorics. Based on work of Alvarez-Bergner-Lopez, we can recursively create directed graphs, referred to as action graphs, that represent the Catalan numbers. Building on this work, Cressman-Lin-Nguyen-Wiljanen developed generalized action graphs for a related sequence, called the Fuss-Catalan numbers. Another sequence related to the Catalan numbers is the Super Catalan numbers, $S(m,n)$. We define action graphs that correspond to the values $S(0,n)$ and discuss our progress towards characterizing the sequences for which action graphs can be constructed in general.

48. Inferring Connectivity for Computational Neural Network Models

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

In this project, we demonstrate the integration of stochastic computational models and statistical inference techniques to identify underlying neural connectivity. We specifically apply the Perturbation Cascade Inference Algorithm (PCI) to neural networks governed by biological computational neuron models. Using well-known models such as the integrate-and-firing model, Wilson-Cowan model, and Hodgkin-Huxley model, we evaluate PCI's efficiency and accuracy for small to large neural networks with various connectivity configurations. The purpose of this research is to further our understanding of the propagation of information within neural systems.

49. The Reduction of Redundancies of a Mexican-Hat Neural Network via Stochastic Shielding

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

Inferences on the connectivity of neural networks have been the subject of intensive study in recent years. The preponderance of computational network models presumes all-to-all connectivity with variable strength of connections. Nevertheless, many of the presumed connections feature high levels of network redundancy. In this project, we extend the stochastic shielding algorithm, an efficient approximation method proposed for Markov processes, to evaluate the contribution of each neuronal connection to the network's overall behavior. Specifically, neurons were arranged using the common Mexican-Hat weight distribution, and we measured the inference errors when all possible combinations of connections were excluded. We identify the minimum weights required to infer the activity of a fully connected network and the optimal reductions for any given tolerance for inference errors.

50. Counting Sibling Portraits

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

We count the sibling portraits of a rotational polygon with n sides in degree d. A polygon in this context is a set of n points on the unit circle that are connected with chords. Sibling portraits are created by duplicating the original points across the unit circle d times including the original, and then joining them into non-crossing polygons that correspond one-to-one in circular order with the original, and include the original. Laminations of the unit disk are a combinatorial and topological model of the (connected) Julia sets of polynomials of degree d. Each sibling portrait is a finite lamination and the seed of at least one infinite lamination that describes a polynomial Julia set. The polygons correspond to cut points in the Julia set, and polygon vertices correspond to approaches from infinity to the cut points. The problem can be solved as a product of n smaller problems $f(i,n)$, where $f(i,n)$ is the number of ways to connect n sets of i evenly spaced points into non-crossing polygons. We prove that $f(i,n)$ is equal to the Fuse-Catalan numbers in two ways: we rederive a recurrence relation, and we describe a bijection with n-ary trees with i internal vertices.

51. Quantifying Seam Shifted Wake in Baseballs

Nicholas Lobraico Western Connecticut State University
George Trejo Western Connecticut State University
Jessica Nyitrai Western Connecticut State University
Advisor(s): Xiaodi Wang, Western Connecticut State University

In this research we explored the physical phenomenon of seam shifted wake in baseballs and aims to quantify what causes it. By analyzing data from 65 right-handed pitchers who throw sinkers from the 2022 season, we found that the most significant determiner of unexpected movement is the amount of gyro spin. We then developed the first differential equation model that predicts the difference in spin direction, which performs exceptionally well in accuracy. Moreover, our study provides insight into ball movement through the air, applicable to other sports with balls or natural spherical objects. Our results show that some gyro spin is converted to sidespin throughout the flight of the ball, which is now quantified. However, our study did not examine the variable of pressure put on the baseball by the pitchers' fingers due to the lack of machinery, and this will be our future research.

52. Information Theory Through Games

Jay Whitmon Stevenson University
Advisor(s): Benjamin Wilson, Stevenson University

In this poster, we investigate games from an information-theoretic viewpoint. Information theory is the scientific study of the quantification and communication of information. One of the most important quantities in information theory is called entropy, which measures the amount of uncertainty in dynamical systems. Specifically, we work with systems known as stochastic processes consisting of the different states of the system and the probabilities of moving from each state to each other state. Many games can be modeled as stochastic processes where a state is a player's status at the start of their turn (for example their position on a board or the cards in their hand). With knowledge of the different states for a given game and the probabilities of going from each state to any other state, we can model a game as a stochastic process. This allows us to compute the entropy of a game and to understand the amount of uncertainty there is in one game as compared to another. Additionally, modeling games as stochastic processes allows for an analysis of the optimal strategy for the game.

53. When Two Things Look the Same

Santure H. Chen Franklin & Marshall College
Zachary Thayer Franklin & Marshall College
Sarah Peichel Franklin & Marshall College
Spencer Davis Franklin & Marshall College
Wenky Xia Franklin & Marshall College
Advisor(s): Annalisa Crannell, Franklin & Marshall College

This poster concerns the projection of line segments and triangles in a two-dimensional extended Euclidean plane ($\mathbb{E}^2$). We are inspired by the question about whether two clusters of stars can look the same from two different planets. This poster investigates the question of when, and under what circumstances, two triangles in the plane can have the same image on a common picture plane. This poster uses a geometrical but not algebraic approach to illustrate the question and proof. This poster shows that, for every observer on a special conic, there exists another observer on the second conic, such that the first triangle's image in the first observer's eye is the same as the second triangle's image in the second observer's eye.

