Abstracts for the MAA Undergraduate Poster Session

Atlanta, GA
January 6, 2017

Organized by

Eric Ruggieri
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and

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MAA

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Committee on Undergraduate Student Activities and Chapters

and

CUPM Subcommittee on Research by Undergraduates

Dear Students, Advisors, Judges and Colleagues,

If you look around today you will see over 300 posters and nearly 500 student 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. We have acknowledged many of them in this booklet; however, many judges here volunteered on site. Their support is vital to the success of the session and we thank them.

We are supported financially by Tudor Investments and Two Sigma. We are also helped by the members of the Committee on Undergraduate Student Activities and Chapters (CUSAC) in some way or other. They are: Dora C. Ahmadi; Jennifer Bergner; Benjamin Galluzzo; Kristina Cole Garrett; TJ Hitchman; Cynthia Huffman; Aihua Li; Sara Louise Malec; Lisa Marano; May Mei; Stacy Ann Muir; Andy Niedermaier; Pamela A. Richardson; Jennifer Schaefer; Peri Shereen; Eve Torrence; Violetta Vasilevska; Gerard A. Venema; and Jim Walsh. There are many details of the poster session that begin with putting out the advertisement in FOCUS, ensuring students have travel money, making sure the online submission system works properly, and organizing poster boards and tables in the room we are in today that are attributed to Gerard Venema (MAA Associate Secretary), Margaret Maurer (MAA), and Donna Salter (AMS).

Our online submission system and technical support is key to managing the ever-growing number of poster entries we receive. Thanks to MAA staff, especially Margaret Maurer for her work setting up and managing the system this year. Preparation of the abstract book is a time-consuming task. Thanks to Beverly Ruedi for doing the final production work on the abstract book.

Thank yous go to Angel R. Pineda (California State University, Fullerton), James P. Solazzo (Coastal Carolina University), Rebecca Garcia (Sam Houston State University), and Dora Ahmadi (Moorehead State University) for organizing an orientation for the judges and authoring the judging form.

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

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The MAA gratefully acknowledges the support of

Tudor Investment Corporation and Two Sigma.

Their generosity on behalf of the 2017 Undergraduate Student Poster Session enables students to interact with peers and role models in the mathematical sciences during the largest mathematics meeting in the world.

Support for the student travel grant is provided by the National Science Foundation (grant DMS-1341843).

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463. Violeta Vasilevska, *Utah Valley University*
464. Mikael Vejdemo Johansson, *CUNY College of Staten Island*
465. Anil Venkatesh, *Ferris State University*
466. John Villalpando, *California Lutheran University*
467. Andreas Vindas, *San Francisco State University*
468. Daniel Alan Visscher, *University of Michigan*
469. Jan Vlachy, *Georgia Institute of Technology*
470. Karl Alvin Voss, *Bucknell University*
471. Dorothy Wallace, *Dartmouth College*
472. Katherine Walsh, *University of Arizona*
473. Nathan Walters, *Earlham College*
474. D Brian Walton, *James Madison University*
475. Xiaolin Wang, *University of Michigan*
476. Xingting Wang, *Temple University*
477. Erika Ward, *Jacksonville University*
478. Kirsti Wash, *Trinity College*
479. Thomas H. Wears, *Longwood University*
480. Douglas Weathers, *Coastal Carolina University*
481. Bryce Weaver, *James Madison University*
482. John Webb, *James Madison University*
483. Kathryn C. Weld, *Manhattan College*
484. Beverly H West, *Cornell University*
485. Tracy Weyand, *Baylor University*
486. Tad White, *Institute for Defense Analyses*
487. Ian Whitehead, *University of Minnesota*
488. Hays Whitlatch, *University of South Carolina*
489. Sylvia M. Wiegand, *University of Nebraska Lincoln*
490. Elizabeth Wilcox, *SUNY Oswego*
491. Steven V. Wilkinson, *Northern Kentucky University*

492. Cassandra Williams, *James Madison University*
493. Anastasia Bridner Wilson, *Augusta University*
494. Roger Wolbert, *Edinboro University of PA*
495. Chung Wong, *The College of New Jersey*
496. Tony Wing Hong Wong, *Kutztown University*
497. Beverly Wood, *Embry-Riddle Aeronautical University*
498. Mary Wootters, *Stanford University*
499. Matthew L. Wright, *St. Olaf College*
500. Lina Wu, *Borough of Manhattan Community College*
501. Justin Wyss-Gallifent, *University of Maryland*
502. Zhifu Xie, *The University of Southern Mississippi*
503. Ling Xu, *University of Michigan*
504. Carolyn Ann Yackel, *Mercer University*
505. Dina Yagodich, *Frederick Community College (Maryland)*
506. Phil Yates, *Saint Michael's College*
507. Zhijun Yin, *University of Akron, Wayne College*
508. Eun-Kyung You, *Abraham Baldwin Agriculture College*
509. Andrea Nicole Young, *Ripon College*
510. Dania Zantout, *Clemson, SC*
511. Paul Zeitz, *University of San Francisco*
512. Joshua Zelinsky, *Birmingham Southern College*
513. Longhua Zhao, *Case Western Reserve University*
514. Ju Zhou, *Kutztown Unviersity of Pennsylvania*
515. Yuan Zhou, *University of South Florida*
516. Renjun Zhu, *University of California, Berkeley*
517. Andrew Zimmer, *University of Chicago*
518. Scott Michael Zinzer, *West Virginia Wesleyan College*

Titles, Authors, Advisors and Abstracts

1. Lie Algebras of Generalized Quaternion Groups

Samantha Clapp Georgia College and State University
Advisor(s): Brandon Samples, Georgia College and State University

For every finite group there is an associated Lie algebra. The Lie algebra can be viewed as a subspace of the group algebra with certain bracket conditions imposed on the elements. If one calculates the character tables of these finite groups, the structures of the associated Lie Algebra can be described. In this work we consider the family of generalized quaternion groups and describe the associated Lie algebra structure completely.

2. Almost Difference Sets

David Clayton University of Richmond
Advisor(s): James Davis, University of Richmond

We present a new construction of almost difference sets. The construction occurs in nonabelian groups of order $4N$ with a subgroup H of order N so that H has an (N, $\frac{N-1}{2}$, $\frac{N-3}{4}$) difference set (and hence N must be an integer that is 3 (mod 4)).

3. The Discrete Fourier Transform on Non-Abelian Finite Groups and "Group-Like" Algebras

Esha Datta Macalester College
Advisor(s): Tom Halverson, Macalester College

The Discrete Fourier Transform (DFT) converts a finite sequence of n data points into their coefficients in the frequency domain. In a group theoretic framework, this can be viewed as a transformation on the finite group Z_n. This transform has been extended to work for all finite groups, including non-Abelian finite groups. Recent research has extended methods to apply to algebras with "group-like" bases, such as the Temperley-Lieb, rook monoid, and Brauer algebras. We contribute to the literature by examining applications of the DFT on similar structures, as recommended in Wolff (2015), a recent PhD dissertation on the subject. Specifically, we implement Wolff's approach to computing Fourier transforms on the Brauer and partition algebra, and explore various applications in which the DFT yields meaningful insights into data.

4. Computing Multiplication Tables for Crossed Products

Samantha Good Butler University
Advisor(s): Chris Wilson, Butler University

Let K/F be a finite field extension with automorphism group G. Create $A = \{\sum a_\sigma x_\sigma | \sigma \in G\}$ and multiply via $x_\sigma \cdot a = \sigma(a)x_\sigma$ and $x_\sigma x_\tau = f(\sigma, \tau)x_\sigma \tau$ where f is a function $f : G \times G \to K^\times$. We can view the set A as a K-vector space. When f is chosen such that A is associative under multiplication, we say that A is a **crossed product algebra**. We explore properties of crossed products where K and F are the fields of fractions of a formal power series ring, especially in the case when G is cyclic or dihedral and when f takes values in the underlying power series rings. We give results concerning symmetries in the "multiplication tables" for A when G is cyclic or $G = S_3$.

5. Rational Combinations of Betti Diagrams of Complete Intersection Modules

Cole Hawkins Amherst College
Advisor(s): Courtney Gibbons, Hamilton College

We investigate decompositions of Betti diagrams over a polynomial ring within the framework of Boij-Soderberg theory. That is, given a Betti diagram we determine if it is possible to decompose it into the Betti diagrams of complete intersection modules. To do so, we determine the extremal rays of the cone generated by the diagrams of complete intersection modules and provide an exponential-time algorithm for decomposition.

6. Symmetries of the Hypercube

Lindsey Heiberger St. Thomas Aquinas College
Advisor(s): Meghan De Witt, St. Thomas Aquinas College

We look at the construction of n-dimensional hypercubes from $(n-1)$-dimensional hypercubes and look at various ways of visualizing the first five dimensions of hypercubes using 2D and 3D modeling. We explore the relationship between the external dimension of a hypercube and its internal elements when increasing either the external dimension or internal dimension by one. Let $X_{n,m}$ be the number of m-dimensional faces inside of an n-dimensional hypercube. We prove, by induction on $k = n + m$, the following recursive formula: $X_{n,m} = 2X_{n-1,m} + X_{n-1,m-1}$. We explore the symmetric group of the n-dimensional hypercube, and discuss the relationship between the internal makeup of an n-dimensional hypercube and the size of the hypercube's symmetric group. We then describe the alteration in the size of the multiplication table if different dimensions are allowed during the hypercube's rotations. Last, we will examine the relationship between the multiplication table of a square and higher dimensional hypercubes.

7. The Sandpile Group of Thick Cycle Graphs

Micah Henson Spelman College
Jonathan Celaya Rice University
Diane Christine Alar San Francisco State University
Advisor(s): Luis Garcia Puente, Sam Houston University

The notion of a sandpile on a graph arose in Physics as a way to model dynamical systems that possess self-criticality. A sandpile is the assignment of non-negative values (grains of sand) to each vertex. If any vertex has value strictly less than its degree, then that sandpile is called stable; otherwise, the vertex will "topple" and sends a grain of sand to each of its neighbors, which may subsequently topple. We designate a sink vertex that never topples to ensure any toppling sequence terminates. A sandpile is recurrent if it can be accessed by all other stable sandpiles through a series of sand additions and topplings. The sandpile group of a graph is the set of all recurrents, along with stable addition. Under stable addition, two sandpiles on the same graph are added and allowed to topple until stable. We examine the thick cycle graph, a cycle graph with multiple edges. Our techniques invoke Kirchhoff's Matrix Tree Theorem and the Invariant Factors Theorem. We provide a formula for the sandpile group of a general thick cycle graph and some interesting corollaries and results. Our results are notable as we have provided one of the first general forms for the sandpile group of a multigraph.

8. Algebras associated with the Hasse graphs of polytopes

Austin Holmes University of Wisconsin-Eau Claire
Geoffrey Glover University of Wisconsin-Eau Claire
Advisor(s): Colleen Duffy, University of Wisconsin - Eau Claire

The main goal of our project is to determine the structures of the graded algebras that are associated to the Hasse graphs of polytopes. The structures of the algebras associated with the A_n, B_n, D_n, and the $I_2(p)$ groups have been determined. We are now focusing on the exceptional cases, primarily the algebra associated to the 600-cell. The symmetry group of the 600-cell is the finite Coxeter group H_4. For each symmetry, we consider the Hasse subgraph consisting of the fixed k-faces of the polytope under the action of the symmetry. From each Hasse subgraph, we determine the graded dimension of the subalgebra by counting the directed paths between each pair of levels in the graph. We are studying the 600-cell using quaternionic matrices and are writing a computer program to determine the generating functions which will give us the graded dimensions of each subalgebra. This in turn allows us to describe the algebras. In the future, we hope to study the other exceptional cases, such as the algebras associated with the E_6, E_7, and the E_8 groups.

9. Factorization Properties of Int$(\mathbb{Z})$

Greg Knapp Case Western Reserve University
Jad Salem Oberlin College
Gabrielle Scullard University of Rochester
Advisor(s): Paul Baginski, Fairfield University

We examine the ring of integer-valued polynomials, i.e., the set of all $f \in \mathbb{Q}[x]$ such that $f(\mathbb{Z}) \subseteq \mathbb{Z}$. This ring, denoted Int$(\mathbb{Z})$, has elements which factor non-uniquely into irreducible polynomials of Int$(\mathbb{Z})$. We quantify the non-

uniqueness of the factorizations of $f \in \text{Int}(\mathbb{Z})$ using two concepts: the elasticity, $\rho(f)$, and the catenary degree, $\text{cat}(f)$. Given a factorization, z of $f \in \text{Int}(\mathbb{Z})$, if the length of z is defined to be the number of irreducible elements appearing in z, then the elasticity of f is defined to be the ratio between the maximal and minimal elements of the set of lengths of f. The catenary degree gives a more fine-grained measure of how dissimilar the factorizations of f are. Given a polynomial of degree n, we prove general upper bounds on the elasticity and catenary degree in terms of n and prove that they are sharp. In addition, given $n \in \mathbb{N}$, we characterize all attainable catenary degrees and elasticities of polynomials with degree n. While these are general bounds, for any $f \in \mathbb{Z}[x]$ which is a product of linear terms, we establish far smaller bounds on $\text{cat}(f)$. This project was supported by NSF grant DMS-1358454.

10. Associated Primes of the Cover Ideals of Graphs

Sabrina Lato Carthage College
Molly Hoch Wellesley College
Corey Brooke St. Olaf College
Bryan Wang University of California, Berkeley
Advisor(s): Janet Striuli, Fairfield University

The techniques of commutative algebra can be used to better understand graphs, and certain properties of graphs create particularly well-behaving families of ideals. Specifically, assigning a variable to each vertex in a graph associates that graph to a polynomial ring. A graph cover is a particular subset of the vertices of graph, and in this way it can be thought of algebraically as a monomial ideal. These cover ideals and their higher powers give a large family of square-free monomial ideals. The goal of this research is to study the associated primes of that family, and use the techniques of graph theory and commutative algebra to explain some of its behaviors.

11. Crossed Product Algebras over Dihedral Field Extensions

Kaitlyn Lee Butler University
Advisor(s): Chris Wilson, Butler University

Let F be the field of fractions of R, a ring of power series with coefficients in some field. Let K/F be a finite Galois extension, and assume the integral closure S of R in K is also a power series ring.
Consider a crossed product algebra $\Sigma_{\sigma \in G} K x_\sigma$ whose cocycle f takes values in S. We give a new proof extending results of Sam Good concerning which of f's values must be invertible in S when G is dihedral.

12. Toric Mutations in the dP_2 Quiver and Subgraphs of the dP_2 Brane Tiling

Zhaoqi Li Macalester College
Thuy-Duong Vuong Massachusetts Institute of Technology
Advisor(s): Gregg Musiker, University of Minnesota

Brane tilings are infinite, bipartite, periodic, planar graphs that are dual to quivers. In this paper, we examine the del Pezzo 2 (dP_2) quiver and its brane tiling, which arise from the physics literature, in terms of toric mutations on its corresponding cluster. Specifically, we give explicit formulas for all cluster variables generated by toric mutation sequences. Moreover, for each such variable, we associate a subgraph of the dP_2 brane tiling to it such that its weight matches the variable.

13. Frobenius Problem For Polynomials

Li Ma Gettysburg College
Yiran Mao Gettysburg College
Advisor(s): Ricardo Conceição, Gettysburg College

Given relatively prime positive integers $a_1, a_2, \ldots, a_n$, the Frobenius Problem(FP) aims at finding the largest positive integer that cannot be expressed as a non-negative integer combination of $a_1, a_2, \ldots, a_n$. Also, in abstract algebra, there are lot of similarities between integers and polynomial rings over a field. We would like to study the relationship between integers and a polynomial ring over a field. Specifically, We would like to understand a translation of the Frobenius Problem to a polynomial ring over a field, and deal with some basic properties.

14. The Moduli Space of Non-Nilpotent Complex 2–3-dimensional Associative Algebras

Chris Magyar University of Wisconsin-Eau Claire
Lucas Buchanan University of Wisconsin-Eau Claire
Haotian Wu University of Wisconsin-Eau Claire
Ai Lie Ching University of Wisconsin-Eau Claire
Advisor(s): Michael Penkava, University of Wisconsin-Eau Claire

We have been studying moduli spaces of complex associative algebras on various Z_2-graded vector spaces. A moduli space of algebras consists of equivalence classes of isomorphic algebras, and a Z_2-graded space has a decomposition into a direct sum of two subspaces, one called the even elements and the other the odd ones. There are 313 algebras in the space, of which 18 are families depending on a projective parameter. We have also studied how the algebras deform, and have classified them according to their deformation theory.

15. Classifying 7 Dimensional Indecomposible Solvable Lie Algebras With Niradical Isomorphic to $A_{5,2} \oplus \mathbb{R}$.

Anthony Pecoraro Grand Valley State University
Advisor(s): Firas Hindeleh, Grand Valley State University

This poster is the fourth in a series that examine seven-dimensional solvable Lie Algebras with a six-dimensional niradical. Low dimensional solvable Lie Algebra classification started back in 1963 by Mubarakzyanov. and were completely classified up to dimension six. A general theorem asserts that if g is a solvable Lie Algebra of dimension n, then the dimension of its maximum nilpotent ideal (called the nilradical) is at least $\frac{n}{2}$. For the seven-dimensional algebras, the nilradical's dimension could be 4, 5, 6 or 7. The four and seven dimensional nilradical cases were classified. We examine the six-dimensional niradical case. We first looked for the six-dimensional nilpotent algebras and found 32 algebras. In this project we focus on the class where the nilradical is isomorphic to a direct sum of the five-dimensional algebra $A_{5,2}$ and the one dimensional algebra denoted by $A_{5,2} \oplus \mathbb{R}$.

16. Noncommutative Quadratic Forms on Four Generators

Jessica Prince Tennessee Technological University
Advisor(s): Padmini Veerapen, Tennessee Technological University

With the notion of quadratic forms extended to the noncommutative setting in Cassidy and Vancliff's work, "Generalizations of Graded Clifford Algebras and of Complete Intersections", a notion of rank, referred to as μ-rank, was defined for quadratic forms on two and three generators was proposed in Vancliff and Veerapen's paper, "Generalizing the Notion of Rank to Noncommutative Quadratic Forms". Our goal is to further generalize the definition of μ-rank to a noncommutative quadratic form on four generators.

17. Computing Commuting Partitions

Carlos Samuels Medgar Evers College
Advisor(s): Carlos Samuels, Medgar Evers College

A square matrix N is called nilpotent if $N^k = 0$ for some positive integer k. By the Jordan Normal Form Theorem, the conjugacy classes of nilpotent n times n matrices are in one-to-one correspondence with the partitions of n. We say that two partitions P and Q of n commute if there is a nilpotent matrix A of partition P and nilpotent matrix B of partition Q such that $AB = BA$. In this undergraduate research project we are using the open-source mathematics software system Sage to find partitions that commute with a partition $P = (u, u - r)$ where $u > r > 1$. Let A be the generic matrix that commutes with a Jordan block matrix of type P. We have written a program that computes all the partitions that can be obtained by setting some of the variables in A equal to 0, and another program that computes all the partitions that can be obtained by letting the variables in A vary over all the values in a finite field.

18. Injectivity of Homomorphisms between Inverse Semigroups and their Algebras

Jamie Scott University of Florida
Advisor(s): David Milan, The University of Texas at Tyler

In 2015, LaLonde and Milan proved a theorem regarding the injectivity of homomorphisms between C^*-algebras when the domain is the reduced C^*-algebra of a cryptic inverse semigroup. Their theorem suggests that a similar

injectivity result for cryptic inverse semigroups holds. After an introduction to inverse semigroups, we prove this result for homomorphisms between any inverse semigroups. We will then use this result to suggest a method of proof for the problem in the context of inverse semigroup complex algebras. We then present a counter example for the case of non-cryptic inverse semigroups and conjecture the case of cryptic.