54. Some Results in Curvilinear Triangle Geometry

Khush Agrawal Grove City College
Jonathan Allarassem Grove City College
Hannah Proctor Grove City College
Advisor(s): Remi Drai, Grove City College

This research is about a new form of triangle geometry where the sides of a triangle are not the usual Euclidean line segments, but curvilinear lines obtained using familiar pre-calculus functions (power/exponential functions). We develop a consistent new form of triangle geometry. Among the proven results is a new version of Ceva's Theorem. We study the relevant notions of angles and length adapted this new form of geometry in order to decide on its Euclidean or non-Euclidean nature. This part of the research is directly inspired by the work of Grossman and Katz on non-Newtonian calculus in the 1970s as well as some several recent publications. In a second part, we use calculus of variations to investigate the metrics for which the curvilinear sides are geodesics, i.e., we place this new geometry within the general framework of Finsler geometry. The results are illustrated using dynamic simulation software.
References

1. Masal'tsev, Incidence Theorems in Spaces of Constant Curvature, 1994.
2. Matsumoto, Geodesics of Two-Dimensional Finsler Spaces, 1994.
3. Matsumoto, Finsler Geometry in the 20th century, 2003.
4. Georgiev, Zennir Multiplicative Differential Calculus, 2022.

55. The Smoothed Decagon Conjecture

Lark Song University of Pittsburgh
Sasha Sluis-Cremer University of Pittsburgh
Advisor(s): Thomas Hales, University of Pittsburgh

In our study of the forthcoming book on Reinhardt's 1934 conjecture by Professor Hales and his graduate student Koundinya Vajjha, we propose an analogous conjecture that the smoothed decagon has the highest packing density among all balanced convex disks. Leveraging the optimal control theory, Hamiltonian mechanics, and interval arithmetic employed by Professor Hales for the Reinhardt conjecture, we formulate the smoothed decagon conjecture as an optimal control problem. In this poster we will explore this conjecture in its weakened form by establishing our proof of the Pontryagin first-order condition, consider the prospects of a complete proof, and discuss possible counterexamples. This research is supported by the Painter and Brackenridge Fellowships for summer undergraduate research at the University of Pittsburgh.

56. Optimal Bubble Clusters in the Plane with Density

Marcus Collins Harvard-Westlake School
Advisor(s): Frank Morgan, Williams College

A circle is the least-perimeter way to enclose given area in the plane. Similarly familiar "bubble clusters" seek the least-perimeter way to enclose and separate several given areas. Especially since Perelman's proof of the Poincaré Conjecture, there has been much interest in such problems in the presence of a density such as r^2 that weights both perimeter and area. Using Brakke's Evolver, we numerically verify conjectured optimal planar double bubbles for density r^p and provide conjectures for triple and quadruple bubbles.

57. A Finitely Ramified Cell Structure on the $2-$nacci Word Fractal

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

The iterated function system (IFS) for the $2-$nacci word fractal gives a non-finitely ramified cell structure. We consider a different cell structure, the "Seafood Cell Structure." In which there are different types of cells, each of which has a different set of sub cells. Notably each adjacent pair of cells intersect at only one point. Our work is to show that the Seafood Cell Structure is finitely ramified. A cell structure being finitely ramified is convenient due to existing literature on the analysis of resistance (similar to Dirichlet) forms on fractals that have a finitely ramified cell structure. That analysis is part of a long-term project to understand the vibration frequencies of the fractal.

58. Circle Packings From Tilings Of The Plane

Mengyuan Yang Swarthmore College
Philip Rehwinkel Swarthmore College
David Yang Swarthmore College
Advisor(s): Ian Whitehead, Swarthmore College

Any circle configuration has a tangency graph, with a vertex for each circle and an edge for each tangency relationship. Let there be a finite set of base circles whose tangency graph is some polyhedron and dual circles whose tangency graph is the dual polyhedron. One can construct a polyhedral packing, defined by Kontorovich and Nakamura, to be the orbit of the base circles under the group generated by reflections through the dual circles. The special case of tetrahedra is the well-known Apollonian circle packing. We study packings that originate from infinite configurations of base and dual circles, a further generalization. We introduce a new class of fractal circle packings in the plane and discuss its relation to crystallographic and Klenian circle packings. The existence and uniqueness of these packings are guaranteed by infinite versions of the Koebe-Andreev-Thurston theorem. We prove structure theorems that give a complete description of the symmetry groups for these packings. The three main circle packings we study are triangular, square, and hexagonal packings. We focus on their arithmetic properties—integrality, super-integrality, and quadratic and linear forms.

59. Fundamental Groups of Hamming Graphs

Keira Behal Emory University
Advisor(s): Tien Chih, Emory University

Recently there has been growing interest in discrete homotopies and homotopies of graphs beyond treating graphs as 1-dimensional simplicial spaces. One such type of homotopy is x-homotopy. Recent work by Chih-Scull has developed a homotopy category, a fundamental group for graphs under this homotopy, and a way of computing covers of graphs that lift homotopy via this fundamental group. In this research, we compute the fundamental groups of all Hamming graphs, show that they are direct products of cyclic groups, and use this result to describe some x-homotopy covers of Hamming graphs.

60. Properties of Chip-Firing Distribution Graphs

Kyle Kelley Kenyon College
Charles Gong Carnegie Mellon University
Philip Thomas Kutztown University
Advisor(s): Eugene Fiorini, University of Delaware

Chip-firing is a mathematical game played on an undirected graph with no loops or multiple edges. A move in the game consists of removing $\deg(v)$ chips from a vertex v and redistributing one chip to each neighbor of v. Thus the total number of chips in the graph remains the same. An initial distribution of chips on a graph G with n vertices is denoted by $D_G = (a_1, a_2, \ldots, a_n)$, where a_i is the number of chips initially on vertex v_i. We examine a variation on the chip-firing game where an additional cost of one chip is assessed when firing from $v \in S$ for some designated subset $S \subseteq V(G)$. Additionally, we investigate the notion of a chip-firing distribution graph on an initial distribution D_G. This is defined as a directed graph $[D_G]$ where the nodes are all distributions on G attainable from D_G by a sequence of chip-firing moves. The arcs are defined as (D_G^i, D_G^j) where D_G^j is attainable from D_G^i via a single chip-firing move. We investigate properties of these chip-firing distribution graphs. This research was done at Moravian University and was funded by the National Science Foundation (MPS-2150299).