19. Invariants of the Free-Fermion Vertex Algebra under the Action of $\mathbb{Z}/2$

Hanbo Shao The Colorado College
Olivia Chandrasekhar The Colorado College
Advisor(s): Michael Penn, The Colorado College

Many authors, most famously H. Weyl in the early 20th century, have studied rings of polynomial invariants. More recently, A. Linshaw and co-authors adapted classical invariant theory to study the invariance of vertex algebras. Drawing on Linshaw's methods, our work describes a linear isomorphism from classically invariant polynomial rings to quantum operator algebras that allows us to apply the first fundamental theorem of invariant theory. Specifically, we study the invariance of the rank n free-fermion vertex algebra under the action of the $\mathbb{Z}/2$ group and obtain its minimal generating set.

20. Computing dynamical degrees of Hurwitz correspondences in high dimensions.

Julio Soldevilla University of California, Berkeley
Advisor(s): David Speyer, University of Michigan, Ann Arbor

A Hurwitz correspondence is a multi-valued self-map of the moduli space of genus zero curves with n marked points, $M_{0,n}$. Considering two n-marked curves $(C, a_1, \ldots, a_n)$ and $(D, b_1, \ldots, b_n)$, given a map ρ from $\{1, \ldots, n\}$ to itself and some ramification data, one obtains a Hurwitz correspondence on $M_{0,n}$ which sends a marked curve $(D, b_1, \ldots, b_n)$ to any of the marked curves $(C, a_1, \ldots, a_n)$ for which we have a rational map $\phi : C \to D$ with $a_i \to b_{\rho(i)}$ that satisfies the required ramification data. The dynamical degree of a Hurwitz correspondence h is the maximal eigenvalue of the induced map $(h)_*$ on homology. We study the case of the induced map on the divisor class group with a particular focus on ramification types, as studied by Koch and Roeder. This experimental study considers the eigenvalues for several Hurwitz correspondences for maps ϕ of low degree. The dynamical degree of the Hurwitz correspondences, in general, is difficult to compute, but in this work we are able to compute the first dynamical degree in very high dimensions. Our main experimental findings are that $\forall \lambda_i$, where λ_i is not a dynamical degree but is an eigenvalue of the induced map on homology $(h)_*$, then $1 \leq |\lambda_i| \leq k$, where k is the global degree of the rational map ϕ. Our results also suggest that when $k < \lambda_{max}$, where λ_{max} is the dynamical degree for a given induced map $(h)_*$ and k is the global degree of the rational map ϕ, then the multiplicity of λ_{max} is 1. The data obtained from this study suggests a generalization of the theorem of Diller and Favre that dynamical degrees of birational transformations of surfaces are Salem numbers.

21. Using Young Tableaux to Study Springer Fibers

Sam Turley Butler University
Advisor(s): Amber Russell, Butler University

The Springer resolution is a resolution of singularities for the nilpotent cone of a reductive Lie algebra. The fibers of this map, called Springer fibers, are interesting objects of study in representation theory. In this project, we use Young tableaux to study intersections and closures of irreducible components of Springer fibers in special cases. In the case where the Young tableaux are hook shape, we focus on work of Lucas Fresse, where he considers whether specific flags are in the closures of the irreducible components. We study these flags using a combinatorial technique developed by Fresse and prove statements connecting Fresse's work to other known results in the field.

22. The Node Firing Game and its Applications to the Grassmannian

Anthony Utehs Lewis & Clark College
Andres Guerrero-Guzman Lewis & Clark College
Advisor(s): Sweta Suryanarayan, Lewis & Clark College

The Grassmannian $Gr(k, n)$ is the set of all k-dimensional subspaces of an n-dimensional complex vector space. It is an important object of study in the field of algebraic geometry. In recent research a general pattern of the Bruhat order

of the Schubert cells of the Grassmannian in the two cases $Gr(1, n+1)$ and $Gr(2, n+1)$ was found using the node firing game applied to Dynkin Diagram of type A_n in two types of fundamental position; node 1 labelled with value 1 and node 2 labelled with value 1. The purpose of this research is to determine a pattern of the complete game chart of the node firing game when applied to Dynkin Diagrams of type A_n in any fundamental position and we use this pattern to study the Bruhat order of the Schubert cells of the corresponding Grassmannian. In our research over the summer we found a general pattern for the game chart of A_n with node 3 labelled with value 1. The pattern involves the previous two known cases. From this result we know the general structure of the Bruhat order of the Schubert cells of $Gr(3, n+1)$.

23. Inverse Semigroups: The P-Theorem

Vincent Villalobos University of Texas at Tyler
Caroline Bang St. Cloud State University
Advisor(s): David Milan, University of Texas at Tyler

In this presentation, we will define and explore the P-Theorem, which states that every E-unitary inverse semigroup is isomorphic to a P inverse semigroup. We use the P-Theorem to study characteristics of E-unitary inverse semigroups. In particular, we give conditions for when an E-unitary inverse semigroup is fundamental and/or combinatorial.

24. Algebraic Geometry and Colorings of Graph Products

John Wallace Trinity College
Advisor(s): Kirsti Wash, Trinity College

Over the past decade, it has become increasingly more popular to reformulate combinatorial problems, such as graph colorings, in the context of algebraic geometry. One particularly difficult graph coloring problem is Hedetniemi's conjecture which states that $\chi(G \times H) \geq \min\{\chi(G), \chi(H)\}$ where $G \times H$ represents the tensor product of graphs G and H. We investigate Hedetniemi's conjecture from an algebraic geometry view point, and we compute Gröbner bases for the associated polynomial ideals generated by specific graphs.

25. Trivial projections of primitive elements of a free group

Cory Weinfeld The College of New Jersey
Advisor(s): Andrew Clifford, The College of New Jersey

In a free group, a primitive element is an element which can be extended to a basis .We define $\pi_a : F[a,b,c] \to F[b,c]$ by $\pi_a(a) = 1$, $\pi_a(b) = b$, $\pi_a(c) = c$. If w is primitive and $\varphi(w) = 1$ then for all $v_1, v_2 \in F[a,b,c]$, if $\{w, v_2, v_3\}$ is a basis of $F[a,b,c]$ then $\{\pi_a(v_1), \pi_a(v_2)\}$ is a basis of $F[b,c]$. Moreover, these are the only w that has this property. That is to say, if w is primitive and $\varphi(w) \neq 1$, then there are $v_1, v_2 \in F[a,b,c]$ so that $\{w, v_1, v_2\}$ is a basis for $F[a,b,c]$ but $\{\pi_a(v_1), \pi_a(v_2)\}$ is not a basis of $F[b,c]$. This begs the question: which primitive elements of $F[a,b,c]$ satisfy $\pi_a(w) = 1$? There do not seem to be that many. Clearly this is true if w is conjugate to a or a^{-1}. I conjecture that if w is primitive and $\varphi(w) = 1$, then w is either conjugate to a or a^{-1}. We have been able to verify the conjecture for specific forms of w.

26. Curve Your Enthusiasm: Constructing Hyperelliptic Curves with a Given Number of Points Over Finite Fields

Erik Wendt Gettysburg College
Advisor(s): Darren Glass, Gettysburg College

An important question in algebraic coding theory is as follows: given a finite field and a positive integer g, can we construct a curve of genus g with a maximum number of points on it defined over this field. While this question has important applications, the general question of constructing curves with a specific number of points has been relatively untouched. This poster focuses on methods for constructing hyperelliptic curves of a fixed genus with specific number of points defined over the prime field $\mathbb{Z}/p\mathbb{Z}$.

27. Heuristics of 2-Torsion in Monogenic and Maximal Cubic Fields

Mikaeel Yunus MIT
Hari Pingali
Stephen New Boston University - PROMYS
Advisor(s): Ila Varma, Harvard / Columbia

Class groups for fields over the rationals have been studied for a long time, but not much progress has been made in sufficiently describing the class groups of different number fields. Bhargava has recently shown that for cubic fields, there is a subtle relationship between the monogenicity of these fields and their class groups. In this paper, we aim to computationally verify the results of Bhargava-Hanke-Shankar and Ho-Shankar-Varma on the asymptotic averages of the 2-torsion sizes of the class groups of these cubic fields. Throughout this paper, we study the properties of discriminants, monogenicity, and maximality of cubic fields and binary cubic forms, as such properties result in averages that deviate from the expected values predicted by well-known conjectures of Cohen-Martinet. Our main result is significant progress on computing the average 2-torsion size of the set of class groups of irreducible binary cubic forms f with height less than Y which are monogenic and maximal at all primes p. We aim to find the limit of this average as Y approaches infinity.

28. Trace Ideals of Modules

Nina Pande Williams College
Advisor(s): Haydee Lindo, Williams College

The trace ideal of a module M over a ring R is the ideal generated by the image of M under every R-homomorphism from M to R. Trace ideals satisfy many useful properties; for example, taking the trace ideal of a module commutes with localization and completion. There are numerous basic questions about trace ideals that have yet to be answered: When is an ideal of R equal to its trace ideal? When is the trace ideal the entire ring R? What does the trace ideal of an ideal of zerodivisors look like? We present new results about trace ideals related to these questions.

29. A Stability Theorem for Feynman's Operational Calculus: A Direct Approach

Scott Brewer Creighton University
Advisor(s): Lance Nielsen, Creighton University

Given the monomial $P^{m_1,m_2}(z_1,z_2) = z_1^{m_1} z_2^{m_2}$, Feynman's operational calculus is used to compute the disentangled operator $P^{m_1,m_2}_{\lambda_1,\lambda_2}(A,B)$ using time-ordering "directions" given by the Borel probability measures λ_1 and λ_2 on $[0,1]$, where $A, B \in \mathcal{L}(X)$ are noncommuting linear operators on the Banach space X. Select sequences $\{\eta_{1,k}\}_{k=1}^{\infty}$ and $\{\eta_{2,k}\}_{k=1}^{\infty}$ of purely discrete finitely supported probability measures on $[0,1]$ which converge weakly to λ_1 and λ_2, respectively. We wish to prove that $P^{m_1,m_2}_{\eta_{1,k},\eta_{2,k}}(A,B) \to P^{m_1,m_2}_{\lambda_1,\lambda_2}(A,B)$ in norm on $\mathcal{L}(X)$. Given a complex-valued function $f(z_1,z_2)$ which is analytic on the open polydisk with radii $\|A\|$ and $\|B\|$ and continuous on its boundary, we can then show, using the Taylor series for f, that $f_{\eta_{1,k},\eta_{2,k}}(A,B) \to f_{\lambda_1,\lambda_2}(A,B)$ in norm on $\mathcal{L}(X)$. Progress has been made with regard to the assertion concerning monomials using $\lambda_1 = \lambda_2 = \ell$, where ℓ is Lebesgue measure on $[0,1]$. This talk will discuss this progress and point out the direction of the future research. So far, we have finished two cases and are working towards finishing the third case. By proving these assertions in a direct fashion, it is expected that new features of the operational calculus will be exhibited and that such features will be able to be exploited to further investigate the operational calculus.

30. Finite-Dimensional Quantum Metric Spaces

Samantha Brooker University of Denver
Advisor(s): Frederic Latremoliere, University of Denver

According to K. Aguilar and F. Latrémolière, approximately finite-dimensional C*-algebras (AF algebras) can be endowed with a quantum metric, which then allows one to prove that AF algebras are limits of finite-dimensional quantum metric spaces for a noncommutative version of the Gromov-Hausdorff distance, named the quantum Gromov-Hausdorff propinquity. Our research concerns the geometry, for the quantum Gromov-Hausdorff propinquity, of the class of these finite-dimensional quantum metric spaces. We have established thus far that several of these spaces are not isometric, in the sense of quantum metrics. The examples that we have studied are described via full matrix algebras endowed with various quantum metrics, and we prove that no automorphism of the full matrix algebra can carry one

quantum metric to another. We hope that our work is a first step in establishing lower bounds on the propinquity between these finite-dimensional quantum metric spaces, which in general are difficult to establish.

31. Using Hermite Functions to Prove Cowling-Price Inequality

Recep Celebi Lafayette College
Advisor(s): Hadi Salmasian, University of Ottawa

G. B. Folland summarizes the uncertainty principle as follows: a function and its Fourier transform cannot both be sharply localized. There are various precise mathematical formulations of this fact; probably the most well-known is of Heisenberg-Pauli-Weyl from 1927. In 1983, Cowling and Price generalize the classic Heisenberg Uncertainty Principle. We use the method of Philippe Jaming, who proved the Heisenberg's classical result using Hermite functions and their spectral theory, to prove the generalized result of Cowling and Price.

32. Analyzing Electricity Consumption Demands for Extreme Temperatures

Jacqueline Gallant Arizona State University
Advisor(s): Eric Kostelich, School of Mathematical and Statistical Sciences

Every year the Phoenix metropolitan area experiences extreme heat during the summer. Being home to over 4.3 million people, these extreme heat events cause a much higher electricity demand, especially during the day, largely due to air conditioning. Electricity companies have to be prepared and able to readily supply this high demand. The task of this project was to analyze 5 years worth of data from a local electricity company. After analyzing our data set, we discovered a number of interesting trends: the daily cyclic behavior of electricity consumption use, the average electricity demand needed when air conditioning and heating are not a factor, and for extreme temperatures above 100 degrees Fahrenheit, a change in the rate at which electricity consumption increases.

33. A New Way of Thinking About Functions: Transfunctions

Zachary Gelinas University of Central Florida
Advisor(s): Piotr Mikusinski, University of Central Florida

Take Φ to be a map between two measurable spaces (X, Σ_X) and (Y, Σ_Y) which sends measures acting on Σ_X to measures acting on Σ_Y. We treat Φ as a general function between X and Y and investigate algebraic and topological properties. The motivation of a transfunction arises from the fact that in the real world, the input is rarely a well defined point of the domain space and the same can often be said about the target space. In order to combat this issue, we think of the input as a "set of points with probabilities" and the output as a "set of outputs with probabilities." More precisely, we are mapping measures in the domain space to measures in the target space. For mathematical convenience, we are not restricting the measures in the domain and range to probabilities measures, but instead we consider arbitrary finite measures. We call these objects *transfunctions*.

34. Constructing Cantor Polynomials

Justina Kaiser Butler University
Advisor(s): William Johnston, Butler University

A well-known function called the Cantor ternary function arises out of the Cantor set. The Cantor function produces a corresponding collection of functions called $L^2(\mu)$. Here, μ is often called the Cantor measure. It is a very sophisticated (real-valued) measure to study because it is a so-called "singular continuous probability measure." The corresponding vector space of functions is infinite-dimensional. This poster shows a new result: what happens when the monomials x^n are run through the (infinite) Gram-Schmidt process to form "Cantor polynomials," an infinite orthonormal set in $L^2(\mu)$. Explicit representations are obtained.

35. Vanishing Dissipation Limits for a generalized Magnetohydrodynamic Equation

Danielle Pham Creighton University
Advisor(s): Nathan Pennington, Creighton University

The Magnetohydrodynamic (MHD) system of equations governs kinematic fluids that are subjected to a magnetic field. The equation is a combination of the Navier-Stokes equation (which governs fluid flow) and Maxwell's equations (which govern magnetic fields). Due to the difficulty in solving the MHD system, it has become common to

study approximating versions of the equation, including the MHD-(α) system, which regularizes the velocity field in exchange for the addition of non-linear terms. Both the kinematic and magnetic parts of the MHD-(α) system have diffusive terms which dissipate the initial energy of the system. Setting those terms equal to zero returns the Ideal MHD-(α) system. The goal of this project is to show that solutions to the MHD-(α) system with diffusion will converge to the Ideal MHD-(α) system as the diffusion parameters are sent to zero by adapting known results for the analogous problem of determining when solutions to the Navier-Stokes equation will converge to a solution of the Euler Equation.

36. Topological Properties of Classical Multiplier Sequences, n-sequences, and Extensions

Kenneth Plante University of Rochester
Christian Hokaj University of Notre Dame
Advisor(s): Tamas Forgacs, California State University, Fresno

We consider topological properties of the space of classical n-sequences and the space of classical multiplier sequences, and show that both spaces are complete and contractible. We classify the boundary points of these sets (as subsets of all real sequences) in terms of the zeros of an associated polynomial, and give both necessary, and sufficient conditions for the extendability of an n-sequence.

37. Non L_2 Low Regularity Solutions to the gMHD Equation

Anh Vo Creighton University
Advisor(s): Nathan Pennington, Creighton university

The generalized Magnetohydrodynamic (gMHD) system of equations is derived from the Magnetohydrodrynamic system by replacing the Laplacian in the dissipative terms with more general Fourier multipliers. In this paper we prove the existence of a unique solution to the gMHD equation with initial velocity vector $u_0 \in H^{r_1,p_1}(\mathbb{R}^n)$ and initial magnetic field $b_0 \in H^{r_2,p_2}(\mathbb{R}^n)$ with $p, q > 2$.

38. Multi-material Decomposition for Dual-energy Computed Tomography

Amanda Alexander Western Washington University
Zach Viray University of the Incarnate Word
Derek Thurmer University of Washington Bothell
Advisor(s): Thomas Humphries, University of Washington Bothell

Dual-energy computed tomography (DECT) is a promising imaging technique in which data generated from two X-ray spectra are acquired at multiple angles around a patient. From these two data sets, DECT is able to provide a decomposition of the patient body into two materials, such as soft tissue and bone. Recent work has shown that using the assumption of volume conservation, decomposition of a third material is possible as a post-reconstruction technique applied to images generated from the two data sets. One limitation of a post-reconstruction method is that images must be corrected for effects which degrade image quality such as beam hardening. An alternative is to use a pre-reconstruction approach which obtains a material decomposition directly from the X-ray data. Using numerical experiments, we show that the pre-reconstruction approach is preferable in quantitative decompositions for cases where mixtures of materials are present. We also show that it is possible to recover decompositions of more than three materials in some cases.

39. Change-point Detection Methods for Body-Worn Video

Stephanie Allen State University of New York at Geneseo
David Madras University of Toronto
Ye Ye UCLA
Greg Zanotti DePaul University
Advisor(s): Giang Tran, University of Texas at Austin

Body-worn video (BWV) cameras are increasingly utilized by police departments to provide a record of police-public interactions. However, large-scale BWV deployment produces terabytes of data per week, necessitating the development of effective computational methods to identify salient changes in video. In work carried out at the 2016 RIPS

program at IPAM, UCLA, we present a novel two-stage framework for video change-point detection. First, we employ state-of-the-art machine learning methods including convolutional neural networks and support vector machines for scene classification. We then develop and compare change-point detection algorithms utilizing hidden Markov models, forecasting methods, and maximum likelihood estimation to identify noteworthy changes. We test our framework on detection of vehicle exits and entrances in a BWV dataset provided by the Los Angeles Police Department and achieve over 90% recall and nearly 70% precision — demonstrating robustness to rapid scene changes, extreme luminance differences, and frequent camera occlusions.

40. An Ensemble Learning Approach to Image Forgery Detection

Terrence Alsup Georgia Institute of Technology
Catherine Sullivan Siena College
Advisor(s): Haixia Liu, Hong Kong University of Science and Technology

Digital information permeates most aspects of the modern world. Such information can play vital roles in decision making and an accurate decision rests upon the veracity of the available data. In particular, images provide an excellent source of information and context given the assumption that the image has not been altered. It has been proposed that the discrete cosine transformation (DCT) coefficients, commonly used in image compression, as well as their first digits follow common distributions. Our results were found to support this proposition. We proceeded to calculate a likelihood map for each 8x8 pixel block of being singly versus doubly compressed in order to analyze the doubly compressed regions. Using stacking as an ensemble learning procedure, both solutions were combined to create a model with an even higher accuracy of 84% for detecting altered images.