61. Turán Problems for Mixed Graphs

Edward Yu Massachusetts Institute of Technology
Advisor(s): Nitya Mani, Massachusetts Institute of Technology

We investigate natural Turán problems for mixed graphs, generalizations of graphs where edges can be either directed or undirected. We study a natural Turán density coefficient that measures how large a fraction of directed edges an F-free mixed graph can have; we establish an analogue of the Erdős-Stone-Simonovits theorem and give a variational characterization of the Turán density coefficient of any mixed graph (along with an associated extremal F-free family). This characterization enables us to highlight an important divergence between classical extremal numbers and the Turán density coefficient. We show that Turán density coefficients can be irrational, but are always algebraic; for every positive integer k, we construct a family of mixed graphs whose Turán density coefficient has algebraic degree k.

62. Master Conductor: Evaluating Ticket to Ride Using Mathematical Concepts

Drew Perkins Centre College
Advisor(s): Prayat Poudel, Centre College

The board game Ticket to Ride requires two to five players to put themselves in the role of a 19th century railroad baron whose sole goal is to control the pathways between 36 North American cities. Players must accumulate points by building train lines that connect certain cities. In this presentation, I will begin with a brief description of the game, followed by a discussion of how we can use techniques from graph theory to make strategic decisions about the game. I will continue with an explanation of the mathematical concepts we utilized before transitioning into how we applied these ideas to Ticket to Ride. I will conclude by mentioning potential extensions of our research that we hope to explore in the future.

63. Network Reliability Parameters

Jean-Pierre Appel Moravian University
Kyle Kelly Kenyon College
Gabby Fishberg Tufts University
Eliel Sosis University of Michigan
Advisor(s): Nathan Shank, Moravian University

Network reliability can be measured by multiple parameters: vertex and edge connectivity, clique number, and more. These were the motivation behind this project started at Moravian Universities' Summer REU program. We examine the size of the largest cycle in a graph or its components, its circumference and *component-wise circumference*, and what they entail. We say a network is operational if it has a circumference of at most size b. Conversely, a network is in a failure state if its circumference is larger than b, or there are no components with circumference of at most size b for *component-wise circumference*. We consider both vertex and edges deletions, and examine these connectivities in regards to different graph classes such as lattices, complete graphs, and complete bipartite graphs.

64. Portfolio Optimization Using the Simplex Method

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

In this research, we examine how the ideal weightings of stocks in a portfolio can be achieved by the Simplex Method. In our algorithm, the objective function consists of a linear combination of the expected returns of the stocks a client wishes to invest in. Meanwhile, the constraints can be altered to address the risk tolerance, budget, and other considerations of each individual client to create a well-diversified portfolio that maximizes returns while mitigating risk. After creating the objective function and constraints, we perform the row operations that are used to systematically test each feasible solution, one of which is guaranteed to be the optimal solution by the Fundamental Theorem of Linear Programming. Applying our method to real data suggests that it outperforms many other methods such as principal component-based methods, copula-based methods, and quadratic programming.

65. Markov Chains Based Statistic Model for Analyzing Voting

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

On August 16, 2022, Mary Peltola, the Democratic candidate for Alaska's at-large congressional district, defeated the Republican candidate, Sarah Palin, in the second round of voting to become the first Democratic representative for Alaska since 1973. This was the first time Alaska used ranked choice voting for a general election. In this research, we created a Markov Chains based model that uses statistics and linear algebra techniques to analyze how Peltola was able to win the election and how different electoral methods would have affected the election such as Weighted Choice Voting. We will show what the Markov Chains will really tell us, and answer the question such as "If voters voted slightly differently would this have affected the election?"

66. Predicting the Outcome of Shotokan Karate Matches

Oliver DiDonato Neumann University
Cindy Casey Gwynedd Mercy University
Advisor(s): Ryan Savitz, Neumann University

This research project introduces a model that addresses the way competitors in Shotokan karate martial arts competitions are evaluated. This new model is a combination of multiple variables that determine the winner of a sparring competition in Shotokan karate. The model we constructed predicts the winner of Shotokan karate matches with a near 100% success rate. The model was constructed using the forward LR variety of logistic regression. Due to some issues of multicollinearity, this model was then refined using the author's knowledge of karate.

67. Elementary Education Action Research on a Cultural Geometry Activity

Devani Sharma Towson University
Anahi Aguilera Towson University
Advisor(s): Diana Cheng, Towson University

Our elementary education action research project is about spatial awareness in geometry, using a cultural puzzle called tangrams. In spring 2023, we taught elementary students and pre-service elementary teachers about the history of tangrams and had them create animals using the tangram puzzle pieces. We show students' work on these activities.

68. Tacos for Thought; Understanding Sets and Relations with Tacos

Lakrisha Berry University of Central Oklahoma
Advisor(s): Brittany Hopkins, University of Central Oklahoma

Intro to proof writing courses are commonly a students first look at logic and more abstract ideas. These concepts are extremely important but can be difficult to grasp. While some texts use venn diagrams for concepts with sets, there are few visualizations used outside of these and those that are tend to be abstract themselves. Our goal was to create effective visuals using graphic design techniques along with the psychology of learning to create images that will increase understanding of sets and relations. By using tacos and taco bars as fun overarching metaphors it's easier to see the relationship between these more abstract concepts. The images use color coordination and typography rules to make the concepts visually stimulating and easy to comprehend. A more cartoon-like aesthetic makes the images less threatening for students. While these initial visualizations were drawn with Intro to Proof Writing courses in mind, I believe these visuals can help anyone who is interested in understanding sets and relations.