41. Snaking in the Swift-Hohenberg Equation in Dimensions 1 vs $1+\varepsilon$

Chloe Avery University of California Santa Barbara-College of Creative Studies
Advisor(s): Bjorn Sandstede, Brown University

Numerical studies have shown that the bifurcation diagram for the two-dimensional Swift-Hohenberg equation is interesting, complicated, and markedly different from that of the one-dimensional equation. We attempt to better understand the two-dimensional case through a dimensional perturbation to the one-dimensional equation; to do so, we consider radially symmetric solutions to the planar equation, effectively embedding the one-dimensional case into two dimensions. Then, we vary the dimension in a formal sense, letting the dimension be $n = 1 + \varepsilon$ as ε tends to 0. Analytically, we are able to show that both snaking and the stationary, localized solutions that caused snaking in the one-dimensional case persist for small ε, allowing us to explain the existence and boundedness of the "lower snaking branch."

42. Locally Linear Embedding of Chromatic Clusterings in Temporal and Spatial Domains

Linda Beverly California State University East Bay
Advisor(s): Shirley Yap, California State University East Bay

The capability to identify chromatic groupings within video is an important application of video processing. In this poster we present an application of Locally Linear Embedding, a method of geometric dimensionality reduction, applied to identifying similar color regions over time within video. This technique preserves the underlying geometric information. Identifying similar regions of color may be used to preprocess information that may be used to prepare the information for video compression and psychovisual optimization.

43. Introducing Fractional Dynamics to Quantum Random Walks

Lucas Bouck George Mason University
Advisor(s): Harbir Antil, George Mason University

Quantum random walks (QRWs) are important tools for the development of algorithms in the growing field of quantum computing. The standard partial differential equation based models of QRWs fail to capture the hereditary/memory effects of QRW dynamics. This research enriches the available PDE models by including the fractional time derivative. The resulting model is the Fractional Fokker-Planck PDE. Fourier transforms are used to compute a numerical solution to this PDE. This poster discusses similarities and differences between this model and other models in the literature.

44. Using Weighted Graphs to Determine the Feasibility of MLB Expansion

Matthew Breen University of Arkansas
Advisor(s): Lance Miller, University of Arkansas

Major League Baseball has expanded several times in its history, the last being in 1998. As it stands now, each league has 15 teams organized into three divisions of five teams each. MLB imposes scheduling restraints regarding travel, home and away games, the length of the season, length of individual series and special team requests. Using each individual constraint, we formulate a series of weighted graphs in order to derive equations for the constraints and determine the maximum number of teams that can be added under the current system. Using historical data, we create a probability distribution of the sequence of home and away games and then use a monte carlo style simulation to generate optimal schedules of the expanded league.

45. Missing weather data imputation for forensic studies

Ashley Bustelo Inter American University of PR - Bayamon Campus
Advisor(s): Carmen Caiseda, Inter American University of PR- Bayamon Campus

Forensic science require weather data to identify changes in microorganisms that will aid in solving cases. Very frequently the available data is incomplete requiring missing-data imputation techniques in order to conduct statistical analysis. This provides an excellent opportunity to develop interdisciplinary research project that includes mathematics, biology and forensic science. In this work we will use missing-data imputation strategies to complete data on six variables: temperature, wind-speed, humidity, precipitation, dew-point and relative humidity. We use cleaned and enhanced data from a local weather station and an in-situ station collected as part of a post-mortem interval forensic research during 2014 and 2015. The complete data is being used by the forensics research team.

46. Urban Heat Island Extreme Temperature and Electricity Consumption

Brentlee Cass Arizona State University
Megan Sopa Arizona State University
Advisor(s): Alex Mahalov, Arizona State University

The Phoenix, Arizona metropolitan area experiences extreme heat during the summer. With a population of over 4.3 million people, these extreme heat events (defined as 110°F) cause much higher peak electricity demand, especially during the late afternoon, largely due to air conditioning. We describe a deeper analysis of a large data set of peak demand as a function of high temperature from a local electricity company. Our poster describes qualitative changes in the functional relationships between the extreme and non-extreme temperatures. In particular, we characterize qualitative changes in demand at high temperature greater than 98 degrees Fahrenheit.

47. New Algorithms for Decoding Insertions in Helberg Error-Correcting Codes

Dane Charlton Rowan University
Advisor(s): Hieu Nguyen, Rowan University

We present two new linear search algorithms for decoding Helberg codes, a class of binary number-theoretic error-correcting codes capable of correcting multiple insertion/deletion errors. The first algorithm recursively corrects multiple insertion errors, while the second corrects a single indel, i.e., an error consisting of one insertion and one deletion, on a word in the codebook. These are the first known algorithms for decoding insertions in Helberg codes.

48. Determining the Sustainability of Food Policies as Global Population Increases

John Cima Virgina Military Insitute
Advisor(s): Jessica Libertini, Virginia Military insitute

The last half of the 20th century saw the most rapid increase of the human population in recorded history. In 2011 United States Census Bureau report the world's population had exceeded seven billion and the population is continuing to grow with the United Nations projecting the world's population will be 9.7 billion in 2050. This implies there are more people on Earth demanding more resources than ever before. Most estimate on the Earth's the carrying capacity is 8 and 10 billion people. In a typical logistic model, the population initially increases, exponentially then reaches a point where the growth rate starts decreasing causing the population to level off around the carrying capacity. In contrast the human population is still increasing at an exponential rate as the population approaches the estimated carrying

capacity. In this mathematical study we try to model the effects of limited food production, available space, and trade policies on population dynamics of the human population as the Earth reaches and surpasses its estimated carrying capacity and how multiple regions are affected by these policies as an interconnected system. In this project we looked at levels of food production within defined regions and develop a system of differential equation to represent the interaction between food production and population to illustrate the population dynamics in a region held in isolation and when trade to other regions is introduced.

49. Stability of Agent-based Models

Cassandra Cole Brown University
Philip Doldo Rensselaer Polytechnic Institute
Qing Fan Pomona College
Advisor(s): Bjorn Sandstede, Brown University

Situations in which interactions of individual agents form macro-level patterns are ubiquitous, and agent-based modeling provides a natural approach to understanding them. This poster is motivated by an agent-based model of pigment cells forming stripes on zebrafish, a tropical fish studied for medical research. We analyze the stability of agent-based models similar to the zebrafish model, in which deterministic and stochastic processes occur on the same timescale. However, it is difficult to analyze agent-based models with randomness. We therefore examine these dynamics in the framework of piecewise-deterministic Markov processes (PDMPs), which consist of continuous-time deterministic flow (described by ordinary differential equations) punctuated by random jumps in position. We use results from previous literature to specify sufficient conditions for the stability of general agent-based models with setups similar to the zebrafish system, and provide examples to illustrate the use of these conditions. We also simulate a one-dimensional toy model of zebrafish cells to numerically explore the effects of deterministic and stochastic processes on the long-term stability of the model.

50. Which cues do listeners use? Discovering networks of phonetic cues for speech sound categorization using Steiner trees

Anne Crinnion Harvard University
Advisor(s): Beth Malmskog, Villanova University

Identifying phonetic cues is central to developing viable models of speech perception. However, current models require assumptions about what those cues are. We present a novel graph theoretic solution to this problem. Specifically, we apply Steiner tree algorithms, recently used to study gene-protein networks, with the goal of extracting relevant acoustic cues for speech sound categorization. Our methods were inspired by Jennifer Chayes plenary lecture at the 2016 JMM. The model uses acoustic measurements ($N = 23$ cues) and fricative classification data ($N = 20$ listeners) from McMurray and Jongman (2010, Psychol Rev). Cues were divided into ten bins spanning the range of acoustic values across the eight fricatives creating 230 cue-bins (codes). Next, bipartite graphs were created for each fricative with nodes for the 20 listeners and the 230 codes, with edges weighted by the inverse likelihood of a listener indicating that fricative given the code. Algorithms implemented in SageMath were used to find Steiner trees, subgraphs that minimize edge weights while connecting all listeners. Identified codes were then eliminated, and the process repeated until no subgraph connected all listeners. In total, 109 cue-values connected all listeners, suggesting that many cues are useful for recognizing sounds. Moreover, most cues identify one or two fricatives, indicating that they are highly informative. These data offer a new approach for identifying phonetic cues and may lead to new models of speech recognition.

51. Standard and Non-Standard Lagrangians

Niyousha Davachi University of Texas at Arlington
Advisor(s): Zdzislaw Musielak, University of Texas at Arlington

A concept of non-standard Lagrangians is introduced and general conditions for the existence of such Lagrangians are presented. The conditions are used to determine classes of ordinary differential equations (ODE's) that can be derived from non-standard Lagrangians. The obtained results are used to obtain non-standard Lagrangians for several ODE's of special interest in applied mathematics.

52. Comparison of Computational Fluid Dynamics Software Packages in Modeling Pollutant Dispersion

Evan Dienstman The College of William & Mary
Advisor(s): Dimi Mavalski, UCLA

When designing a building, city planners and engineers must take into account a building's effect on air pollution in order to minimize the negative health and environmental impacts. The first step in accomplishing this task is to understand how wind and pollutants move around buildings. In the past, scientists have conducted expensive wind tunnel experiments to gather this information. However, as computers have become increasingly more powerful, the scientific community has shifted toward using relatively inexpensive computational fluid dynamics (CFD) software to replace the wind tunnels. CFD software employs numerical methods to solve the partial differential equations that describe the motion of wind and pollutants. Currently, the leading commercial CFD software is Fluent, but one open-source software called OpenFOAM has recently started gaining traction. Under the direction of AECOM, an engineering consulting firm, our goal is to test the performance of OpenFOAM against Fluent to justify the use of OpenFOAM in research and consulting. We will use a wind tunnel experiment taken from Tokyo Polytechnic University (TPU) to serve as a control case in evaluating performance. The wind tunnel experiment consists of a single block with wind entering perpendicular to the front face and pollutant being released from the rear. With additional software packages, we can create the same geometric setup on the computer, then solve the equations of motion for wind velocity and pollutant concentration in each software package. Our computer simulations demonstrate that Fluent provides closer results to the wind tunnel data than OpenFOAM does. However, further work still needs to be done in studying OpenFOAM's capabilities and performance in different cases.

53. Space Filling Curves

Shaquille Dixon Coastal Carolina University
Advisor(s): Andrew Incognito, Coastal Carolina University

This poster introduces the concept of a space filling curve, including the examples of Peano and Hilbert. We prove that there exists a recursively defined function from the unit interval onto the unit square. Furthermore, this function is not one-to-one. We also prove that the function is continuous on the unit interval but nowhere differentiable by considering the limit of a sequence of functions. Lastly, we will present applications of space filling curves to computer science.

54. Modeling and Predicting the Consequences of Climate Change: Seasonal Changes in Early 20th Century Nova Scotia and the Work of Alexander MacKay

Laura Farro Northern Kentucky University
Madison Culbertson Northern Kentucky University
Advisor(s): Andrew Long, Northern Kenucky University

Phenology is the study of seasonal timings of natural phenomena and a strong indicator of climate change. Plant flowering, animal migration, and even potato harvesting can be harbingers of a changing climate. Alexander MacKay, superintendent of Nova Scotia schools in the early 1900s, had his students gather phenological data like these in one of the earliest citizen-science projects. For 25 years MacKay compiled the data into summary reports, published in Nova Scotia's leading scientific journal. We extracted this summary data and created an electronic database that reconciled missing values and inconsistencies in the data (using techniques such as nonlinear regression based on the Singular Value Decomposition (SVD)). GIS is used to display, analyze, and animate the data, as well as to incorporate climate data unavailable to MacKay. Using geographic coordinates of nine sub-regions of Nova Scotia, regressions allow us to find correlations between flowering times, location, and climate change surrogates such as temperature, precipitation, ice and snow. Mathematical models are created based on SVD and tensor SVD decompositions of the data to predict "first appearance time" of plants in Nova Scotia. We test our models against modern data collected in emulation of MacKay's project.

55. On Tornadoes and Attractors

William Frost University of Saint Thomas
Advisor(s): Douglas Dokken, University of Saint Thomas

Tornadoes ravage the central United States and many other parts of the world yearly. Due to their chaotic origins, they are impossible to predict far in advance, and difficult to predict even in the short term. While this problem can

be remedied by exponentially increasing the computational power dedicated to existing simulations, such attempts quickly become impractical. This research seeks to understand the nature of tornadogenesis by employing and developing an attractor model based on the works of Sasaki, Smale, Williams, as well as established mathematics and meteorology.

56. Cluster With Caution

Craig George University of Houston

Advisor(s): Bernhard Bodmann, University of Houston

This work examines the performance of k-means clustering and Peng and Wei's convex relaxation of the Lloyd algorithm. We consider $k = 2$, a special case of two groups of random vectors. These two groups of vectors are taking values in two spheres of unit radius that touch at the origin. With a prior of equal probability for either of the two groups, the problem of optimizing the expected least-squares objective function for Lloyd's clustering algorithm can then be replaced by selecting a cutoff for an appropriate linear functional that measures the distance from the subspace touching the spheres. We computed the dependence of the objective function on the cutoff explicitly in dimensions 2, 3, 5, 7 and 9 and verified numerically that the global minimum is achieved for a non-zero cutoff in dimension 2 and at zero in dimensions 3, 5, 7 and 9. This behavior is also observed in implementations of Peng and Wei's version of the clustering algorithm.

57. Finding Theta Oscillations Using Independent Component Analysis

Kiefer Green Beloit College

Advisor(s): Erin Munro, Beloit College

Prior research using independent component analysis observed theta type oscillations in slow-wave sleep of rats whereas before theta had only been observed in REM sleep and while awake, so this could simply be a false positive. In order to confirm that the observed presence of theta oscillations using independent component analysis means that theta is actually present, we need to know the probability of a false positive. We present an explorative mathematical model for recordings of the brain in order to determine the probability of observing a theta type signal using independent component analysis. We find the probability of observing theta that is not significant at the 97.5% level.

58. An Analysis of the Accuracy of Reported Clery Statistics: and a Comparison with Westminster College

Marin Hauptman Westminster College

Advisor(s): Carolyn Connell, Westminster College

In 1986, Jeanne Clery was attending Lehigh University in Pennsylvania, when another student entered her dorm room, raped, and murdered her. Jeanne's parents lobbied for approval of the Jeanne Clery Act, which went into effect in 1991, requiring full disclosure of an annual report detailing criminal activity on and around campus, as well as notifying students of serious crimes on campus in a timely manner. While studies have been done to attempt to measure the influence of the act, the purpose of this study was to use the reported Clery statistics to see the data contained outliers, which may indicate inconsistencies in reporting. While colleges are held accountable for any discovered errors in reporting, the handbook for reporting provided by the U.S. Department of Education is comprised of 197 pages of guidelines that have the potential to be misinterpreted. For this study, two groups of institutions will be analyzed. First, four-year institutions in Utah. Then four-year, private, institutions with student attendance between 2500 and 3500 in the West, and Southwest regions of the United States. These criteria were chosen in order to examine institutions similar to Westminster College in Salt Lake City, Utah. Data was downloaded from the U.S. Department of Education, and collected for the years 2010-2014. Reported Clery crime categories include Criminal Offenses, Hate Crimes, and Arrests, among others. A Two-Proportion Z test was used to determine if differences in reported proportions was statistically significant, and it was found that in public Utah institutions, reported proportions for many categories were smaller than expected.

59. Identifying the Static Kick Point in a Golf Shaft

Kay Levin Hoffmann Florida Southern College
Jordan Rassmann Florida Southern college
Advisor(s): Lisa DeCastro, Florida southern college

The static kick point is the maximum bending point of a golf shaft and can visually be seen as the point furthest away from a line connected to both ends of a loaded shaft. Different kick points in shafts generate different ball flight trajectories and thus are an important factor when it comes to golf club fittings. We focused on finding a model for the static kick point (bending moment at position x) due to an applied vertical load $M = -20.0x$ on two types of golf shafts: a steel shaft for irons and a tapered graphite shaft for a driver.

60. Modeling Voting Dynamics in a Two-Party System: Person To Person Interactions and Media Effect

Caleb Ignace East Tennessee State University
Advisor(s): Christopher Kribs, University of Texas at Arlington

The current 2016 US presidential primary election, characterized by many unexpected results, provides an interesting context to study how voters are influenced in deciding who to support. We address this question by developing a class of models driven either by the effect of mass media or by social interaction among voters and members of the parties. The dynamics are modeled using four compartments with a transition matrix in describing the evolution of a discrete-time Markov chain. Each model is studied and fit to poll data from the 2012 and 2016 presidential elections using numerical methods. A comparison across elections indicates that the social influence of each group changes from one election to another, but response to media is similar in both cases.

61. Police Patrol Zone Realignment in Huntington, WV

David Jones Marshall University
Sara Brumbaugh Marshall University
Advisor(s): Michael Schroeder, Marshall University

The Huntington Police Department patrol zones have, due to changes in crime distribution and the makeup of the city, become ineffective over the last 14 years. In this poster presentation, we explore various methods for analyzing the effectiveness of patrol zones and computing new zoning plans. We analyzed a decade of crime data. To create better plans, we began by creating naïve maps, which were then optimized using a method of gradient descent. The naïve maps were tested, and optimized maps were found by way of an evaluative fitness function. A discrete event simulation, which mimics the overall patrol patterns of an officer, produces a workload distribution and response time scores useful for comparison of zone plans. This project was part of the PIC Math program, which is sponsored by the MAA, NSF, and SIAM.

62. Modeling the Spread of Mononucleosis in a College Setting

Lydia Karel Lee University
Anne Kelton Lee University
Advisor(s): Debra Mimbs, Lee University

This model was created to study the spread of mononucleosis in a college population. Mononucleosis is an infection caused by the Epstein-Barr virus (EBV). Literature states that 90–95% of people have been infected with EBV by the time that they are 30 years old. Most documented cases of mononucleosis occur in high school and college students. Therefore, we sought to discover what would happen if a small number of infected students were placed into a large population of healthy college students. In particular, we wanted to see how quickly the virus would spread through the initial population and how subsequent freshman classes would be affected by infected upperclassmen.

63. Optimization of Down Syndrome Specialty Care Clinics

Madeline Kersten Simpson College
Emma Christensen Simpson College
Nicholas Joslyn Simpson College
Advisor(s): Heidi Berger, Simpson College

As the field of healthcare continues to grow and evolve, specialized and coordinated care for extraordinary conditions becomes more and more necessary. Down syndrome, one of these extraordinary conditions, is a chromosomal disorder

that is often accompanied by other severe medical conditions that affect an individual's overall health. Currently, there are 71 Down syndrome specialty care clinics in 34 states in the U.S. that serve less than 10% of the eligible population. Using operations research, specifically p-median and maximal covering models, we found that the current placement of these 71 clinics adds to the problem of inaccessibility. Our research presents the optimal locations for Down syndrome specialty care clinics in the continental United States and offers potential future clinic locations given the current placement.

64. ODE Modeling of Zika Virus

Aneesh Malhotra George Mason University
Advisor(s): Stephen Saperstone, George Mason University

We develop an ordinary differential equation to model the spread of Zika virus. Our model is based on malaria models and the SIR model but also takes into account sexual transmission and population dynamics. We analyze the ODE model and find a value for its basic reproductive number. We also investigate a modified version of our model that adds a time delay, creating a system of delay differential equations . This poster shows the numerical solutions to our models and compares them to others in literature.

65. Security Questions For a Device Independent Quantum Key Distribution

John Mangles Creighton University
Advisor(s): Randy Crist, Creighton University

Quantum computing utilizes the principles of quantum mechanics to show how computations beyond a classical computer's wildest dreams could be done. The following protocol utilizes entropy accumulation to help users Alice and Bob communicate securely while a third party, Eve, attempts to break their communication. We present an analysis of the efficiency and security of this specific Device Independent Quantum Key Distribution (DIQKD).

66. A Markov Chain Analysis of NFL Overtime

Renee Martin University of St. Francis
Advisor(s): Megan Powell, University of St. Francis

Prior to the 2012 National Football League season, if there was a tie at the end of a NFL game, the captains would report to mid-field and the visiting captain would call the coin toss in the air to determine who would receive or defer the kickoff. The team that scored first, whether it was a field goal or touchdown, would win the game, even if the other team did not have a chance to possess the ball. This created a build-up of controversy from around the league because the team that received the ball first in overtime won more often, and their wins seemed predominantly dependent on a coin toss. Thus, the league changed the rules to a modified sudden death format, where the game could only be won in the first possession with a touchdown. Then a 2016 playoff game was won in overtime by the Arizona Cardinals scoring a touchdown on the first overtime possession, renewing criticism that the overtime system was still not fair. In this project, we create and analyze a Markov chain model of the sudden death and modified sudden death overtime formats during the regular season, neglecting playoff games which cannot end in a tie. In addition, we propose an alternative modified sudden death format where both teams are guaranteed possession of the ball at least once. Our model shows the team possessing the ball first has win percentages of 59%, 55%, and 54% for the three formats discussed, while the average length of overtime stays between 6 and 8 minutes.

67. Modeling Coral Reef Ecosystems

Eliza Matt Williams College
Andre Archer Macalester College
Colin Okasaki Harvey Mudd College
Advisor(s): Julie Blackwood, Williams College

Coral reefs in the Caribbean have been in crisis since the mass die-off of keystone herbivore Diadema antillarum in 1983. Since then, reef coverage has declined dramatically, and macroalgae have proliferated to become the dominant occupier of space in many reefs. Though this system has been well studied, there is a need for models of intermediate complexity, that capture a small number of complex interactions and provide insight into the resulting system behavior. To respond to this need, we have constructed several models of Caribbean coral reefs. We focus in particular on

parrotfish, whose life-cycle is complex and whose role as grazers of macroalgae is unclear; sea urchins, which are effective grazers but require careful conservation efforts if they are ever to reach their previous population levels; and the importance of spatial information and violations of the mean-field approximation commonly used in reef modeling.

68. The Behavior of Soliton Waves Associated with Nonlinear PDEs

Sergio Melendez University of the Incarnate Word
Advisor(s): Theresa Martines, University of the Incarnate Word

In order to better understand the behavior of soliton waves we analyze solutions to the Korteweg-de Vries and sine-Gordon equations for the single and multiple soliton cases. Through deliberate manipulation of entries, we notice relationships with the matrices and the representations of solutions. We analyze the matrices in the n-soliton case and its behaviors including multiplicities and minor changes to the entries of the matrices.

69. Classification of Massive, Imbalanced Data for Online Advertising

Rodrigo Morales Mendoza Instituto Tecnol gico Aut nomo De M xico
Krishan Bhalla University of Oxford
Advisor(s): Thuy Vu, UCLA

Online ad exchanges handle high volumes of traffic between the supply and demand sides of online advertising. Less than five percent of this traffic, however, generates revenue for the ad exchanges. Hence, vast amounts of computational resources are wasted on unprofitable traffic. In this study, we explore methods to predict whether incoming traffic is likely to generate revenue; if it is not, we want to filter it out. To perform this task, we implement and compare various machine learning classication models, including Naïve Bayesian models, Support Vector Machines, and Extreme Gradient Boosting. Using the literature, particularly on imbalanced class classification, we explore a wide range of other methods to improve performance. In particular, we introduce a reservoir-based online filtering system, which allows us to dynamically account for noise and concept drift in the streaming bid data. We empirically examine the predictive capability of our models using various statistical and financial metrics. Based on the data from June 2016, our proposed system — using Extreme Gradient Boosting as a classifier — can maintain a high recall of 97.5%, while filtering out over one-third of the advertising traffic. This saves $23,450 each month, which is equivalent to $281,400 per year.

70. Predicting methane concentration in the atmosphere through mathematical modeling, computation and simulation

Christopher Moro Inter American University of PR Bayamon Campus
Advisor(s): Padmanabhan Seshaiyer, George Mason University

The mathematics of sustainability is a current research area that generates global interest. Climate change and greenhouse gases have been at the center of scientific debate, showing the common interest of protecting our environment. Methane is identified as an important greenhouse gas with a warming radiative forcing that is 25 times greater than carbon dioxide. It is also an important gas present in the emissions from the US oil and natural gas industries. Therefore methane concentration levels are being discussed between these industries and the EPA to regulate methane emissions in the atmosphere. In this talk we present the mathematical modeling of methane concentration in air. We use a benchmark problem to study the convergence rate of the numerical schemes. The numerical solution of the advection-diffusion equation by the use of the Finite Difference theta-method is obtained and implemented for both: constant and linear diffusion coefficient. Finally a parameter estimation code is implemented in order to simulate best the experimental data to be obtained.

71. Coding Van Gogh

Rachel Newell Brigham Young University
McKay Kerksiek Brigham Young University
Advisor(s): Mark Hughes, Brigham Young University

How could you sort through a collection of art images? We could sort through the collection manually and assign a time period to every piece, but what if there are 10,000 pieces? We have been working on an approach to this problem. Using convolutional neural networks, we can sort through a portion of the images and teach the network to recognize

what the different time periods look like. The network will then predict what time period a given image was created in. In this display we will explain how we used python and TensorFlow to train this network.

72. Mathematical Model to Noninvasively Detect Dry-Eye Diseases

Trini Nguyen California State University Fullerton
Advisor(s): Charles H. Lee, California State University, Fullerton

Wavelength-dependent interferometry is a noninvasive diagnostic technique for patients with dry-eye diseases. It requires shining a light at multiple wavelengths on the eye while measuring its reflectance, which then allows for the thicknesses of the tear film layers to be extracted implicitly. In a 2013 patent, a mathematical model for the measurement of the reflectance was presented. However, the model only fitted with some sets of data and not for others because it lacked the scalar light scattering theory, which accounts for the light that is scattered at a rough surface. To force the model to fit, the author of the patent added an exponential term to mimic the light scattering effect and resulted in an empirical, rather than physical, model. In this work, a model that describes the reflectance of the eye is derived. The model takes into account electromagnetic properties of the light that is transmitted through several layers and reflected back to the surface, material properties and thicknesses, and the incident, reflectance and transmittance angles. In addition, a numerical scheme based on this model has been implemented, which was quite complicated in the patent because its scheme took up over ten pages of code and 45 minutes to produce the thicknesses. Our scheme runs within a few seconds, making it practical for clinical diagnostics of dry-eye diseases. Our future work will include refining the application of the scattering theory into the model as well as improving the speed of the algorithm.

73. Quantum Steganography Method and M-Band Wavelet with Patch Group Prior based Denoising in QR Color Barcode

Hieu Nguyen Western Connecticut State Univeresity
Julia Yu Ridgefield High School
Sarah Zhao Phillips Academy
Advisor(s): Xiaodi Wang, Western Connecticut State University

Color barcode is being interested by many big corporations and researchers due to high capacity storage. The purpose of our research is to enhance the applications of color barcode. Steganography is the practice of hiding secret information into host data and making the secret message becomes unrecognizable to the third party. In this research, we use color barcode as host data to embed secret information such as images and audio into the color channels using M-Band Wavelet and Pseudo Quantum Steganography. The result of our algorithm has shown a high capacity, robustness, and undefectablity of a M-Band wavelet based steganography scheme. In addition, we are interested in denoising a noisy and unreadable color barcode using the method of Wavelet based Patch Group Prior Denoising. The denoising algorithm can remove heavy noise, and its efficiency was being calculated using peak signal-to-noise ratio (PSNR). In remark, with the new steganography and denoising algorithms being applied to a high capacity color barcode, this research might contribute to a commercial usage in the near future.

74. Necessary and sufficient condition for shortest vectors in lattices of low dimension

Jeongeun Park Ewha Womans University
Boyun Choi Ewha Womans University
Hyemin Gu Ewha Womans University
Youngin Cho Ewha Womans University
Advisor(s): Hyangsook Lee, Ewha Womans University

A lattice in the Euclidean space is an important issue for cryptography these days. In general it is very challenging to find a nonzero shortest vector because of its computational difficulties. People are interested in sufficient conditions for a basis including a nonzero shortest vector. However, there are few researches on properties of bases having a nonzero shortest vector. In low dimensions, gaussianity of basis vectors is a key factor to be a shortest vector of a lattice among basis vectors of the lattice. In this article, first of all, in dimension 2, we introduce that we already know an algorithm that makes any basis vectors of a lattice gaussian. Therefore, the shortest basis vector is shortest in the lattice and the inverse is also true. In dimension 3, we prove a necessary condition having this property and suggest an algorithm to make basis vectors of any basis for a lattice pair-wise gaussian. Moreover we conclude that if the shortest basis vector is shortest in a lattice, basis vectors are pairwise-gaussian and has another property. Finally we can combine the

minimal sufficient condition that has already been proven by others with our results so that we have a necessary and sufficient condition for a shortest vector in a lattice in dimension 3.

75. Mathematical Models for Surface Reconstruction in Materials Science

Channing Parker James Madison University
Molly Rowland James Madison University
Michael Boyle James Madison University
Advisor(s): Hala Shehadeh, James Madison University

We consider the evolution of crystalline materials. Atoms evaporate from and condensate on the crystal surface. We numerically compare a continuum model for a radially symmetric crystal with a discrete model based on statistical mechanics using KMC simulations. Facets reflect a long range order of the atoms on the crystal surface. We're interested in the mathematics of facet formation.

76. Spectral Theory of Koopman Operators

Micah Pedrick Harvey Mudd College
Ryan Utke Grinnell College
Carter Chain Purdue University
Advisor(s): Bjorn Sandstede, Brown University

There has been much progress in global stability analysis of nonlinear dynamics recently through spectral theory of the Koopman operator, a linear operator which captures the full dynamics of a nonlinear system. Despite this success, many aspects of Koopman analysis remain unexplored. In particular, the dependence of spectral properties on the underlying function space have not received much attention in the literature, nor has the presence of unstable fixed points and their effect on spectra and numerical stability. We explore some techniques to address these questions, both theoretical results on the structure of the eigenspace and numerical investigations of spectral approximations. These include conditions for infinite dimensional eigenspaces and the introduction of pseudospectral methods.

77. Mathematical modeling of the spatio-temporal dynamics of migratory species

Sadie Piatt Emmanuel College
Connor Higgins Emmanuel College
Advisor(s): Christine Sample, Emmanuel College

Understanding the influence of specific habitats on the survival of a migratory species is an essential part of making successful conservation and management decisions. Migration is a complicated process, and mathematical models of these networks offer a way to understand the importance of different parts of an organism's annual cycle. Representing the system as a graph in which habitats are nodes and migratory paths are edges, the reproduction, survival, and movement of the population are modeled with time- and density-dependent functions. Under this framework, we assess the importance of each node to the viability of the species by calculating two values: the C-metric and K-metric. The C-metric estimates the per-capita contribution of cohorts using a given node. The K-metric estimates the overall growth rate in the absence of a given node. We also investigate the effect of changes to the network by performing a perturbation analysis of our nonlinear model. Matrix calculus is used to derive the sensitivity of equilibrium population size to changes in parameters such as node and edge survival, and reproduction rate. We demonstrate how the proposed node metrics and sensitivities can be used to analyze a variety of hypothetical migratory networks of four habitats and two seasons.

78. Center Stability of the Blum Medial Axis

Natasha Pillai California State University, Channel Islands
Advisor(s): Kathryn Leonard, California State University Channel Islands

Determining a part's importance within a shape has been a major challenge in the field of shape analysis. To develop an algorithm for determining shape part importance, we consider a special class of radially symmetric shapes of constant width called n-foils. We use two different methods, one based on length and the other on area, to determine centers of the n-foil along its skeleton, the Blum medial axis. We then determine which types of boundary deformations of the n-foil cause its centers to change position. This method gives us a quantitative measure for when a deformation creates an "important" part of the shape and can also be used to compare and formulate stability conditions for the two

constructions of the shape center. We expand this method to shapes without radial symmetry and explore the utility of other stability conditions along the Blum Medial Axis.

79. Using Individual Patient Data to Quantify a Mathematical Model for the Interactions of Matrix Metalloproteinases and Their Inhibitors in a Wound

Ayush Prasad Western Kentucky University
Advisor(s): Richard Schugart, Western Kentucky University

Because the medical treatment of diabetic foot ulcers remains a challenge for clinicians, a quantitative approach using patient data and mathematical modeling can help researchers understand the physiology of the wounds. In this work, we extend a previously developed mathematical model describing the interactions among matrix metalloproteinases, their inhibitors, extracellular matrix, and fibroblasts (Krishna et al., 2015). In the previous work, the model was curve-fitted to the averaged data of patients with diabetic foot ulcers from Muller et al. (2008), and the model parameters were estimated using ordinary least-squares. The model and parameter values were then analyzed using global and local sensitivity analyses, which were used to describe how sensitive each parameter value of the model was to changes in the system. This work uses the individual patient data obtained from Muller for curve-fitting a modified model using similar techniques from the previous work. The goal of this work is to quantify and understand differences between patients in order to predict future responses and individualize treatment for each patient.

80. Optimizing Option Pricing using PCA, Wavelets, and Monte Carlo Simulations

Abdul Rahimyar Western Connecticut State University
Hieu Nguyen Western Connecticut State University
Advisor(s): Xiaodi Wang, Western Connecticut State University

With the ever-growing complexity of big data in today's world, there is a strong need to transfer such data into a more efficient form. The demand for such a system is especially high in the financial world where time and proper data analysis is of high value. The research in this paper will be especially focusing on data analysis techniques such as Principal Component Analysis (PCA), wavelet analysis, and the Monte Carlo method in regards to option pricing; all of which can be extremely useful in correctly satisfying the big data demands of today. Wavelet analysis is useful in reducing variance and removing noise from the factors associated with option pricing (i.e., risk-free rates, credit ratings, strike pricing, ask & bid price,. . . , etc.). After the trend of each factor is obtained by wavelet transform, PCA is applied to measure the effectiveness of these factors, and Monte Carlo simulation is then used so that the variance will be further reduced. Through these methods, the error in decision making with option pricing can be minimized.

81. A Mathematical Analysis of Languages

Gerald Roman-Gonz alez Stevenson University
Advisor(s): Benjamin Wilson, Stevenson University

Using concepts from information theory such as entropy, we analyze the complexity of several natural and fictional languages. The entropy of a written language, as defined by Claude C. Shannon in his landmark 1948 paper, A Mathematical Theory of Communication, measures how much information is produced on average for each letter of text in the language. Shannon's work led to the foundation of information theory which has shaped the ways in which we communicate today. In a subsequent paper, Prediction and Entropy of Printed English, Shannon estimated the entropy of written English by doing experiments to approximate word and letter frequencies. Since Shannon's work, a multitude of attempts have been made to estimate the entropy of different written languages such as English, Spanish, and Russian. We will analyze and compare the entropy and other similar quantities of constructed languages such as Dothraki (Game of Thrones), Tengwar (Lord of the Rings), Na'vi (Avatar), Klingon (Star Trek), Esperanto, and Lojban as well natural languages such as English, French, and Spanish.

82. Graphic Connectivity Indices As Applied to the Evolutionary Analysis of Chagas Disease Vectors

Katherine Ruddy Montclair State University
Advisor(s): Aihua Li, Montclair State University

Triatoma dimidiata is a parasite that causes Chagas disease, which has infected approximately 8 million people in Latin America. In order to better understand the characteristics of this insect vector's many variants, traditional methods of

DNA sequence alignment and analysis are often employed. These approaches require sophisticated computation and tedium. As a different approach, we apply a graph theory method that uses Randic connectivity indices to analyze DNA sequences from specimens of T. dimidiata. We modify the graph theory-based connectivity formula and carry it out to the nth order. We develop an algorithmic code and perform principal component analysis to create a phylogenetic tree from the data. This method is more efficient and the results that it generates have a reasonable degree of similarity in comparison to those found via the traditional method. The graph theory approach gives an alignment-free method of related evolutionary analysis.

83. Betting Better on Broadway: the Application of Statistical Matrix Theory to the Prediction of the Tony Awards for Best Play and Best Musical

Jack Ryan North Central College

Advisor(s): Katherine Heller, North Central College

In this work, we employ methods previously used to rank sports teams to analyze particular quantifiers pertaining to art. The research uses statistical principles and matrix theory to predict which show will win a Tony Award in a given season. Using weekly statistics including weekly gross profit, percentage of seats sold, average ticket price, top ticket price, and number of seats sold, we rank Tony Award nominees from the past ten years using two algorithms: the Colley and Massey methods. The method and quantifier combination that most often successfully yields accurate results is used to predict the winners of the 2016 Tony Awards for Best Play and Best Musical.

84. Social network analysis based on Principal Component Analysis and Markov Chains

Hunter Schloss Western Conneticut State University

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

Social network analysis has long studied how the local structure of a network influences its global properties and how that in turn can be related back to the bonds that make it up. Two very influential theories in regard to this are structural hole theory (Ronald S. Burt 2000, 2001) and Simmelian tie theory (David Krackhardt 1998, 1999, Simmle 1950) both focus on the brokering of information through otherwise disconnected sections of the network. They differ in the fact that structural hole theory focuses on dyadic bonds that connect disconnected parts of the network while Simmelian ties may be embedded in multiple disconnected cliques. In this research, I will develop methods based on Principal Component Analysis, as well as a metric from Markov Chains that utilizes the rate and total convergence of the probability of a random walk starting at node B and going to node A in finite steps. I will then compare the results of mine and other methodologies on real world networks.

85. Synchronicity among Gender-Identifying Pairs and Quantifying the Complexity of Rectilinear Motion

Thomas Simms Maryville College

Advisor(s): Jesse Smith, Maryville College

We present an approach to test the synchronicity between college students that identify as the same gender compared to college students that identify as different genders by calculating area between position curves. This calculation allows us to explore how absition relates to harmonizing motion. Our avenue is inspired by the “Mirror Game” used in a research study by Lior Noy, Erez Dekel, and Uri Alon. The “Mirror Game consist of two people moving a traceable object on a single axis to mirror each other’s motion as closely as possible. By replicating this game with standard physics equipment, real-time data is created by students to be used for study. Our use of this data in the classroom revamps a past study titled “A Rectilinear Motion Activity for the College Calculus Sequence.” After analyzing the collected data, we compare each group’s synchronicity based on absition. One of our goals is to develop a metric for the complexity of rectilinear motion. Modeling the complexity of each round requires us to look at an array of variables such as velocity, acceleration, jerk, patterns of movement, and more. Taking into consideration complexity, we hypothesize that like gender pairs will more closely synchronize than non-like gender pairs.

86. An Area Based Fan Beam Projection Model

Richard Steele Georgia Southern University
Advisor(s): Jiehua Zhu, Georgia Southern

Area based projection models mitigate errors by treating X-Rays as beams, whereas traditional line based projection models treat an X-Ray like a line and not a beam, which generates significant error. In the area based fan beam projection model a rotation matrix, **Q**, is used to simulate the rotation of the emitter detector pair. This reduces the computational load at the cost of introducing approximations. When the grid is rotated, the squares will no longer align with each other. To eliminate approximations we derive an exact formula for the entries of **Q**. Using a rotation of axes and by considering the neighboring cell's contribution to the area, the result has formulations for the exact calculation of the matrix **Q**. Thus the phasing out of approximations allows for the minimization of error in the projection data for image reconstruction.