69. Minorities in STEM Fields & Increasing Diversity

Emily Arellano Texas Woman's University
Chasatee Summons Texas Woman's University
Jessalie Hunter Texas Woman's University
Naomi Bielmas Texas Woman's University
Advisor(s): Junalyn Navarra-Madsen, Texas Woman's University

The goal of this research is to educate the reader about the steps that need to be taken in order to increase the number of minorities in the STEM fields; which will inevitably lead to more diversity in the STEM fields. This will be done by using reliable resources with important statistics and information. We specifically are looking at factors that lead to minorities and first generation women degrees in STEM and how the diversification of STEM yields from minority students deciding to major in STEM related fields. At the end of this paper, we hope to convince the reader that from lack of representation and limited mentorship opportunities from other minorities, students from poor circumstances find a new identification by breaking into the fields of STEM.

70. Analyzing the Impact of Alternative Assessment, Growth Mindset, and Test Anxiety

Dayanna Sanchez Lewis University
Advisor(s): Michael Smith, Lewis University

Alternate assessment techniques such as mastery grading, specifications grading, and standards- based grading are assessment techniques professors are implementing in order to support a growth mindset of learning. This paper will support a multi-institutional collaboration that studies the impact of mastery grading assessment techniques on the growth mindset of students in a variety of mathematics classes. By analyzing pre- and post-surveys with questions adapted from Dweck's Mindset survey, we will explore whether there is a difference in the growth mindset between various cross-sections of student populations between classes (mastery and non-mastery, specific courses, universities, etc.) and whether the growth mindset of students changed by the end of the semester. Additionally, we will perform a qualitative analysis on student interviews that were taken place pre- and post-exam. This research will explore whether there is a difference in students' mindset of learning mathematics between various cross-sections of student populations between classes and whether the growth mindset and test anxiety of students changed by the end of the semester.

71. 3D Printing and its applications towards learning and student comprehension in Calculus 3 Classrooms.

Michael Ernst United States Air Force Academy
Advisor(s): Shelby Stanhope, United States Air Force Academy

Both 3D Printing and Calculus 3 have something in common, 3 dimensions. Students often struggle with Calculus 3 due to this extra, foreign dimension to wrestle with. This creates the need for a different approach to making student activities and reviews that have the same or greater impact to comprehension as worksheets do for Calculus 1 or 2. Here lies the entry point for 3D Printing in math classrooms. Newly printed objects and activities are presented to revamp the existing Calculus 3 toolbox for teachers so that learning, understanding, and even student enjoyment can be improved drastically across the board.

72. Student Understandings of the Limit Definition of the Derivative

Samuel Dolinger Middle Tennessee State University
Advisor(s): Jeremy Strayer, Middle Tennessee State University

Calculus is a foundational steppingstone for anyone studying mathematics in universities today. One of the fundamental ideas of Calculus is the derivative, which permeates the subject. However, most calculus curricula focus on using the derivative, rather than deeply understanding the derivative. As a result, students struggle with the definition of the derivative or the limit definition. I conducted a case study that utilized task-based interviews with four Calculus II students to investigate how they use their concept images of functions, rate of change, and limits to understand the limit definition of the derivative. The findings of this study explore the ways that a strong understanding of average rate of change is needed to grasp the limit definition of the derivative.

73. Minimal discriminants of elliptic curves with non-trivial isogeny

Jewel Aho University of St Thomas
Louis Burns Pomona College
Stephen Hutchins California State University Stanislaus
Thea Nicholson Xavier University
Advisor(s): Alexander Barrios, University of St. Thomas

Consider the implicit function $E : y^2 + a_1xy + a_3y = x^3 + a_2x^2 + a_4x + a_6$ where each $a_i \in \mathbb{Q}$. We say that E is a rational elliptic curve if there is an additional point $\mathcal{O}$ not on the graph of E and the discriminant Δ of E is nonzero. Two elliptic curves are said to be isogenous if a surjective group homomorphism exists between the elliptic curves with a cyclic kernel. The order of the kernel is called the degree of the isogeny. By an isogeny graph, we mean a graph whose vertices are isomorphism classes of elliptic curves and whose edges are isogenies of prime degree. In this project, we study parameterizations of non-trivial isogeny graphs of elliptic curves and explicitly determine the minimal discriminants of the elliptic curves appearing in the graph. This work was conducted as part of the Pomona Research in Mathematics Experience (DMS-2113782).

74. Arithmetic Connections to the Mathieu Moonshine in Weight 3/2

Wade Twyford UC Berkeley
Manon Bedou UC Berkeley
Advisor(s): Lea Beneish, UC Berkeley

Moonshine refers to unexpected connections between finite simple groups and modular forms. The most well known example of this is monstrous moonshine where the coefficients of the Fourier expansion of the modular j-invariant were famously observed to be sums of dimensions of irreducible representations of the monster group. Observations by physicists have led to the conjecture of another type of moonshine called Mathieu moonshine, which is part of a larger class of moonshines. Recently, there have been works relating these more general instances of moonshine to arithmetic, in particular, when packaged into weight 2, Mathieu moonshine implies divisibility conditions on the number of F_p points on certain elliptic curves. Our goal in this poster will be to explore these arithmetic connections with Mathieu moonshine in weight 3/2.

75. Approximating Irrational Triangles

Emmy Lin Muhlenberg College
Advisor(s): Byungchul Cha, Muhlenberg College

In 1934, Berggren created a matrix multiplication system to generate all Pythagorean triples, which are three integer side-lengths of a right triangle. Using Berggren's system, we can approximate a triangle whose side-length ratios are irrational. We have recently used diagonalization from Linear Algebra to find the nth Pythagorean triple for an "almost" 1-1-$sqrt2$ triangle, where the two legs differ only by one unit. We use the same method and tools to generate the nth triple of an almost 120-degree isosceles triangle. We expand our toolset to approximate other irrational triangles.