87. Extension of image decomposition algorithms to video sequences with atmospheric turbulence

Alex Tarter Creighton University
Advisor(s): Jerome Gilles, San Diego State University

In image processing, image decomposition algorithms allow for the separation of structure and texture components of an image. Many algorithms exist that work well for non-distorted images, but results have shown poor algorithm performance when applied to images containing atmospheric turbulence. In these noisy images, certain decompositions separate the noise component with texture due to their shared high-oscillatory nature. Methods exist to remove noise from single images, but little work has been done to remove turbulence from entire sequences of images. We report on the augmentation of a known decomposition algorithm to allow for atmospheric turbulence that varies with time. The extended algorithm has provided early positive results in tracking the motion of an object across a turbulent sequence.

88. The Student Becomes the Master: Using artificial intelligence and math to create game-winning computers.

Zach Taylor Brigham Young University
Gabriel Bradford Brigham Young University
Advisor(s): Michael Dorff, Brigham Young University

There's a lot of interest in programming computers to learn on their own. Recently, programmers at Google built an artificial neural network to beat the world champion at Go. Another similar method is called Q learning, in which the computer accesses a matrix in order to learn the best choice in given situations. In this presentation, we ll discuss how we ve used both Q learning and neural networks to teach a computer how to win at a simple two-person game called 21 and TicTacToe. Currently we re working on refining these two methods to teach the computer more complex games such as Connect4. In the future, we plan to apply this to other more complicated games.

89. Brainz: Geometrically Classifying Healthy and Schizophrenic Brain Images with the Blum Medial Axis

Robben Teufel California State University, Channel Islands
Robert Aroutiounian California State University, Channel Islands
Advisor(s): Kathryn Leonard, California State University, Channel Islands

Diagnosing schizophrenia is currently a process of trained symptom observation and individual interpretation by doctors. The objective of this research project is to automate diagnosis by developing an algorithm which categorizes MRI-scanned brain images as healthy or schizophrenic based entirely on shape information. We utilize the Blum medial axis (BMA), a skeletal model of shapes, to represent corpus callosum images and then compute various geometric values along paths in the BMA to develop a threshold to categorize healthy and schizophrenic corpora callosa. We do this by isolating the most salient path through the BMA using continuity properties of a depth measure called the Extended Distance Function, and then investigating principle geometric attributes including curvature, a measure of shape "tubiness" called Shape Tubularity, and interesting geodesic distances along the BMA.

90. A Study of Sasaki's Variational Theory of Supercell Formation and Tornadogenesis

Connor Theisen University of St. Thomas - St. Paul, MN
Advisor(s): Douglas Dokken, University of St. Thomas

We derive the Euler Equation following the approach that Sasaki uses in his paper: Entropic Balance Theory and Variational Field Lagrangian Formalism: Tornadogenesis. He assumes two constraints: conservation of mass and conservation of entropy, which lead to Lagrange multipliers associated to these two constraints. To derive the Euler Equation Sasaki uses the Calculus of Variations, which leads to the Euler-Lagrange Equations for five variables. We also want to test the validity of the Sasaki's Entropic Balance Theory (EBT) and his Entropic Right Hand Rule. We then want to see if both the EB and the Entropic Right Hand Rule can be applied to different parts of the supercell, which were not mentioned by Sasaki in his papers. We ran simulations using the numerical weather-modeling program, ARPS (the Advanced Regional Prediction System) and used the visualization software ViS5d to visualize isosurfaces for various variables. We gathered data and made code changes to the numerical weather model, ARPS, and simulated supercell thunderstorms. The code changes helped us view variables Sasaki uses to understand the processes that lead to supercell and tornado formation. Using ViS5d we view the model output and we witness entropic anomalies and relationships between the anomalies and other variables.

91. Dynamics of Fisher-KPP on Networks

Robert Truong George Mason University
Advisor(s): Matthew Holzer, George Mason University

We study the Fisher-Kolmogorov Petrovsky Piscounov (Fisher-KPP) system of ODEs that models population spread throughout a network. This admits two dynamics: a local logistic growth dynamic, and diffusion between network nodes, with a diffusion parameter α controlling the comparative amounts of each. With a positive initial condition at one node and zero elsewhere, this usually results in a traveling front throughout the graph. We examine the case where the network is a homogeneous tree, and we find that the traveling front speed is non-monotone as a function of α, which is unlike the traditional Fisher-KPP PDE.

92. Equivalence and Classification of 4D Adinkras

Tyrell Umbach Concordia University
Lucas Kang Brown University
Advisor(s): Mariana Frank, Concordia University

Adinkras are powerful and concise tools for the representation of complex supersymmetrical algebras as graphical objects. As these graphs can be seen as topologically equivalent to hypercubes of varying dimensions then these objects can be studied in terms of their underlying matrix structure. We have discovered a means of classifying all 4D Adinkra graphs in terms of attributes of their colour-sign superimposition matrices. Our efforts culminate in research towards the construction of a simple object for computing Adinkras using a minimum number of these matrix attributes. This result leads to a prediction of all possible solutions of topologies, with our focus upon the Chiral Supermultiplet.

93. War-Gaming Applications for Achieving Optimum Acquisition of Future Space Systems

Paul Vienhage Emory University
Avery Black Lehigh High University
Karel Marshall Andrews University
Heather Barcomb SUNY Geneseo
Advisor(s): Hien Tran, North Carolina State University

In 2014, The federal government spent nearly half a trillion dollars ($447,474,451,718) on contractor projects out of $3.5 trillion in total expenditures. Motivated by the Space Modernization Initiative and the Defense Innovation Initiative, which seek to reinvigorate war-gaming and make the Department of Defense practices more innovative, the DoD is interested in developing an algorithm to optimize the acquisition of government contracts. This Unified Game-based Acquisition Framework Advanced Game-based Mathematical Framework (UGAF-AGMF) makes use of game theory, probability and statistics, non-linear programming and mathematical modeling components to model negotiations between governmental agencies and private contractors. This project focuses on generating the optimum Program and Technical Baseline (PTB) solution and its corresponding acquisition strategy with associated contract incentives for a typical Fixed-Price Incentive Firm (FPIF) contract type and a Fixed Price Seal Bid (FPSB) contract type with the end

of goal of implementing the system to acquire a Ground Tracking Station for future Satellite Operations. An "optimum solution" is obtained by compromising the system and acquisition objectives to achieve low lifecycle cost/total ownership cost, innovative design, decreased acquisition time, while meeting warfighter needs. Each of these games can be played from the perspectives of the Department of Defense or a contractor. This project culminates in a collection of MATLAB (Mathworks) programs which model contractor and governmental interactions. The newly developed strategy shows strong convergence to nash equilibrium values for all cases in the bidding games and successful selection of PTB solutions in contract construction games.

94. Two-Dimensional Heat Equations

Dalton Watts Coastal Carolina University
Advisor(s): Rajendra Dahal, Coastal Carolina University

Mathematics is a versatile subject that is frequently used to model phenomena in the real world. In this poster, we will mathematically model the way thermal energy moves through a rectangular plate using partial differential equations and solve this by the method of Separation of Variables. We will consider the case with homogeneous Dirichlet boundary conditions.

95. First Integrals of Elliptic Monge-Ampere Equations

Andrea Weaver University of Central Arkansas
Advisor(s): Daniel Arrigo, University of Central Arkansas

Partial differental equations (PDEs) are equations that describe most of the physical laws of nature. They have been used to model a wide variety of phenomena such as diffusion where milk would diffuse into coffee, the motion of waves as one would see at the beach and steady state temperatures of objects as we would see a cake coming out of an oven. The subject is divided into two classes; linear and nonlinear equations. Linear PDEs is fairly well developed and continues to be actively used in Applied Mathematics and Physics. However, techniques to solve nonlinear PDEs exactly is still rather underdeveloped and continues to be an active area of research. In 1877 Sophus Lie was able to show that if a given nonlinear hyperbolic Monge-Ampere equation admits two sets of intermediate integrals, then it can be transformed to the wave PDE. We show that if an elliptic Monge-Ampere equation admits two complex intermediate integrals, then it can also be transformed to Laplaces equation.

96. Nonlocal Topography Influences Vegetation Pattern Wavelength in the Horn of Africa

Elle Weeks Macalester College
Daniel Schmidt Harvey Mudd College
Jacob Ramthun Macalester College
Advisor(s): Chad Topaz, Macalester College

In semi-arid ecosystems, the growth of plants is limited by water scarcity. Under certain conditions, this scarcity can lead to the formation of striped vegetation patterns. Classical mathematical models exist for such stripes; however, many of these models ignore the underlying topography and hydrological conditions. Recently, spatial ecologists have sought to better understand these patterns by comparing wavelength and other properties to the surrounding topography. To study these patterns, we combine satellite imagery and remotely sensed elevation data over an extensive region of northern Somalia to determine the relationships between stripe characteristics and the regional topography. We develop methods for combining and denoising various remotely sensed data in order to measure topographical characteristics and identify vegetation stripes. We find a critical range of local slope over striped regions to be a necessary, but not sufficient, condition for pattern presence, and corroborate previous results relating gradient to stripe presence and wavelength. Additionally, our analysis finds positive correlations between catchment area and the thickness, length, and area of stripes, suggesting that local water accumulation explains more of the variance in stripe properties.

97. Kinetic Monte Carlo Simulations for Crystalline Surfaces

Dylana Wilhelm James Madison University
Jenny Frank James Madison University
Benjamin Dulaney James Madison University
Advisor(s): Hala Al Hajj Shehadeh, James Madison University

We perform KMC simulations for type A material grown on type B substrate, and compare our results with known experimental results for specific materials.

98. Reliability of Using a SIR Model to Track the Spread of Diseases

Daniel Zelaya California State University, Fullerton
Advisor(s): Roberto Soto, California State University, Fullerton

There have been many news reports recently documenting the spread of diseases locally and internationally, such as the measles in Anaheim, CA and Ebola in West African countries. The spread of these diseases is usually modeled by variations of the S.I.R. model and many such models are capable of tracking the number of infected people over a relatively short period of time for diseases that are not chronic. We adapt one such model to be able to accurately predict the infected count of other such diseases with similar characteristics. By predicting the number of infections and deaths that result from such diseases, we can potentially disseminate to the public the necessary information needed to prevent the occurrence of further cases as well as encourage the afflicted population to prepare and take precaution to avoid contamination. Models such as these demonstrate that the lack of immunity to such diseases can be harmful, and in some cases fatal.

99. A Dynamic Model Of Protein Hydrogel Mechanics

Kirill Shmilovich University of Wisconsin - Milwaukee
Advisor(s): Gabriella Pinter, Associate Professor of Mathematics

Protein hydrogels serve as an excellent scaffold for artificial tissues and smart drug delivery systems. A protein hydrogel is a highly cross-linked network of multi-domain proteins. These proteins show a force sensitive response to folding and unfolding of their individual domains. Here, we report a dynamic model of protein hydrogel mechanics based on an empirically verified model of single molecule mechanics. Our model explains how protein orientation and domain unfolding affect the elastic behavior of protein hydrogels, such as hysteresis and stress-relaxation response. By using a custom built force clamp instrument, we can verify our model with empirical data. The model and measurements both provide a stepping stone for formulating the future of protein-based smart materials, such as those used in artificial skin and 3-D organ printing.

100. Connectivity Estimation in Neuronal Networks: The Hidden Node Problem

Falastein Alie NCSU
Advisor(s): Franz Hamilton, NCSU

The human brain is a complex system consisting of billions of neurons. The network connectivity of these neurons gives rise to a variety of dynamical behaviors and understanding it is key to describing the underlying evolution of the system. However in our analysis of network connectivity we are often confronted with the problem of hidden nodes, or parts of the network that we are unable to observe but that are strongly influencing the network. Identifying these hidden nodes, and the parts of the network they are affecting, is key to understanding the network and making predictions of the future network state. We investigate this problem of connectivity estimation, in the presence of hidden nodes, in random networks of Fitzhugh-Nagumo neurons. Our hypothesis is that we can identify the presence of hidden nodes by detecting abnormalities in the estimated network connectivity.

101. Parameter Identifiability on a Mathematical Model for Prostate Cancer Treatment

Allen Alvarez Loya California State University, Fullerton
Advisor(s): Fabio Milner, Arizona State University

The original goal of our summer project was to modify an existing model used to approximate the time intervals of between androgen suppression treatment. But as we ran the simulations, we faced two main problems. The algorithm was very sensitive to the parameter initial values and bound constraints. This resulted in some cases in aleatory (and quite illogical) fittings and predictions. In order to explain these results we asked whether the inverse problem of identifying parameters given the data was well posed. By determining the structural identifiability of the parameters we are able to explain the problems that can arose in parameter identifiability or our model.

102. Modeling the Effects of Tannin on Giraffe Physiology

Kristina Benton University of Central Oklahoma
Advisor(s): Brittany Bannish, University of Central Oklahoma

Tannin (a bitter-tasting organic substance) is produced by acacia trees as a defense against over-browsing by giraffes. In conservatory enclosures, where food sources are limited, giraffes are forced to eat the tannin-rich acacia trees, which

can adversely affect their health. I built a mathematical model of how the tannin levels of the acacia tree affect the health of the giraffe. This model consists of the different interactions in the gut of the giraffe between tannin, protein, parasites, and salivary muco-proteins. I will present results of the model that can be used to help conservationists with the health and wellness of the endangered Rothschild giraffe species by recommending ideal population levels and proper feeding systems.

103. Modeling Single Cell Gene Expression in Developing C. Elegans

Harout Boujakjian George Mason University
Advisor(s): Vipul Periwal, NIH

Advances in single-cell measurement techniques are revolutionizing biology. The large amounts of data generated by single-cell experiments are especially exciting for addressing the challenge of inferring predictive dynamic models of biology. At present, experimental techniques do not allow for following single-cell gene expression patterns in time. However, published single-cell measurements of gene fluorescence during development in *C. elegans* can be used to test approaches for inferring biological dynamics from temporal single-cell data. We developed a mathematical model using statistical physics and Bayesian analysis to predict the changes in gene expression. We also clustered the data using k-means, DBSCAN, and the *C. Elegans* cell lineage, and applied the prediction method to each cluster individually. Lastly, a directed graph of gene interactions that predict dynamic changes in gene fluorescence was developed.

104. Mathematical Model of Swimmer's Itch with Praziquantel Treatment

Kelly Buch Southern Illinois University - Edwardsville
Rob Hendrickson University of Minnesota - Twin Cities
Advisor(s): James Peirce, University of Wisconsin - La Crosse

Swimmer's itch is a water-borne, emerging disease caused by parasites known as avian schistosomes. Typically, these parasites use birds as definitive hosts, but will mistakenly infect a wide-range of dead-end hosts, including humans. When parasite larvae penetrate the skin of humans they initiate an allergic reaction that causes itching and discomfort that can last for weeks to months. Previous research has shown that the Common Merganser serves as a key host for schistosomes in the Midwest, with infection rates exceeding 60% in some regions. While most efforts at schistosome control have focused on other hosts in the parasite's life cycle (snails), recent attempts have been made to target waterfowl using the anti-parasitic drug, Praziquantel. Based on this novel approach, we developed a mathematical model to explore the effects of Praziquantel dose and treatment frequency on the occurrence of swimmer's itch in a typical Midwestern lake. We modeled susceptible and infected mergansers (both juvenile and adult), and snails using first order differential equations and introduced aspects of Praziquantel treatment into the system. Results from this model help to identify treatment regimes which lower merganser infection rates and ultimately reduce the occurrence of swimmer's itch.

105. Functional Data Analysis of Copy Number Alterations in Bladder Cancer

David Burton East Tennessee State University
Sarah Robinson University of Georgia
Advisor(s): Miranda Lynch, Los Alamos National Labratory

Genomic structural changes known as copy number alterations (CNAs) have a role in tumor progression. CNAs are changes in the chromosome where regions are either amplified or deleted. It is thought that bladder cancer subgroups have varying CN profiles that are similar within groups but differ across groups. We analyze array comparative genomic hybridization (aCGH) data from 93 bladder cancer patients whose profiles are in muscle invasive and non-muscle invasive subgroups. We are treating these CN profiles as functions across the entire chromosome, and using functional data analysis tools for inference. We use Bayesian, wavelet-based, functional response regression to characterize the CN profiles of muscle invasive and non-muscle invasive patients. We develop simulated aCGH profiles in order to test these methods. We find that our wavelet bases method using a fixed effects model for functional regression confirms the results of prior research about CN amplifications at 1q23.3, 1q21.2, and 11q13.2. Further, we find on chromosome 11 of our dataset that RRM1, RIN1, FG19, and ANO1, genes which are known to be associated with bladder cancer, are altered due to the effects of muscle invasiveness within a tumor.

106. Modeling the Seasonal Dynamics of Waterfowl Disease in the Upper Mississippi River

Casey Carter Northern Kentucky University
Annika Fredrickson St. Olaf College
Advisor(s): James Peirce, University of Wisconsin-La Crosse

Invasive species have the potential to alter native communities, particularly if they are associated with disease transmission. As part of our research project we developed a novel mathematical model to explore the seasonal population dynamics of an invasive snail (*Bithynia tentaculata*) and its trematode parasite, *Cyathocotyle bushiensis*, which has been associated with outbreaks of waterfowl disease in the Upper Mississippi River (UMR) and other flyways in North America. In this particular system, the parasite spreads through snail intermediate hosts before transmitting specifically to American coots (*Fulica americana*) which serve as the definitive host. For the model, each host species was first separated into categories based on life stage and infection status. Host categories were then represented using a system of differential equations. To better reflect the biological relevance of the system, we also separated the model into four distinct seasons based on *F. americana* migrational events. Each season was assigned different parameter values based on snail life-history expression and parasite transmission patterns which were acquired from empirical studies. By altering a number of seasonal assumptions within the model, we hope to gain better insight into the long term patterns of waterfowl disease in the UMR.

107. Detecting Hidden Nodes in Complex Networks

Sergio Chavez North Carolina State University
Beverly Setzer North Carolina State University
Advisor(s): Franz Hamilton, North Carolina State University

The identification of network connectivity from noisy time series is a problem found throughout the physical sciences. Accurately reconstructing the nodal interactions is critical to understanding the dynamics of the network and how it evolves over time. To this end, numerous methods have developed for connectivity estimation. However, the problem becomes significantly more complicated when we consider the possibility of hidden nodes within the network. These hidden nodes can lead to the identification of false connections, resulting in incorrect network inference. Detecting the presence of these hidden nodes, or more specifically the parts of the network they are acting on, is thus critical. We propose a method for detecting hidden nodes in complex networks using nonlinear Kalman filtering. The Kalman filter is utilized to reconstruct the full connectivity matrix in a network, and by examining the filter statistics we are able to identify the parts of the network affected by the hidden node.

108. DNA Statistics and the Null Hypothesis

William Deaderick Rice University
Kelly Coffey Towson University
Advisor(s): Jane Carlen, RIPS - University of California Los Angeles

Determining a specific feature of a genome which is related to a genetic trait exhibited by a biological organism is of crucial importance to many endeavors in bioinformatics. However, the high-dimensionality of genomic data together with the relatively small datasets common to the biological sciences makes it difficult to efficaciously apply traditional machine learning techniques to this problem. Once a potentially significant genomic feature has been discovered from our high dimensional sample space, how can we determine its relevance to the trait of interest? We define a partitioning genomic subsequence to be one that is present in every genome of a group of organisms which all exhibit a certain trait, and absent from every genome of a group of organisms which all lack that trait. We formalize and derive a nontrivial upper bound on the probability of finding a partitioning genomic subsequence by considering the capacity of subsequences to overlap with themselves. We then analyze the distribution of subsequences in a collection of genomes of Influenza A/H1N1 virus segments, introducing computational techniques for comparing this data to randomly generated genomes. Lastly, we explore the problem in the context of Bayesian inference in order to better model the structure of real DNA.

109. Yellow Fever Vaccination and The Theory of Games

Chasity Dorsett Bennett College
Advisor(s): Hyunju Oh, Bennett College

Yellow Fever is a hemorrhagic disease transmitted to humans by infected mosquitoes. Yellow Fever infects about 200,000 humans per year, and the Center for Disease Control and Prevention recommends the vaccine for humans

aged 9 months and older who are traveling to or living in areas at risk for yellow fever virus transmission in South America and Africa. We constructed a schematic diagram of the yellow fever model with the presence of a vaccine, whose protection may decrease over time. We derived a threshold vaccination rate. We showed that endemic exists when the mortality rate of the mosquitoes is less than the given threshold, the vaccination rate is greater that the given threshold and recovery rate is greater than given threshold. In contrast, when the reproductive number is greater than one and the vaccination rate greater than a given threshold, the disease will die o . We will use this analysis to plan vaccination strategies. Our goal is to determine when humans should receive the yellow fever vaccination and when being vaccinated is the best choice.

110. Elucidating serine richness in Arabidopsis thaliana transcript using the Exact Distribution of the Number of Clumps

Dustin Ford Philander Smith College
Advisor(s): Deidra Coleman, Philander Smith College

Cultivation of crops is essential for sustaining life in both humans and domesticated animals. However, crops are susceptible to fungal pathogens warranting the identification of antimicrobial proteins that function in innate immunity. A trypsin inhibitor, from the serine protease family, has been identified in Aspergillus flavus resistant corn. Thus, the analysis of Arabidopsis thaliana genome for a trypsin inhibitor with a similar sequence will suggest the same antimicrobial properties are present. Using the GenBank database provided by the NCBI's website and the Exact Distribution of Clump Statistics, the genome is analyzed to determine the abundance of the amino acid serine. This analysis is key in providing a link in the A. thaliana transcript and trypsin inhibitor. Determining the abundance of this particular amino acid suggest the presence of trypsin inhibitor in this model plant. Identifying this will lead to better molecular breeding for microbial resistance in crops. Results of our findings will be provided.

111. Mathematically Modeling Splenic Artery Aneurysms

Kirsten Giesbrecht Centre College
Advisor(s): Ellen Swanson, Centre College

Splenic artery aneurysms (SAAs) are the most common splanchnic aneurysms, accounting for approximately half of visceral aneurysms. Little is understood of their cause or their prevalence compared to other visceral aneurysms. However, a possible factor contributing to the development of SAAs is the distinct curling shape characteristic of the artery. The influence that pressure, velocity, and wall shear stress have on artery structure and aneurysm development is explored using ANSYS Fluent computational fluid dynamics software. Additionally, artery geometries are considered to investigate possible locations that may be likely for aneurysms to form or rupture.

112. The Effects of Culling and Quarantine on Reducing Antibiotic Resistance in a Cohort of Beef Cattle

Mary Gockenbach University of Texas at Arlington
Noah Padgett University of Wisconsin - Whitewater
McKenna Cortez University of Nevada - Reno
Advisor(s): Christopher Kribs, University of Texas at Arlington

Antibiotic resistance is a global health concern that involves animals as well as humans. In zoonotic diseases, not generally fatal to humans, antibiotic resistance provides a reservoir from which pathogenic bacteria can gain resistance. Reducing antibiotic resistance in bovine infections is a key part of any plan to slow resistance in human diseases. A two-stage mathematical model is constructed in order to find the most ideal combination of isolation, treatment, and culling that reduces the number of beef cattle with antibiotic resistance at the time of maturity. New legislation, starting in 2017, will restrict the use of antibiotics in cattle feed to veterinary prescription. To compare the impact of this legislation with current practices, an additional set of parameter values is used to simulate the dynamics of antibiotic resistance among beef cattle populations. Culling rates are shown to have a negligible effect, but quarantine rates of 0.5–1 per week lead to a decreased ABR rate. We find that under the new legislation the proportion of cattle with ABR at slaughter decreases by a statistically significant amount. In addition, the number of cattle colonized with antibiotic susceptible bacteria increases. However, the proportion of sellable cattle at the time of slaughter remains roughly the same.

113. Potential Biological Removal Modeling and Analysis of the Indiana Bat Population

Humza Haider University of Minnesota Morris
Rosa Moreno California State University of Channel Islands
Advisor(s): Eric Eager, University of Wisconsin - La Crosse

Wind energy is one of the key technologies facilitating the transition from fossil fuels to renewable energy. However, this resource can come at a cost to wildlife. For example, Indiana Bats (Myotis sodalis) are at a heightened risk of extinction due to their continual collisions with wind turbines during migrations. To better understand the effects of wind-energy developments on M. sodalis, we evaluated a number of current population models in collaboration with conservation managers at agencies such as the US Fish and Wildlife Service (USFWS). Potential biological removal (PBR), a measure of allowable harvest, was evaluated for M. sodalis using a logistic growth model and a model incorporating Allee effects (which had not been done for this bat species). On average, PBR overestimated by 82% using the logistic growth model. Furthermore, when PBR from the logistic model was applied to the Allee-effect model, the Indiana Bat population decayed to extinction. Results from this work suggest that policymakers should take Allee effects into account when using models to predict the impacts of wind technology on populations of bats in general, and the Indiana Bat in particular.

114. Simple Mathematical Model for Tumor Spheroid Growth

Yixuan He Dartmouth College
Advisor(s): Dorothy Wallace, Dartmouth College

Cancers figure among the leading causes of morbidity and mortality around the world. This year alone, an estimated 1.5 million new cases of cancer will be diagnosed in the United States. Unfortunately, the demands for anticancer drugs cannot be met due difficult and extensive process of drug synthesis. To facilitate and expedite drug production, we designed a simple mathematical model for cancer growth in vitro in order to better study the effects of various drugs on tumor growth. In the past, numerous models of various complexities for tumor spheroids have been propose. However, the simple models only attempt to match total tumor size but does not account for other factors of tumor growth. Complex models, on the other hand, require knowledge of many specific parameters, some of which are hard to obtain. Our model is composed of the simplest possible system of ordinary differential equations that produces the qualitative results observed in tumor growth in vitro, such as the size of the necrotic core, VGEF levels, and tumor necrosis factor production. Using our model, we were able to successfully characterized the 3D spheroid growth of a neuroblastoma, the leading type of cancer in infants, with and without the treatment of anti-VGEF and cytotoxic anti-cancer drugs.

115. Topology of lasso proteins

Adam He Pomona College
Advisor(s): Erica Flapan, Pomona College

Historically, proteins have been viewed as topologically linear. Within a single polypeptide chain there may be many folds, helices, and subdomains, but if one disassociated the intermolecular interactions holding the tertiary structure together, the protein could be continuously deformed into a planar structure. However, work in the 1990s determined that a substantial minority of proteins contain topologically complex structures, including knots, links, and non-planar spatial graphs, that cannot be deformed into the plane. Some of these structures, most notably knotted proteins, have received extensive theoretical attention. A more recently discovered class of proteins, known as lasso proteins, have not been very well characterized from a topological perspective. These proteins consist of a closed loop pierced by some number of chain termini. This geometric complexity is believed to influence their stability and play a role in their physiological functions. We propose topological models of these proteins that are both consistent with biochemical principles and that capture the apparent stability of their tertiary structures.

116. Modeling Dermal Diffusion and Metabolism for Consumer Products

Megan Hollister Baylor University
Advisor(s): Marina Evans, North Carolina State University

The US EPA Toxcast program is interested in predicting toxicity information for over 80,000 chemicals. Dermal exposure of consumer products is a major concern. When a chemical comes in contact with the skin, it increases the likelihood that the chemical will penetrate the skin and enter the bloodstream, potentially resulting in toxicity for

several body organs. Given that performing experiments for each of these chemicals is costly and inefficient, the EPA has developed a research program to predict the toxicity effects of these chemicals. Computational methods, such as mathematical modeling and numerical analysis, play an integral part in dermal absorption predictions. Mathematical modeling has predominantly been used for the *in silico* calculation of dermal absorption parameters like permeability and penetration lag time. Dermal metabolism may contribute to clearing chemicals from the skin and therefore can prevent them from entering circulation. Current dermal models do not include metabolism, but a method for quantifying clearance after dermal absorption could significantly improve current model's results. Our research aims to develop a more accurate dermal model which will incorporate skin metabolism, absorption, and diffusion. Optimization will be used to find parameter values without experimental data, and then numerical methods will be used to approximate the analytical solution of our model. Our goal is to minimize the number of parameters while increasing confidence in our model's predictions. *(The views expressed in this paper are those of the authors and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.)*

117. Reverse Engineering Functional Brain Networks from fMRI Data Using Probabilistic Boolean Networks

Tiffany Jann University of California, Berkeley
Erin Boggess Simpson College
Advisor(s): Paola Vera-Licona, University of Connecticut Health Center, Center for Quantitative Medicine

The brain functions by communicating information across regions, and neurological diseases can alter the way these regions communicate. To characterize brain disorders and eventually propose systematic approaches to diagnosis, we should study the brain as a system and consider both its structure and dynamics. In the present work, we proposed a pipeline to reverse engineer static functional brain networks and dynamic mathematical models from fMRI data. Using probabilistic Boolean networks (PBNs) as our mathematical framework, our pipeline iterates through several steps, each with non-trivial aspects to resolve. We studied these steps using fMRI data generated from in silico networks, and successfully validated steps (1–2). For step (1), reverse engineering static functional brain network from fMRI data, we applied 44 reverse engineering methods and proposed a way to combine top-performing methods such that the result outperformed any individual method. In step (2), discretizing fMRI data into Boolean states, we proposed a novel metric to benchmark and rank 11 discretization methods. For step (3), inferring dynamical models, our preliminary studies are consistent with results from our proposed metric from step (2), and future work should focus on the validation of dynamic models.

118. Modeling *Toxoplasma gondii* transmission in cats

Emily Kelting University of Central Oklahoma
Advisor(s): Brittany Bannish, University of Central Oklahoma

We will discuss the transmission of *Toxoplasma gondii* and its effects in cats. Due to the severity of *T. gondii* spillover infections in pregnant women and monk seals, understanding its transmission dynamics in cats is key to unlocking preventive measures against this parasite. Taking into account susceptible and infectious cats and kittens, chronically infected cats, and the surrounding environment, I built a differential equations model of *T. gondii* transmission in cats. I will present my model and the results, identifying details of how the parasite is transmitted between cat hosts and how the risks to other species can be minimized.

119. A Mathematical Model for Copper Homeostasis in *Pseudomonas aeruginosa*

Brianna Kozemzak Saint Mary's College
Advisor(s): Pedro Mendes, Center for Quantitative Medicine, UConn Health

Copper is a necessary cofactor in many biochemical reactions, but it becomes toxic to cells when present in high levels. We are interested in modeling the copper homeostasis system in *Psuedomonas aeruginosa*, a bacterium responsible for thousands of healthcare acquired infections in the U.S. annually, as a complete model of this system could assist in the development of new antibiotics that target cuproproteins in the face of growing antibiotic resistance. Based on data provided to us by the Arguello group at WPI, we constructed a compartmental model for copper homeostasis using a series of ODEs that describe the changes in amounts of cuproproteins in the cell. We performed a systematic comparison of several combinations of global and local parameter estimation algorithms to approximate both kinetic parameters and the concentrations of cuproproteins in *P. aeruginosa*. We were able to sufficiently fit our model to

the data by invoking up-regulation of a certain cuproprotein. However, there is evidence that some parameters are highly interdependent, but measurement of a few protein levels could address this issue. These results will help our collaborators design experiments that produce the most crucial information for expanding our current model.

120. Using Optimal Control Theory to Treat Chronic Wounds With Oxygen Therapy

Nikhil Krishna Western Kentucky University
Arjun Kanthawar Western Kentucky University
Advisor(s): Richard Schugart, Western Kentucky University

Chronic wounds such as diabetic foot ulcers are the leading cause of non-traumatic amputation in developed countries. In order for researchers to better understand the physiology of these wounds, a mathematical model describing oxygen levels at the wound site can help predict healing responses. Daulton (2013) used optimal control theory to formulate a differential-equation model to optimize hyperbaric oxygen treatment strategies. The model consisted of three variables - oxygen, bacteria, and neutrophils - and a control variable for supplemental oxygen. Using a similar approach, we formulate a differential equation model with four variables adding a chemoattractant to better describe the healing response of the wound. We then numerically solve these differential equations to find the optimal amount of supplemental oxygen that would result in the most rapid rate of healing in a chronic wound.

121. Modeling Within Host Dynamics of Schistosomiasis

Alexandra Lara Emory Undergraduate
Luc Olivier University of South Florida
Advisor(s): Shelby Wilson, Morehouse College

Schistosomiasis, also known as snail fever, is a disease transmitted by several species of flatworms that are carried by freshwater snails. The primary goal of the present work is to model disease progression using systems of nonlinear ODEs. Parasite components considered are larvae, immature worms, mature worms, and eggs. Immune components modeled are resting macrophages, active macrophages and T lymphocytes (T-Cells). We investigate the sensitivity of the model with respect to relevant parameters. We then use the Quasi Steady State Assumption (QSSA) to derive two reduced models of schisto-immune dynamics. We compare the behavior of the reduced models to the behavior of the original system. In each case, a linear stability analysis is done.

122. Optimal Net Energy and Foraging Behavior of the Grus americana

Kristen Lawler Marist College
Advisor(s): John Alford, Sam Houston State University

The Aransas-Wood Buffalo whooping crane population is the last migratory flock of whooping cranes (*Grus americana*). They migrate from Wood Buffalo National Park (WBNP) in Alberta, Canada to Aransas National Wildlife Refuge (ANWR) in Texas every autumn. Whooping cranes became endangered during the late 1800s and the early 1900s due to overhunting and habitat loss, of which the latter remains a concern to this day. The energy accumulated while wintering in Texas plays a crucial role in the future survival of the whooping cranes both on an individual and reproductive basis. As a result, our research will focus on the net energy intake of the whooping crane and will analyze conditions under which we might expect a higher probability of reproductive success. We will then analyze the conditions in our parameter space under which maximization of the crane's energy intake occurs.

123. Association of Low-Frequency Variants in Regulatory Regions with Non-Syndromic Orofacial Clefts

Jessica LeClair Emmanuel College
Advisor(s): John Shaffer, University of Pittsburgh

Orofacial clefts (OFCs) are a category of birth defects occurring in 1 per 700 births. To determine genetic factors contributing to risk of non-syndromic OFCs, genome-wide association studies have been performed, detecting a multitude of associations. However, OFC heritability is not entirely explained by these findings. Being that OFCs are a consequence of a malfunction during development, enhancer sequences specific to craniofacial development thus are of great interest. Therefore, this study tested associations between low-frequency variants (minor allele frequency <1 5%) in regulatory craniofacial enhancers and non-syndromic OFCs using two statistical tests: Sequence Kernel Association

Test (SKAT) and Combined Multivariate and Collapsing Method (CMC). Our study revealed an association between cleft palate and an enhancer on chromosome 3, known to regulate the branchial arch during development (SKAT MAF<1% p-value:4.95×10^{-5}). There was also a suggestive association between cleft lip with or without cleft palate and an enhancer on chromosome 9, known to regulate the forebrain during development (SKAT p-values:5.0×10^{-3}, CMC p-values:1.4×10^{-3}). These findings demonstrate that low-frequency variants in craniofacial regulatory regions contribute to the complex etiology of OFCs.

124. Algebraic Structures Associated to Convex Neural Codes

Caitlin Lienkaemper Harvey Mudd College

Advisor(s): Mohamed Omar, Harvey Mudd College

Humans and other animals rely in part on hippocampal neurons known as place cells in order to form a mental representation of the external world and to locate themselves within it. These place cells become associated to convex regions of space known as their receptive fields: each place cell fires at a high rate precisely when the animal is in the receptive field. The firing pattern of a population of n place cells may summarized with combinatorial neural code, a subset $\mathcal{C} \subset \{0,1\}^n$ listing which sets of cells fire together. We say a neural code $\mathcal{C}$ is convex if there exist convex open sets $U_1, \ldots, U_n \subset \mathbb{R}^d$ such that, if the U_i were taken as place fields, the neural code they generate would be $\mathcal{C}$. We discuss strategies to identify which neural codes are convex and construct realizations of these codes using algebraic and combinatorial structures associated to them.

125. Impact of Light and Temperature on the Transpiration Ratio of Plants

Payson Lippert Montana Tech of the University of Montana

Advisor(s): Laurie Battle, Montana Tech of the University of Montana

A plant's efficiency is affected by different factors including light, temperature, water, and carbon dioxide uptake. When the stomata open to allow uptake of carbon dioxide for photosynthesis, water is lost through transpiration, and plants control this balance by opening and closing the stomata based on environmental conditions. While there are many factors that contribute to the loss of water and carbon dioxide uptake, the only factors used here are light and temperature. All other environmental factors were constant for this study, including soil moisture and relative humidity. One measure of efficiency is the transpiration ratio, defined as the rate of water loss through transpiration divided by the rate of carbon dioxide uptake. This balance is most efficient when the transpiration ratio is at its lowest. Three models were produced for the transpiration ratio as a function of light, temperature, and both light and temperature. Applying these models to potatoes, for instance, yielded a method to estimate the transpiration ratio according to the temperature of the leaf and the amount of radiance. Using these models, one can discover the ideal light and temperature conditions for a plant to be most efficient.

126. Tasmanian Devils and the End Game

Christian McRoberts Morehouse College

Advisor(s): Shelby Wilson, Morehouse College

A cancer known as Devil Facial Tumor Disease (DFTD) is currently ravaging the Tasmanian devil population in Tasmania. This cancer is of particular interest because it is communicable via physical contact between animals. Through the use of agent-based modeling (ABM), we created a population density model using MATLAB. This model outlines the spread of the disease including factors such as: age of reproduction, age of natural death, age of death due to disease, contact frequency, and migration rates. We use this model to simulate different strategies designed to maintain the population of healthy Tasmanian devils. Strategies investigated are quarantining susceptible individuals versus quarantining infected individuals. We also consider the frequency with which these interventions must be performed in order to maintain the population of healthy animals. Our preliminary work confirms that the spread of the disease depends on the frequency of animal interactions as opposed to the density of animals in a particular region. This model suggests eradication strategies of DFTD which might save the current Tasmanian devil population from going extinct.

127. Dynamically modeling the financial impact of influenza: an actuarial approach to epidemiology

Chaisonne Moore University of Central Oklahoma
Advisor(s): Sean Laverty, University of Central Oklahoma

The goal of this project is to use mathematical models to determine the most cost effective decisions on treatment of influenza as different stages of the epidemic unfold. We will build a model that describes how an epidemic progresses by tracking the transitions of individuals between different stages of infection and accumulated healthcare-related costs relative to in-place health care policy decisions. The annual variation of disease burden will be modeled dynamically and allow for a more specific response each year in terms of cost.

128. Implementing BLAST on the GPU Utilizing MERCATOR

Kimberly Orlando Saint Mary's College
Advisor(s): Jeremy Buhler, Washington University in Saint Louis

We performed the beginning steps of verifying the MERCATOR framework by implementing the BLAST algorithm on the GPU with no prior experience working with GPUs. BLAST is a biology algorithm that searches for matching sections of DNA between a query sequence and a database. MERCATOR is a framework designed to take care of all the queuing, irregular data flow, and movement between modules that is difficult to perform on a GPU.