76. Nonvanishing of mock theta functions

David Metacarpa Amherst College
Wenche Tseng Amherst College
Advisor(s): Amanda Folsom, Amherst College

The legacy of the mock theta functions, a collection of q-series (infinite basic hypergeometric series in the variable q) originally studied by Ramanujan c. 1920, persists today. Over the course of the last 100 years, they have been studied for their rich analytic and combinatorial properties, as key examples of mock modular forms in Analytic Number Theory, and for their connections to other areas of mathematics including Topology and Mathematical Physics. Our research investigates the fundamental problem of understanding the (non)vanishing of mock theta functions at nth roots of unity on the unit circle in the complex plane. Our work is additionally motivated by the fact that this central attribute of mock theta functions relates to Ramanujan's original analytic definition of mock theta functions, yet is also such that many open questions remain. Our methods and results are analytic, and complement research by others on both the mock theta functions, and the general question of understanding the vanishing of sums of roots of unity.

77. How Less is More (With Origami) : The Second Delian Problem without Field Theory

Medha Ravi N/A
Advisor(s): Robert Geretschlager, N/A

This paper presents a new proof of the impossibility of doubling a cube's volume with straightedge and compass. Unlike previous methods that rely on Field Theory, the proof uses simple geometry and induction, offering an alternative general approach to solving origami math problems, including the other two Delian problems.

78. Adinkras as Origami

Arsh Chhabra Pomona College
Xuehuai He Pomona College
Elena O'Grady Reed College
Melinda Yang Pomona College
Cameron Thomas University of Georgia at Athens
Advisor(s): Edray Goins, Pomona College

Around 20 years ago, physicists Michael Faux and Jim Gates invented Adinkras as a way to better understand Supersymmetry. Recently, Charles Doran, Kevin Iga, Jordan Kostiuk, Greg Landweber and Stefan Méndez-Diez determined that Adinkras are a type of Dessin d'Enfant by explicitly exhibiting a Belyi map as a composition $\beta : S \to \mathbb{P}^1(\mathbb{C}) \to \mathbb{P}^1(\mathbb{C})$. The first arrow is a map from a certain Riemann surface S to the Riemann sphere, and the second is a map which keeps track of the "coloring" of the edges. Adinkras naturally have square faces which keep track of the non-commutative nature of the supersymmetric operators. While Dessin d'Enfants correspond to triangular tilings of Riemann surfaces, there is a similar construction—called "origami"—which correspond to square tilings. In this project, we express the construction of Doran et al. as a composition $\beta : S \to E(\mathbb{C}) \to \mathbb{P}^1(\mathbb{C})$ for some elliptic curve E such that the first map is an "origami", that is, a map which is branched over just one point. This work was conducted as part of the Pomona Research in Mathematics Experience (DMS-2113782).

79. Divisors: from Chaos to Structure, from Density to Rupture

Evelina Dubovski Staten Island Technical High School
Advisor(s): Irina Goldman, SchoolPlus Enrichment Program

Divisor function $\sigma(n)$ is equal to the sum of all divisors of n. In 1977, Wolke proved that ratio $\sigma(n)/n$ is dense in $[1, \infty)$. I consider the generalization $f(s, n)$, which is equal to the sum of the sth powers of divisors divided by the sth power of n. Thus, $f(1, n) = \sigma(n)/n$ is dense in $[1, \infty)$ whereas $f(0, n)$ is equal to the number of divisors and, thus, cannot be dense. I analyze computationally different values of parameter s and demonstrate that there exist two threshold values s_1 and s_2 such that if $0 < s_1 < s < s_2$, then the range of function $f(s, n)$ is dense but outside this interval, for $s < s_1$ and $s > s_2 > 1$, experiences ruptures and the density is lost. I show how the chaotic behavior within (s_1, s_2) generates structures, which eventually lead to structuring and ordering. Two open density-related problems are stated, showing the next steps in my research.

80. Sums of kth powers in ramified 2-adic rings

Sarah England McDaniel College
Reagan Knowles McDaniel College
Advisor(s): Spencer Hamblen, McDaniel College

Generalization of Waring's Problem—that for every natural number k there exists an integer $g(k)$ such that every natural number can be written as the sum of at most $g(k)$ kth powers—have been studied in a variety of contexts from algebraic number fields to non-commutative groups. We will examine values of $g(2k)$ for rings of integers of certain families of wildly ramified extensions of $\mathbf{Q}_2$.

81. Sums of kth powers in ramified 3-adic rings

Hannah Wright McDaniel College
Joe Burton McDaniel College
Advisor(s): Spencer Hamblen, McDaniel College

Generalization of Waring's Problem–that for every natural number k there exists an integer $g(k)$ such that every natural number can be written as the sum of at most $g(k)$ kth powers—have been studied in a variety of contexts from algebraic number fields to non-commutative groups. We will examine values of $g(3k)$ for rings of integers of certain families of wildly ramified extensions of $\mathbf{Q}_3$.

82. An Algorithm Expressing a Prime Number 1 mod 4 as the Sum of Two Squares Using Stern-Brocott Tree

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

A well-known theorem due to Fermat is that every prime number $p \equiv 1 \pmod 4$ can be uniquely expressed as the sum of two squares. In this study, we will utilize the continued fraction and the Stern-Brocott tree to establish an algorithm to determine the two integers, a and b, for any given prime number $p \equiv 1 \pmod 4$ such that $p = a^2 + b^2$. This algorithm will effectively make use of elements in the special linear group $SL_2(\mathbb{Z})$. We will also introduce a few applications of the algorithm such as the factoring of Gaussian integers and the factoring of integers of the form $n^2 + 1$ along with the proofs of some new identities involving Fibonacci numbers.

83. p-Adic Valuation Trees

Dillon Snyder University of Connecticut
Laura Vaughan Vanderbilt University
MaeKayla Minton Kentucky Wesleyan College
Advisor(s): Olena Kozhushkina, Ursinus College

The p-adic valuation of an integer is the largest power of some prime p that divides the given integer. This can also be extended to rational numbers. A p-adic valuation tree is a visual aid that allows us to represent a generated sequence of valuations. We investigate how nodes split on a variety of trees, such as those formed from a product of lower degree polynomials or from non-polynomial generating sequences. We describe the infinite branches of these trees and the valuations of their terminating nodes.