129. Modeling Pioneer Plant Populations in the Monteverde Cloud Forest

Sarah Petersen Hope College
Advisor(s): Brian Yurk, Hope College

The pioneer plants that colonize forest canopy gaps require high light conditions for germination and eventual reproduction. The light environment, which changes rapidly as the gap ages, is dependent on the initial size of the gap. To persist, a pioneer plant population must have a large enough presence in the seed bank and grow rapidly enough to take advantage of new gaps, which are infrequent (comprising about 1.6% of forest area each year) and ephemeral (sometimes closing within a few months). We investigate questions related to gap formation dynamics and gap-size dependent plant demography, within the context of over thirty years of field data from the cloud forest of Monteverde, Costa Rica. The resulting empirical models will be used to understand the spatial interactions between forest gap dynamics, avian dispersal of seeds, and plant demography. We will discuss some of the initial gap size — demography relationships that we have found, as well as a method for estimating the distribution of canopy gaps of a particular size across the whole forest given the occurrences of gaps along a transect, a generalization of Buffon's needle problem.

130. Mathematically Modeling Cancer Metastasis Through Mechanical Properties Detected By A Microfluidic Microcirculation Mimetic

Sruti Prathivadhi Creighton University
Advisor(s): Andrew Ekpenyong, Creighton University

Accounting for over 90% of cancer deaths, metastasis is a complex process by which cancer translocates to organs away from the primary tumour site. Unfortunately, existing cancer drugs do not target metastasis as our understanding of the process is limited. In this project we mathematically model the mechanical properties of metastasizing cancer cells during their circulation in blood vessels. Specifically, we consider the fluid dynamics involved behind our microfluidic platform which mimics capillary constrictions of the pulmonary and peripheral microcirculation. Using the Navier-Stokes equation and COMSOL Multiphysics® simulations, we extract the elastic and viscuous properties of the cancer cells. This work is a first step towards establishing cell mechanics as a readout to assist in effective anti-metastatic drug development.

131. Using Latin Hypercube Sampling and Partial Rank Correlation Coefficient Analysis on a Wound Healing Model

Carson Price Western Kentucky University
Vishnu Boyareddygari Western Kentucky University
Advisor(s): Richard Schugart, Western Kentucky University

Latin Hypercube sampling (LHS) is a stratified method that samples from a multidimensional parameter distribution. Partial Rank Correlation Coefficients (PRCC), a multivariable regression analysis, of the LHS values assesses the

sensitivity of the parameters. This method has been used in conjunction with a wound-healing ordinary differential equation (ODE) model formulated by Krishna and Pennington (2015). By assigning various probability distributions to the parameters to be sampled by LHS, more accurate parameter estimates may be produced. Thus far, a uniform distribution has been utilized due to the availability of only average patient data. From curve fits of patient data, a mean and standard deviation can be found for forming a normal distribution for all the parameters. The output of the ODE model when the parameter values are substituted may be compared to actual wound healing responses to measure the validity of our model. A combination of new patient data, output from the ODE model, and PRCC values should indicate the most sensitive attributes of wound healing, in regards to diabetic foot ulcers.

132. Solving a Tear Film Model with a Spectral Method

Tim Reid George Mason University
Advisor(s): Daniel Anderson, George Mason University

We study a model that couples tear film dynamics, blinking, and contact lens motion. The model is a partial differential equation that approximates tear film thickness on a contact lens. The contact lens motion is governed by an ordinary differential equation that depends on blinking. A numerical solution for the model is calculated using a modified Chebyshev spectral method for the spatial derivatives, and the method of lines for the time evolution. The numerical solution is then compared to similar models that measure tear film thickness in the absence of a contact lens and during an up/down saccade of the eye.

133. Investigating the Spatial Effects of Severe Drought on a California Newt Population

Slade Sanderson Pepperdine University
Advisor(s): Timothy Lucas, Pepperdine University

The severe drought in Southern California has widespread consequences on the local ecosystem. The California newt (*Taricha torsosa*), an amphibian that is native to the Santa Monica Mountain stream system, is facing population declines due to pressures such as climate change. The current drought in Southern California is limiting the space available for newt oviposition because newts prefer to lay their eggs in deep, slow-moving pools of water. We create a mathematical model to investigate the effects of persistent drought on a newt population in Cold Creek, a pristine creek in the Santa Monica Mountain stream system. We build from a previous discrete model that describes California newt life-stages and expand it to create a spatial compartmental model that represents specific stream segments that can be altered by drought. We use our model to predict the spatial effects of climate change on the newt population in Cold Creek.

134. Modelling Host, Parasite, and Commensal Interactions to Determine Pollution Levels

Monika Satkauskas Creighton University
Advisor(s): Rebecca Gasper, Creighton University

Pollution can affect the biodiversity of an area. Environmental scientists have proposed the severity of pollution of an area can be determined by studying the interactions of organisms in an area. Using field site data from the Pine Ridge Indian Reservation, we offer a model for a freshwater snail-trematode-Chaetogaster ecosystem, which is composed of five coupled ordinary differential equations. This host-parasite-commensal model was modified to account for the effects of pollution in the microsystem. A numerical solver in Mathematica 10 was utilized to create simulations for the model, using NDSolve to manipulate slider graphs. We found the periodicity between the populations changed as the level of pollution was varied. Our results suggest increasing pollution changes the steady state of the system.

135. Modeling the Spread of the Zika Virus in Rio de Janeiro During the 2016 Olympics

Brian Satterthwaite University of Portland
Advisor(s): Hannah Callender, University of Portland

The Zika Virus (ZIKV) is an arbovirus that is spread by mosquitoes of the Aedes genus and is also strongly associated with Microcephaly, a condition that affects the development of the brain of a fetus. With the recent emergence of Zika in Brazil, we developed an agent based model to track mosquitoes, locals and tourists throughout the 18 days of the 2016 Olympics in Rio de Janeiro in order to determine how the Olympics would affect the spread of the virus. There are many unknowns regarding the spread and prevalence of Zika, and as many as 80% of infected individuals are not

aware of their infectious status. We therefore discuss results of experiments where several parameters were varied, including the rate at which mosquitoes successfully bite humans, the percent of initially infected mosquitoes, the size of the human population, and the size of the mosquito population. From these experiments we offer projections on the possible severity of Zika spread throughout the Olympics.

136. Biological Network Motifs from Gene Duplication

Ashley Scruse Clark Atlanta University
Advisor(s): Robert Robinson, University of Georgia, Athens

Studies of network growth by duplication and the occurrences of motifs motivated my project. In my research project gene biological network motifs from gene duplication in full and partial duplication models are studied. Given an original graph G0 we used statistical methods used to calculate the expected number of any given motif in both models. We analyzed the expected number of copies of a random gene and the number of edges after d duplications in the graph Gd for both the full and partial duplication models. In then end, we were able to produce an expression for the expected number of copies after d duplication for the full and partial duplication models for a k-vertex motif. Also, for the full duplication model we were able to find expressions for the standard deviation for the k-vertex motif.

137. Analyzing the Zika Virus Through the Replicator-Mutator (RM) Model

Isabel Serrano California State University, Fullerton
Advisor(s): Anael Verdugo, California State University, Fullerton

Currently, the Zika virus is being investigated due to its recent outbreak in Latin America. Although properties of the virus have been identified—including its mode of transmission and link to birth defects—the infection's subtle symptoms make the illness difficult to diagnose. Given that the infection was perceived as a mild illness many of the diseases properties remain unknown. As simple models graze over the unique behaviors diseases exhibit, this work aims to create a robust model that analyzes disease transmission from an evolutionary perspective. We incorporate compartmentalizing techniques inspired by the Susceptible-Infected-Recovered (SIR) model and ordinary differential equations to assess the diseases progress within a population. Based on current literature, we found the Replicator-Mutator (RM) model, which describes a population with three competing subgroups. The RM model contains the three principles of Darwinian evolution—replication, mutation, and selection. In addition, the model accounts for competitive strategies and interactions between subgroups, providing a biologically accurate assessment of a population. Applying the RM model to the Zika virus, we analyze the model's parameters to create a best-fit curve for the data compiled on the Zika outbreak.

138. Curvature Profile of Crawling Worms

Faith Shaw James Madison University
Advisor(s): Eva Strawbridge, James Madison University

Worm movement can be quantified by acquiring data from videos of them crawling. Therefore, it is possible to see differences in motion for wild type versus mutated worms. We collect videos of crawling C. elegans in order to elucidate differences between genetically-altered and wild-type worms. Our work implements an algorithm that extracts the center line and computes the curvature of a worm using undergraduate calculus. Our data shows that as time passes, the location of areas of maximum curvature increases linearly in time. If successful, this experiment can be applied to understand more about basic research in locomotion, which may have broad impacts for the study of diseases, such as Parkinson's Disease.

139. Modeling Two-Patch Populations with Logistic Growth and Allee Effect

Jasper Short Virginia State University
Advisor(s): Junping Shi, The College of William and Mary

Species experience various challenges or situations in different population. So not all populations are the same for the same species. After researching previous models, we notice some parts in their symmetrical patch model we could change. We try to model these difference of populations through asymmetric patches with Logistic Growth and Allee Effect differential equations. When Logistic Growth is used to model a population extinction isn't possible. However, when Allee Effect is used to model a population extinction is very possible. But when they are combined the two in a

network structure we prove that one population helps the other population survive. We also, the study the number of Equilibrium point and where they are located. Plus, knowing that there is an absence of periodic orbits is important to know the system converges to the Equilibrium points. Also, our diagrams give us some knowledge as of where the number of Equilibrium points change.

140. A Mathematical Model of Skeletal Muscle Regeneration

Elizabeth Stephenson University of Texas at Arlington
Advisor(s): Hristo Kojouharov, University of Texas at Arlington

While the cellular mechanisms behind mammalian skeletal muscle regeneration have been rigorously studied, no mathematical models have previously been established to demonstrate the regenerative process of disease-free, damaged muscle. Such a model can aid the scientific and medical communities as they seek to more effectively heal patients with damaged muscles by giving researchers a tool with which to mathematically forecast the outcomes of new treatments prior to implementation. A system of seven ordinary differential equations is introduced to model the interactions between classically and alternatively activated macrophages, satellite cells, myoblasts, myotubes, healthy myofibers, and damaged myofibers. The equations incorporate the sequential, overlapping stages of muscle regeneration following injury: immune response and subsequent cell proliferation, differentiation, and fusion. The system is mathematically analyzed, yielding one stable, biologically meaningful equilibrium which suggests total recovery. A set of numerical simulations is performed to illustrate the performance of the proposed equations. The ability to mathematically forecast the outcome of changes in medication could prove useful in healing damaged muscle faster and more completely. Next, we plan to collaborate with colleagues researching bone rehabilitation to explore the interactions between muscle and bone in the regenerative process.

141. Numerically Solving a System of Partial Differential Equations modeling Bacterial Infection

Stefan Stryker Western Kentucky University
Advisor(s): Richard Schugart, Professor of Mathematics at WKU

Chronic wounds can cause medical complications for patients. Oxygen therapy can be used to treat these injuries, but improvements to oxygen therapy could occur if a mathematical model was used to investigate the wound healing process. Our research is to numerically solve a system of four partial differential equations that represent densities of bacteria, neutrophils, oxygen, and chemo-attractant. We are solving this system by using a finite volume approach that can provide numerical solutions that will later be incorporated into an optimal control model.

142. Characterization of migration phenotype of pancreatic cancer cell lines using mathematical modeling

Enakshi Sunassee University of South Florida
Advisor(s): Arig Hashim Ibrahim, Moffitt Cancer center

Based on the acid-mediated tumor invasion theory, cancer cell growth is promoted in an acidic environment which is usually toxic to normal cells. The aim of this project was to model the impact of acidic tumor microenvironment on the migration of pancreatic cancer cell lines. Methods: Two cell lines from the same heterogeneous tumor from mice with Kras, Trp53 mutations (KPC mice) were used: UN-KPC-960 and UN-KPC-961. From pancreatic cancer literature, it is known that UN-KPC-960 represents the less acid producing cell line while UN-KPC-961 depicts the higher glycolytic cell line. The Boyden chamber migration assay was performed and migration trends were determined based on the degree of staining in each pH condition. The extent of migration was compared. Agent-based mathematical models were generated in MATLAB using a series of differential equations to further investigate the behavior of both cell lines separately in each pH conditions. Migration rates from experimental results were used in the simulations. The models were also extended to analyze the tumor growth when both cell lines compete. Results: The results from our experiments and mathematical models show that not only does a normal pH record a slower tumor growth but it also promotes the growth of the less glycolytic-hence less invasive- cell line. Conclusion: Thus, by increasing the pH of the tumor microenvironment-possibly via bicarbonate treatment- we can potentially promote the growth of the less invasive cell line and control pancreatic cancer.

143. Nonlinear Elastic Dynamics of Vascular Ehlers-Danlos Syndrome

Timothy Thorn University of North Carolina at Asheville
Advisor(s): Becky Sanft, University of North Carolina at Asheville

Vascular Ehlers-Danlos Syndrome (vEDS) is a genetic disorder that affects connective tissue. Stemming from a mutation in the type III procollagen gene (COL3A1), this disorder often results in major artery rupture and frequently is only diagnosed post-mortem. These factors and others make vEDS difficult to study clinically, and much is still unknown regarding the nonlinear elastic dynamics of the large arteries whose rupture is the most common cause of death for vEDS patients. A previous study was identified which used linear elasticity to calculate the modulus of elasticity using data from a group of patients with age and gender matched controls. In this study, the artery is modeled as a hyperelastic thick-walled tube. Using blood pressure and wall displacement measurements from vEDS and control patients, the inverse problem was solved to approximate the wall stiffness. The model exhibits differences in the nonlinear elastic dynamics between the patient and control group, though some differences were statistically insignificant, possibly owing to a small original cohort ($n = 16$). Our results indicate that application of our technique to a more sophisticated data set should result in more conclusive findings.

144. Demographic Modeling of an Indiana Bat Population to Wind-Energy Stress

Tiffany Tu The George Washington University
Sarah Oldfield Sewanee
Advisor(s): Eric Eager, University of Wisconsin, La Crosse

Wind energy development is an increasingly prevalent source of renewable energy in the U.S. and worldwide. However, an increase in wind energy use comes at a cost. The Indiana Bat (Myotis sodalis) faces a risk of extinction due to wind energy development through collisions with wind turbines during migration. We collaborated with conservation managers at agencies such as the US Fish and Wildlife Service (USFWS) to model population trends of the M. sodalis (e.g., Thogmartin et al. 2013) and recovery efforts for future management decisions (e.g., Erickson et al. 2014). Using a population projection matrix adapted from Thogmartin et al., we calculated the growth rate, population inertia, extinction probability, and sensitivity and elasticity with respect to each parameter, which will be used to assist in the recovery and conservation efforts of Indiana Bat populations. The matrix model is stage-structured and divided by reproductive status: pups, juveniles, and adults. The survival and reproductive parameters transition between the four seasons. We found that the most sensitive parameters were the adult winter survival and the adult summer survival; therefore, conservation efforts should focus towards protecting adult bat populations during the winter and summer.

145. Using Bayesian Statistics and DRAM code to Analyze Parameters in a Differential Equations Model

Rachel Turner Western Kentucky University
Jacob Menix Western Kentucky University
Advisor(s): Richard Schugart, Western Kentucky University

The purpose of this project is to use Bayesian statistics to analyze values of parameters for a system of differential equations that models wound healing. This model was formulated by Krishna and Pennington to demonstrate the healing process of diabetic foot ulcers by describing relationships between matrix metalloproteinases, their inhibitors, and extracellular matrix. A Bayesian approach is used when the availability of data is sparse, as it is in this case. A Metropolis-Hastings algorithm is implemented using Delayed Rejection Adaptive Metropolis (DRAM) code to estimate parameters with previous estimations as the informative prior. Running the DRAM code using the differential equations model, prior estimations, and individual patient data, allows us to refine the parameters and find associated confidence intervals. This will help improve the wound-healing model in order to better predict wound-healing outcomes for individual patients.

146. One bird, two bird? Red bird, blue bird? Analyzing bird songs using wavelets, image processing, and neural networks

Alli VanderStoep Hope College
Advisor(s): Paul Pearson, Hope College

Biologists, ecologists, and bird enthusiasts want to estimate bird population trends in order to monitor changes in ecosystems. Recently, time-consuming field observations of birds have been augmented by audio recordings of birds.

In the lab, we deciphered the types of birds singing in these recordings. We used wavelet transforms to convert audio signals into images called scalograms. These scalograms display bird songs in a format similar to sheet music; they show how the pitch and volume of a bird's song change over time. After applying denoising methods to the images, we trained a neural network to identify the birds from the processed images.

147. Comparative Analysis of Linear and Nonlinear Dimension Reduction Techniques on Mass Cytometry Data

Emily Vidal Angelo State University
Nathan Jekel Penn State Harrisburg
Advisor(s): Anna Konstorum, University of Connecticut Health Center

Mass cytometry is a new technology for immune cell classification that can measure up to 100 markers per cell. We compare the performance of four mathematical dimension reduction techniques—principal component analysis (PCA), isometric feature mapping (Isomap), t-distributed stochastic neighbor embedding (t-SNE), and diffusion maps—on high-dimensional mass cytometry data. First, we implement the techniques on a benchmark data set with manually gated cell populations and compare the results using three metrics: computation time, residual variance, and neighborhood proportion error. We find that t-SNE and diffusion maps are the most effective methods for preserving local distance relationships among cells. Also, in two-dimensional visualizations, t-SNE exhibits well-defined phenotypic clustering and diffusion maps appear to show cell differentiation pathways with projections along each diffusion component. Next, we apply diffusion maps to a novel dataset from mouse-derived T cells, representing acute inflammation. In two dimensions, we observe that a rare population of T cells, TCRgd, maps to the extreme range of a top diffusion component. This indicates that the phenotype of these cells is distinct from the assayed cell population with respect to the majority of markers.

148. Using an Agent-Based Approach to Analyze the Effects of Barriers on Crayfish and Newt Population Dynamics

Rachel Schueller University of Miami
Advisor(s): Courtney Davis, Pepperdine University

The California Newt (*Taricha torosa*) is a native amphibian species found in the Santa Monica Mountain stream system. The population has been in recent decline leading to localized extinctions. Their primary predator is the red swamp crayfish (*Procambarus clarkii*), an invasive species originally from the Southeastern United States. This crayfish is resistant to the newt's natural defensive toxins and preys on newt egg masses and larvae. It has been shown that extensive trapping of the crayfish can help to protect the newt populations. Natural and artificial barriers have also been shown to moderately hinder crayfish movement between stream segments. I have built an agent-based model that uses the program NetLogo to create a biologically grounded simulation of newt and crayfish population dynamics using local field data. Specifically, this model implements spatial stream components and artificial barriers. We also incorporate previous work on crayfish trapping with the addition of these optimized barriers to simulate the effects that man-made interventions can have on the crayfish population and predict how well these various measures could be implemented to help save local newts.

149. Modeling growth, nutrient uptake and nitrate reductase activity in phytoplankton from a freshwater urban pond and lake

Karl Schuchard University of Wisconsin-Milwaukee
Advisor(s): Gabriella Pinter, University of Wisconsin-Milwaukee

Freshwater phytoplankton are typically limited by nitrogen or phosphorus. Additions of these nutrients lead to blooms, so understanding nutrient metabolism is important in predicting ecosystem responses. Nitrate metabolism was studied in an urban pond and large lake using controlled incubations of whole-water cultures. Cultures were either not enriched, or enriched with phosphate, and nitrate or ammonium and followed for two weeks, measuring nutrients, chlorophyll, particulate C and N, the activity of a key enzyme, nitrate reductase (NR), and kinetics of nitrate uptake and NR activity. An agent-based mathematical model is built to investigate whether community responses to nitrate can be predicted from properties of individual species and community composition. Literature values are used to parameterize the model for four common phytoplankton species. The model uses an internal quota for nitrogen that is increased by uptake through NR activity, and determines when a cell divides. Two sources of nitrogen, nitrate and ammonium, are

assumed to be present in the environment, and are accounted for as the community grows. Ongoing work includes the comparison of the agent-based model to population-level models and the experimentally collected data.