84. A study on the parameter α in the LLL-algorithm and the rank of the lattice

Tobi Oguntuase Texas A&M University-San Antonio
Syrus Redhouse Texas A&M University-San Antonio
Advisor(s): Jingbo Liu, Texas A&M University - San Antonio

When $n \geq 2$, a lattice L of rank n has infinitely many distinct bases. Among these bases, one usually views those consisting of relatively short and almost orthogonal vectors "better" than the others. One of the fundamental problems in lattice reduction theory is to study how to derive a "good" basis for L out of a given "bad" basis. The Lenstra-Lenstra-Lovász (LLL)-algorithm is a lattice reduction algorithm invented by Arjen Lenstra, Hendrik Lenstra and László Lovász in 1982. For each reduction parameter $\frac{1}{4} < \alpha < 1$ and a given "bad" basis, LLL-algorithm can produce a "good" basis within polynomial time. In this presentation, we will study the relation between the smallest value of that parameter α in the LLL-algorithm which generates the shortest LLL-reduced basis vector and the rank of the lattice. This work is supported by the MAA's National REU Program.

85. A study on the parameter α in the LLL-algorithm and the determinant of the lattice

Liliana Villanueva Texas A&M University - San Antonio
Matthew Trevino Texas A&M University - San Antonio
Advisor(s): Jingbo Liu, Texas A&M University - San Antonio

Let $L = \mathbb{Z}\overrightarrow{b_1} + \mathbb{Z}\overrightarrow{b_2} + \cdots + \mathbb{Z}\overrightarrow{b_n}$ be a lattice and B be the matrix with $\overrightarrow{b_1}, \overrightarrow{b_2}, \ldots, \overrightarrow{b_n}$ as its columns. The determinant $\det(L) = |\det B|$. When $n \geq 2$, L has infinitely many distinct bases. Among these bases, one usually views those consisting of relatively short and almost orthogonal vectors "better" than the others. One of the fundamental problems in lattice reduction theory is to study how to derive a "good" basis for L out of a given "bad" basis. The Lenstra-Lenstra-Lovász (LLL)-algorithm is a lattice reduction algorithm invented by Arjen Lenstra, Hendrik Lenstra and László Lovász in 1982. For each reduction parameter $\frac{1}{4} < \alpha < 1$ and a given "bad" basis, LLL-algorithm can produce a "good" basis within polynomial time. In this presentation, we will study the relation between the smallest value of that parameter α in the LLL-algorithm which generates the shortest LLL-reduced basis vector and the determinant of the lattice. This work is supported by the MAA's National REU Program.

86. A motivated proof of the Bressoud-Göllnitz-Gordon identities.

John Layne University of Virginia
Sam Marshall University of Central Florida
Emily Shambaugh Dickinson College
Advisor(s): Christopher Sadowski, Ursinus College

In this project, we present what we call a "motivated proof" of Bressoud's $\mod 4k-2$ analog to the Andrews-Göllnitz-Gordon identities. Recently, similar proofs have been given for other partition identities, including the Rogers-Ramanujan identities, Gordon's identities, the Andrews-Göllnitz-Gordon identities, and Bressoud's identities. In our proof, we introduce and use "ghost series" similar to those introduced in Kanade, Lepowsky, Russell, and Sills's motivated proof of Bressoud's identities. This work was done as part of the Summer 2023 Ursinus College NSF REU, grant number 1851948.

87. Generalized Alder-Type Partition Inequalities

Bryan Ducasse University of Central Florida
Liam Armstrong Oregon State University
Thomas Meyer Amherst College
Advisor(s): Holly Swisher, Oregon State University

In 2020, Kang and Park conjectured a "level 2" Alder-type partition inequality which encompasses the second Rogers-Ramanujan Identity. Duncan, Khunger, the fourth author, and Tamura proved Kang and Park's conjecture for all but finitely many cases utilizing a "shift" inequality and conjectured a further, weaker generalization that would extend both Alder's (now proven) as well as Kang and Park's conjecture to general level. Utilizing a modified shift inequality, Inagaki and Tamura have recently proven that the Kang and Park conjecture holds for level 3 in all but finitely many cases. They further conjectured a stronger shift inequality which would imply a general level result for all but finitely many cases. In this presentation, we share the results from the 2022 Oregon State University REU in Number Theory.

Namely, we prove Inagaki and Tamura's conjecture for large enough n, generalize the result for an arbitrary shift, and discuss the implications for Alder-type partition inequalities.

88. Abelian extensions arising from torsion points of elliptic curves

Alex Abrams Loyola Marymount University
Tesfa Asmara Pomona College
David Bonds California State University Los Angeles
Aniyah Stephen Hartwick College
Japeth Varlack Wake Forest University
Advisor(s): Lori Watson, Trinity College

Abstract: If K is a number field and E is an elliptic curve defined over K, we can obtain a Galois extension $K(E[n])/K$ of K by adjoining all of the points on E of order dividing n. In general these extensions are nonabelian; in fact, if E/K is an elliptic curve without complex multiplication, then for all sufficiently large primes p, the Galois group of $K(E[p])/K$ is isomorphic to $\mathrm{GL}_2(\mathbb{Z}/p\mathbb{Z})$. Nevertheless, abelian extensions $K(E[n])/K$ do occur. In 2015, Gonzalez-Jimenez and Lozano-Robledo determined when $\mathbb{Q}(E[n])/\mathbb{Q}$ is an abelian extension. In this project, we investigate which abelian extensions $K(E[n])/K$ can arise when K is a real quadratic field. This work was conducted as part of the Pomona Research in Mathematics Experience (DMS-2113782)

89. The error term of the sum of binary digital sum functions

Erdenebileg Erdenebat Brigham Young University - Hawaii
Advisor(s): Ka Lun Wong, Brigham Young University - Hawaii

Let n be a non-negative integer and $q > 1$ be a positive integer. Let $s_q(n)$ be the sum of digits of n written in base q. In, 1940, Bush proved that $\sum_{n\leq x} s_2(n)$ is asymptotic to $\frac{x\log x}{2\log 2}$. In 1968, Trollope proved an explicit formula for the error term, labeled by $-E_2(n)$. In 1975, Delange extended Trollope's result to an arbitrary base by another method and labeled the error term $nF_q\left(\frac{\log n}{\log 2}\right)$. When $q = 2$, the two formulas of the error term are supposed to be equal, but they look very different. In this project, we prove directly that those two formulas are equal.

90. Convergence of Stochastic Gradient Ascent by Multithreading (Parallelization)

Jake Giguere Wentworth Institute of Technology
Advisor(s): Barry Husowitz, Wentworth Institute of Technology

Steepest ascent/descent and stochastic gradient ascent/descent are widely used techniques to approximate parameters for multiple linear regression, logistic regression, and artificial neural networks to name a few. However, one of the problems with stochastic gradient ascent/descent is that in most cases it does not converge and rather wanders around the approximate solution. To get convergence, we parallelized (multithreaded) stochastic gradient ascent for logistic regression and took the average of the updated parameters from each thread. This average updated parameter was then used in the next iteration of the stochastic gradient approach. This not only speeds up the calculation but also is an effective way to get convergence for stochastic gradient approaches. NFL team data for the winning percentage verses points for and points against was used to analyze and justify this approach.

91. Predicting the leading cause of death for 2023 in the USA using an LSTM network

Alexandra Hatley University of West Florida
Advisor(s): Archef Cohen, University of West Florida

In 2022, the Centers for Disease Control and Prevention (CDC) reported that heart disease was the leading cause of death among Americans. Data provided by the CDC has some select causes of death recorded from each state per week from 2014 to 2022. The goal of this research is to develop a predictive model to predict the leading cause of death for the year 2023 in the USA. A Long Short-Term Memory (LSTM) network is a well-established artificial neural network for classification, forecasting, and artificial intelligence applications. We demonstrate how LSTM works in R for prediction purposes and the results for the predicted leading cause of death in 2023 per state. Keywords: long-short-memory network, predictive modeling, time series

92. AI Consulting Project for CBEC comparing Naïve Bayes and Non-Naive Networks to Mitigate Limitations in Collected Data

Eli Hellmig Francis Marion University
Bhakti Patel Francis Marion University
Advisor(s): Ivan Dungan, Francis Marion University

Our research project focuses on using AI to evaluate the efforts of the Cell Biology Education Consortium (CBEC), an education initiative funded by the NSF to incorporate cell culture-based research into the classroom. The project explores how machine learning techniques can be leveraged to evaluate an education initiative funded by a grant. In particular, we explore the potential of Bayesian networks as a tool for modeling and evaluating CBEC user behavior using Wix website analytics data to train and test our models. We compared two different Bayesian network models, a naive Bayes approach and a causal network. As a proxy for CBEC user interest, the target variable we used for these networks is the duration of a given user session on the website, with the hopes of identifying useful indicators of increased website engagement. Each model considers the same variables but structures the respective networks differently. K-Fold validation was used to evaluate the performance of our Bayesian models developed using data collected from CBEC's website.

93. Balance between Time of Experiment and Quality of Benchmark Dose Estimation in Risk Assessment

Marleen Barron California State University, Monterey Bay
Advisor(s): Steven Kim, California State University, Monterey Bay

In chemical risk assessment, a goal is to estimate the benchmark dose (BMD). The BMD is defined as a dose which is associated with a given risk level, and it becomes a reference point for population safety. For the estimation of BMD, researchers often conduct animal-based experiments, and ethical perspective and time concerns are of importance. The BMD estimation is better with a larger number of animals (sample size), but the statistical information for BMD can increase by using a proper experimental design for a fixed sample size. There are many well-known experimental designs, but an experimental design can be improved if animals are placed sequentially after observing data. Under a logistic regression model, we use simulations to investigate the balance between the number of sequential designs (i.e., experimental times) and the quality of BMD estimation, and we would like to provide a practical suggestion. We hope that this suggestion addresses both ethical and time concerns. (This project is supported by the NREUP at California State University, Monterey Bay.)

94. Reliable Measurement in the Presence of Learning and Fatigue Effects with Stopping Rules

Stephanie Lara-Sotelo California State University, Monterey Bay
Advisor(s): Steven Kim, California State University, Monterey Bay

In exercise science, researchers sample recreational-level subjects because professional-level subjects are rare. When a subject is given a task (e.g., jump, sprint), we assume there are three phases: learning phase, familiarized phase, and fatigued phase. In literature, most researchers use arbitrary rules to remove the effect of learning phase and fatigued phase. In our previous study, we attempted a statistical model which accounts for the learning phase, but not the fatigued phase. In this study, we attempt to account for the fatigued phase to estimate the subject's true ability (denoted by μ). Since the true learning and fatigue phases are unknown, we consider all possible cases using piecewise linear models and estimate μ by the average of individual model estimates weighted by the Akaike Information Criterion. In addition, we develop a stopping rule to end an experiment early. We anticipate that the weighted average results in a lower mean square error (MSE) for μ than the previous model, and the stopping rule will help save time, effort, and cost with a small increase in the MSE. (This project is supported by the NREUP at CSU Monterey Bay.)

95. Generalized Gamma Harris-G Family of Distributions

Aaron Stringfellow University of West Florida
Ashraf Cohen University of West Florida
Advisor(s): Shusen Pu, University of West Florida

We present a novel family of distributions, the Risti-Balakrishnan-Harris-G (RB-Harris-G) family of distributions, which generalizes the gamma and Harris-G families of distributions. The reliability measures, incomplete and conditional moments, Rényi entropy, distribution of order statistics, stochastic orderings, and probability-weighted moments of the new family of distributions are covered in-depth. The maximum likelihood estimation method is used to estimate the parameters of the RB-Harris-G family of distributions. The robustness of the estimations is evaluated using Monte Carlo simulations. The goodness-of-fit of the new family of distributions is examined via four real data applications.

96. Offense vs. Defensive: Measuring Predictors of Winning Percentage in NCAA Basketball

Austin Raymond Towson University
Gerad Dixon Towson University
Banghee So Towson University
Advisor(s): Stella Tomasi, Towson University

Among college basketball fans, the question of whether a great offense or great defense is more important has been an age-old debate. The aim of this research project was to determine which metrics are the best predictors of team success, and whether better offensive or defensive metrics are a greater overall indicator of team success in modern NCAA Division I Basketball. The sample consisted of data from the 2013-2021 NCAA D1 Basketball seasons. The metrics measured to predict team success included 8 offensive and 8 defensive variables. A series of linear regression analyses were performed for each variable in relation to winning percentage. Then, multiple linear regression via the stepwise method was performed to identify the best predictor variables that influence winning percentage. Finally, logistic regression was performed to assess the variables that predict the likelihood of winning a championship or not.

97. Survival Probabilities of Counting-Out Games on a Line

Bryce Thalheimer Johns Hopkins University
Advisor(s): John Wierman, Johns Hopkins University

Suppose there are n people in a line at positions $1, 2, \ldots, n$. Each position is either vulnerable or safe, and in each round of the counting-out game, one person in a vulnerable position is selected uniformly at random to be eliminated. When the person at position i is eliminated, the remaining people are shifted to fill in position i by moving each person in a position k such that $k > i$ to position $k-1$. The game continues until only one person remains, who is the survivor. The person who starts at position k is called person k. The survival probability, denoted $p_n(k)$, is the probability that person k will be the survivor in a game starting with n people. By mathematical induction, a formula for the survival probability is derived for any arrangement of vulnerable and safe positions. Specific arrangements of vulnerable and safe positions are provided which produce sequences of survival probabilities that asymptotically approximate linear, exponential, and square root functions of k.

98. Effects of Riparian Buffers to Maintain a Healthy Environment in Shenandoah Valley, Virginia

Jacob Steger Vassar College
Holland Bill University of Notre Dame
Elke Doby James Madison University
Daniel Trudell Rhodes College
Dhanuska Wijesinghe James Madison University
Advisor(s): Prabhashi Withana Gamage, James Madison University

Shenandoah Valley is a scenic valley which has the greatest agricultural activities and farming practices in Virginia. The heavy agronomic land use has taken the attention of the authorities with some issues related to the eco-system health of Shenandoah Valley. To reduce the pollution due to these practices, U.S. Department of Agriculture has suggested the landowners to install a riparian buffer-an area between the pollutant source and the water stream which

is often vegetated with grasses and trees. In this project, we focus on several farms in Shenandoah Valley to determine the water quality by measuring pH levels, chloride/ sulfate/ nitrate, calcium/ magnesium concentration, etc. The GIS software is used to quantify some environmental factors to include but not limited to slope of the land, elevation, distance to the farm from the stream. We will develop some linear models to determine the impact of riparian buffers and offer general guidance on installing riparian buffers (such as the size of the buffer, species richness, etc) to preserve the water quality in Shenandoah Valley. This work is supported by an NSF-REU grant (# 1950370) at James Madison University in Summer 2023.

99. Hyperbolicity in arc graphs of punctured spheres

Darrion Thornburgh Bard College
Sami Aurin Georgia Institute of Technology
Dan Margalit Georgia Institute of Technology
Advisor(s): Wade Bloomquist, Georgia Institute of Technology

Hyperbolic metric spaces, as introduced by Gromov, have proven to be useful in geometric group theory. Using the standard path length on a graph, this extends to the notion of a hyperbolic graph. More precisely, we say that a vertex v in a graph Γ is a δ-center of a geodesic triangle if the distance from each side of the triangle to v is less than or equal to δ. If all geodesic triangles in Γ have a δ-center, then we say that Γ is δ-hyperbolic. The arc graph of a surface is the graph where vertices are arcs and the edges represent disjointedness. It was proven by Hensel, Przytycki, and Webb that all arc graphs are 7-hyperbolic. Focusing on the case of the 5-punctured sphere, we look at how optimal 7 is in this particular case. More specifically, we provide explicit constructions and examples of δ-centers and geodesic triangles in the 5-punctured sphere. This work is supported by the NSF through the Georgia Tech Math REU of Summer 2023.

100. Graph Partitioning and Criminal Network

Julia Burnside New York City College of Technology
Katie Salas New York City College of Technology
Advisor(s): Urmi Duttagupta, New York City College of Technology

We partitioned criminal networks based on communication strength among actors. Given the graph $G = (V, E)$ with node set (actors) V, edge set E (communications between actors), weight matrix W (W_{ij} = communication strength between ith & jth actors), can we partition G into subgraphs GA & GB using spectral clustering to optimize function Mcut that maximizes similarities $W(A)$ & $W(B)$ within each cluster A & B while minimizing similarities between clusters cut(A, B)? Does a combination of spectral clustering + linkage-based refinement lower cut value? Can we partition networks based on similarity measures such as amount of information exchanges? Graph partitioning will help us identify nodes more connected among themselves than others; Which sub-community is more robust (survive on its own). Can we find common properties among actors of the same group after partitioning? This work can assist law enforcement evaluate which actors are more connected and strategize an efficient plan for disruption.

Index

SAVE THE DATE!

MAA MATHFEST
2024 | INDIANAPOLIS, IN

August 7–10