150. An Investigation of the Equilibrium Statistics of Vortex Filaments and the Pivot Algorithm

Aleksandr Lukanen Augsburg College
Advisor(s): Pavel Belik, Augsburg College

A replication and expansion of previously published results by Chorin in the early 90s concerning the statistical equilibrium of vortex filaments on a cubic lattice are presented here. The numerical and graphical results help show that the modified pivot algorithm presented here gives a much better estimation of the point of statistical equilibrium for a vortex filament over a larger range of temperatures, both positive and negative. The most interesting of these results is that statistical equilibrium of a filament found with the original pivot algorithm depends on the initial configuration of the SAW (self-avoiding walk), using our algorithm can help alleviate this pattern. In addition, the entropy of these vortex filaments is computed using the hypothetical scanning method of Meirovitch.

151. Finding Minimal Spanning Forests in a Graph

Phillip Nadolny St. Olaf College
Abdel-Rahman Madkour St. Olaf College
Advisor(s): Matthew Wright, St. Olaf College

In the computation of multidimensional persistent homology, a popular tool in topological data analysis, a family of planar graphs arises. We have studied the problem of partitioning these graphs in a way that will be useful for parallelizing the persistent homology calculation. Specifically, we desire to partition an edge-weighted, undirected graph G into k connected components, $G_1, \ldots, G_k$. Let w_i be the weight of a minimum spanning tree in component G_i. For our purposes, an ideal partition is one that minimizes $\max\{w_1, \ldots, w_k\}$. This problem is known to be NP-hard in the case of general graphs and we are unable to find this specific problem in the graph partitioning literature. We propose two approximation algorithms, one that uses a dynamic programming strategy and one that uses a spectral clustering approach, that produce near-optimal partitions in practice on a family of test graphs. We present detailed descriptions of these algorithms and the analysis of empirical performance data.

152. Complexities of Bi-Colored Rubik's Cubes

Taylor Pieper Butler University
Advisor(s): Jonathan Webster, Butler University

Which of two bi-colored cubes is the simpler puzzle? The differences in the coloring of the cubes creates different symmetries that dramatically reduce the number of states each cube can reach. Which of the symmetries is most reductive? The answer to these questions can be achieved by discovering and comparing the "God's Number" for these cubes.

153. Local Regularization Methods for Image Deblurring with Poisson and Mixed Poisson-Gaussian Noise

Jeremy Rachels Reed College
Advisor(s): Xiaoyue Luo, Linfield College

Photon-limited imaging arises when the number of photons collected by a sensor array is small relative to the number of detector elements. Photon limitations are an important concern for many applications such as spectral imaging, night vision, nuclear medicine, and astronomy. We examine the method of local-regulation for the solution of convolution equations in the presence of Poison and mixed Poisson-Gaussian noise. We use a Gaussian approximation to the Poisson noise statistic, establish a correspondence between the local regularization and standard Tikhonov regularization methods, and discuss effective parameter selection strategies. We include a numerical implementation that demonstrates the efficacy of this method.

154. Accelerating Thermoacoustic Thomography

Parisa Samareh Virginia Tech
Advisor(s): Julianne Chung, Virginia Tech

Thermoacoustic Tomography (TAT) is an imaging technique used to display a cross section through a solid object. TAT exceeds the health benefits of other tomographic methods such as x-ray and ultrasound because it does not require as much radiation, making it a safer alternative. However, like many inverse problems, the process of TAT is extremely involved and subsequently still under development. This research investigates computational improvements to TAT that increase the method's efficiency as well as overall accuracy.

155. Dynamical Systems: Bouncing Superball

Sam Tang Weston High School
Jena Yun Philips Exeter Academy
Vandana Agarwal Stuyvesant High School
Advisor(s): Jeremy Booher, Stanford University

In this Bouncing Superballs research project, we start by exploring the physics of a bouncing superball and its differences with an ordinary ball. Once we have understood the physics and use math to model the motion of the superball, we further investigated the ball's periodic and dense orbits in different environments such as bouncing between the table and ceiling and bouncing in regular polygons. We proved the existence of periodic orbit when the ball bounced in the polygon and disproved periodic orbits when bouncing between two walls. We then used a technique called the unfolding technique to analyze how an ordinary ball bounced within a polygon, concluding that a dense orbit was possible. However, we note that not every polygon can be modelled using this technique. We then explored how a superball bounces up and down a staircase and the existence of dense orbits in polygons with more than 4 sides.

156. Developing Colorimetric Comparisons for Paper Analytical Devices

Catalina Vajiac Saint Mary's College
Advisor(s): Ian Bentley, Saint Mary's College

Paper Analytical Devices (PADs) use a series of colorimetric chemical tests that indicate the presence of active ingredients in a chemical sample. While the trained eye can determine if colors of interest show up on a PAD, digital image analysis can provide a faster and more objective way of analyzing color, particularly for semi-quantitative tests. We are developing an automated analysis code that will allow any user to interpret the results of a PAD, even without background in chemistry. We implemented an algorithm that compares an image of a PAD to an existing catalog by assigning Boolean values to each pixel. We find an accepted range for RGB values by assuming that these values are normally distributed. We also developed a metric which determines the background lighting of an image. Binning groups of RGB values allows for an automated routine to differentiate between yellow and blue light, as well as between dim and brightly lit images. The methods used implement specific techniques of image recognition, creating a rapid automated analysis that has practical implications in the use of PADs as a tool to detect low-quality pharmaceuticals in third-world countries.

157. Geometric Flows of Polygons

Elijah Barnes Lewis & Clark College
Mack Beveridge Lewis & Clark College
Advisor(s): Paul Allen, Lewis & Clark College

We study polygon flows, in which the vertices of a polygon move according to a differential equation. Previously Chow and Glickenstein studied a linear flow that takes polygons to affine transformations of regular polygons. We study two nonlinear flows, which we conjecture take polygons to regular polygons. We present numerical evidence for our conjecture and prove the conjecture in certain symmetry classes.

158. CVC of Lorentzian 3-Dimensional Model Spaces with Diagonalized Ricci Operators

Anastassia Doktorova Colorado College
Advisor(s): Corey Dunn, California State University San Bernardino

This research revealed that Lorentzian, 3-Dimensional model spaces, whose curvature tensor's associated Ricci operator is diagonalizable, will have constant vector curvature (we say M has $cvc(\epsilon)$ for some $\epsilon \in \mathbb{R}$) under some

circumstances. In these circumstances, we know the value of ϵ, and ϵ is unique. In the circumstances where the model space does not have $cvc(\epsilon)$, we know which vectors in the model space prevent it from having $cvc(\epsilon)$. These vectors form a subspace tangent to the light cone.

159. Splitting Numbers of 10-Crossing Links

Erin Frassetto Ripon College
Rebecca Sorsen University of Nebraska-Lincoln
Advisor(s): Luke Williams, Kansas State University

The splitting numbers of links with 9-crossings or less are known. Using methods previously implemented on links with 9-crossings or less, we recover the splitting numbers of 10-Crossing links. These methods uncovered the splitting numbers of almost all of the 287 10-crosings links, which had previously been unknown.

160. Polygon spaces and quaternionic Grassmannians

Seungji Kim Ewha Womans University
Advisor(s): JaeHyouk Lee, Ewha Womans University

In this paper, we study the polygon spaces and related Grassmannian spaces. We introduce new model or the relation between Grassmannians and moduli space of polygons in $\mathbb{R}^3$ by using Hermitian matrix group over complex. And extending these to quaternions, we show the relations between quaternionic Grassmanians and polygons in $\mathbb{R}^5$ via spin represenation. Moreover, we also give a hierarchical ralation among Gassmanians and polygon spaces over real, complex and quaternions via involutions induced from complexification.

161. Solutions of Einstein Constraint Equations using the Conformal Method

Tamara Kozareva University of California, San Diego
Advisor(s): James Dilts, University of California, San Diego

The Einstein constraint equations have been a subject of research since the middle of the 20th century. The Einstein constraint equations represent restrictions on initial data in general relativity and are given by a system of elliptic differential equations. When studying these equations, one objective is to find the full set of initial data on a given Riemannian manifold. Since there are four equations with twelve unknowns, a useful decomposition of initial data is needed. The conformal method provides a suitable decomposition of initial data. It offers a way to split initial data into determined and freely specifiable pieces. The conformal method has been useful for the development of solutions with constant mean curvature (CMC) on closed manifolds, because for CMC data the equations decouple, which makes working with them relatively simple. However, little is known about the far-from-CMC case; hence, it is important to establish whether the parameterization of initial data using the conformal method for the far-from-CMC case is as simple as for the near-CMC case. It was thought that all mean curvature cases will share the simplicity of the near CMC case. However, our numerical results show that for the far-from-CMC case the conformal method is not as useful as for the near CMC case. In this project, we came to the conclusion that the conformal method provides a poor parameterization of initial data for far-from-CMC data. Therefore, improvement of the conformal method is needed to get better parameterization of initial data.

162. Equal Point Separation by Planar Cell Decompositions

Nikhil Marda MIT PRIMES-USA
Advisor(s): Borys Kadets, Massachusetts Institute of Technology

We investigate the problem of separating a set X of points in $\mathbb{R}^2$ with an arrangement of K lines such that each cell contains roughly the same number of points. The stabbing number of a curve is the maximum number of intersections possible between the curve and a line in the plane (possibly excluding a finite number of lines). We show that large subsets of X lying on Jordan curves of low stabbing number are an obstacle to equal separation. We further discuss Jordan curves of minimal stabbing number through X. Our results generalize recent bounds on the Erdős-Szekeres Conjecture, showing that for fixed d and sufficiently large n, if $|X| \geq 2^{c_d n/d + o(n)}$ with $c_d = 1 + O(\frac{1}{\sqrt{d}})$, then there exists a subset of n points lying on a Jordan curve of stabbing number at most d.

163. Generating Space-Filling Trees

Nicholas Nelsen Oklahoma State University
Advisor(s): Henry Segerman, Oklahoma State University

Many objects in nature display self-similar fractal patterns during growth, including snowflakes, trees, and vascular networks. A mathematical object that behaves similarly is the space-filling tree. A space-filling tree is an infinite sequence of trees T_i, $i \in \mathbb{N}$, embedded in space such that T_i contains T_{i-1} and the closure of the union of the T_i is the whole space. We write an algorithm in Python that generates a sequence of trees in $\mathbb{R}^2$ or $\mathbb{R}^3$ that begin at a root on the boundary of a closed convex region and iteratively spread out with new branches into this region according to a predetermined rule. Different parameters were introduced to vary the appearance and characteristics of the space-filling trees, which we visualized in Rhinoceros 3D. We show that in $\mathbb{R}^2$, the resulting sequence of trees will be space-filling. We also calculate the average path length from the root to an arbitrary point in the space for different space-filling trees. Motivated by considering an efficient design of a transport system such as the human bronchial tree, we expect there to exist an optimal tree with a small average path length. We weigh this notion of optimality for various cases.

164. Lorentzian Geometry on Lie Algebras

Sabrina Walker Longwood University
Advisor(s): Thomas Wears, Longwood University

We present a preliminary report on the investigation of Lorentzian scalar products on Lie algebras. We make use of the automorphism group of a Lie algebra to establish canonical forms of Lorentzian scalar products. We then use the canonical forms to find scalar products that correspond to algebraic solitons.

165. Combinatorial and Algebraic Properties of the Generalized Crown Graph

Carlos Agrinsoni Santiago University of Puerto Rico at Cayey
Advisor(s): Luis Garc a Puente, Sam Houston State University

Given a graph, one can study an algebraic invariant of the graph known as a sandpile group. These sandpile groups have been studied and determined for many families of graphs. In 1974, Trotter defined a family of undirected graphs known as *generalized crown graphs*. In this paper we discuss some combinatorial and algebraic properties of the generalized crown graph. We show that certain types of generalized crown graphs are isomorphic to other well known families of graphs, some of whose sandpile groups have already been determined and others are still unknown.

166. Sequences of Line Graphs of Star Graphs and Variants

Brenden Balch University of Central Oklahoma
Advisor(s): Liz Lane-Harvard, University of Central Oklahoma

In 1965, van Rooij and Wilf considered sequences of line graphs, in which they grouped sequences of line graphs into four categories. We'll add to their research by presenting results on sequences of line graphs for star graphs. We will then investigate slight variations of star graphs.

167. Non-Existence of Uniformly Most Reliable Two-Terminal Networks

Hayley Bertrand St. Norbert College
Owen Goff Rensselaer Polytechnic Institute
Advisor(s): Christina Graves, University of Texas at Tyler

A 2-terminal network is a network in which resources are assumed to flow from one node, called the source, to another, called the sink. We represent these networks as graphs, where the 2-terminal reliability of such a graph is the probability that there exists a path from the source vertex to the sink vertex when each edge is included with probability p. Given a fixed number of vertices n and a fixed number of edges m, a graph is uniformly most reliable if it is most reliable for all p in $[0, 1]$. We present specific values of n and m for which a uniformly most reliable graph does not exist as well as values of n and m for which there does exist a uniformly most reliable graph.

168. Games on Graphs: Seepage!

Julie Bowman Southwest Baptist University
Nicholas Lindell University of Georgia
Advisor(s): Robert Bell, Michigan State University

The game of Seepage, first described by Clarke, et al. in 2009, is played by two players, Sludge, S, and Green, G, on a directed acyclic graph with a single source and several sinks. S and G alternately claim vertices of the graph, which subsequently cannot be claimed by the opponent. Sludge begins by claiming, or 'contaminating', the source. Afterwards, in sequence, G can claim, or 'protect', any vertex on the graph, while S can contaminate any vertex adjacent to an already contaminated vertex. S is said to win if any sink is contaminated; otherwise, G wins. The generalized version of this game allows G to claim multiple vertices each turn. The *green number* of a graph H, $gr(H)$, is defined to be the minimum k such that G can guarantee victory with at most k moves on each turn. Graphs are called *green-win* if $gr(H) = 1$, *sludge-win* if $gr(H) > 1$ and k-*green-win* if $gr(H) = k$. In their paper, Clarke, et al. characterized green-win and k-green-win rooted trees T, providing a polynomial time algorithm for determining if $gr(T) = k$. We introduce a more generalized algorithm that determines if $gr(H) = k$ for any directed acyclic graph, as well as methods to reduce the number of vertices and edges of a graph without changing the green number.

169. Labeling crossed prisms with a condition at distance two

Serena Chen Olin College
Jessica Oehrlein Olin College
Advisor(s): Denise Troxell, Babson College

An $L(2,1)$-labeling of a graph is an assignment of nonnegative integers to its vertices such that adjacent vertices are assigned labels at least two apart, and vertices at distance two are assigned labels at least one apart. The λ-number of a graph is the minimum span of labels over all its $L(2,1)$-labelings. A generalized Petersen graph (GPG) of order n consists of two disjoint cycles on n vertices, called the inner and outer cycles, respectively, together with a perfect matching in which each matching edge connects a vertex in the inner cycle to a vertex in the outer cycle. A prism of order $n \geq 3$ is a GPG that is isomorphic to the Cartesian product of a path on two vertices and a cycle on n vertices. A crossed prism is a GPG obtained from a prism by crossing two of its matching edges; that is, swapping the two inner cycle vertices on these edges. We show that the λ-number of a crossed prism is 5, 6, or 7 and provide complete characterizations of crossed prisms attaining each one of these λ-numbers.

170. Packing Colorings of Graph Products

Catherine Cooper Trinity College
Advisor(s): Kirsti Wash, Trinity College

The packing chromatic number $\chi_\rho(G)$ of a graph G is the smallest integer k such that $V(G)$ can be partitioned into disjoint classes $X_1, \ldots, X_k$ where any pair of vertices in X_i are distance greater than i apart for each $i \in \{1, \ldots, k\}$. Goddard et al. showed that for any grid graph $P_m \square P_n$, $\chi_\rho(P_m \square P_n) \leq 23$. It was later proven by Ekstein et al. that $\chi_\rho(\mathbb{Z}^2) \geq 12$ where $\mathbb{Z}^2$ represents the infinite 2-dimensional grid. In an effort to give the exact upper bound for $\chi_\rho(P_m \square P_n)$ for any positive integers m and n, we investigate packing colorings in the hierarchical product of two paths.

171. Decompositions of a Complete Graph with a Hole

Jessica Finocchiaro Florida Southern College
Roxanne Back
Advisor(s): **Roxanne Back, Florida Southern College**

The most well-known design is a Steiner Triple System which can be constructed by starting with a complete graph and decomposing it into triangles. In general, a G-design on H is an edge-disjoint decomposition of H into isomorphic copies of G. In the designs studied, we let H be a complete graph with a hole and G be a complete graph on four vertices minus one edge, $K_4 - e$. Many of these designs can be constructed by using one-factors and difference methods. The necessary conditions will be presented along with some generalized results.

172. A Computer-Aided Approach to Edge-Colored Graph Problems

Eric Frazier La Salle University
Advisor(s): Janet Fierson, La Salle University

Let G be an edge-colored connected graph. G is said to be rainbow connected if for each vertex pair u, v in G there exists some u-v path in which each edge has a unique color. We create a coloring graph for G in which each rainbow coloring of the graph G is represented by a vertex, and an edge is inserted for each pair of vertices corresponding to two rainbow colorings of the graph G that differ only in the color of a single edge. Using technology, we represent graphs as adjacency matrices and adjacency lists and determine whether each graph is rainbow connected, properly edge colored, or both. By generating all possible adjacency matrices corresponding to a graph on a given number of vertices, we can observe properties of coloring graphs under rainbow connection, as well as under proper edge coloring. We can identify members of graph families such as cycles that can appear as coloring graphs, and we can propose graphs that cannot appear as coloring graphs. After employing technological assistance as a means to form conjectures, we subsequently apply mathematical tools to prove these conjectures.

173. An Exploration of Divisor Graphs and Fractional Matching Number

Justin Groves Winthrop University
Advisor(s): Arran Hamm, Winthrop University

A divisor graph is a particular graph whose vertex set consists of positive integers and edge set is given by the division relation. This type of graph is relatively unstudied and we have been exploring its properties. Specifically we have analyzed the fractional matching number of the divisor graph concretely using *Mathematica* and asymptotically when the number of vertices tends to infinity. We hope to fully determine the asymptotic value of this graph parameter as well as examine related parameters for this family of graphs.

174. Concussion Detection using Graph Theory and Logistic Regression

Devika Jhunjhunwala University of Richmond
Shuyi Chen University of Richmond
Quinn McDonough University of Richmond
Advisor(s): Kathy Hoke, University of Richmond

Current methods for diagnosing concussions focus on self-report of injury and the symptoms that follow. Toward a more physiological approach, we examined the utility of quantitative electroencephalography (qEEG) in aiding the diagnosis of concussions. As a first step, we evaluated the utility of graph theoretic techniques as tools for measuring the connectivity of the brain. For each subject, we converted coherence data from qEEG into unweighted, undirected graphs, with each node corresponding to an electrode on the subject's scalp. We then computed measures across the whole graph, as well as two subgraphs corresponding to the left and right halves of the brain. In addition, we developed indicators of fault tolerance by removing key nodes from the graph and then re-computing the measures. In the end, we used these measures to distinguish subjects who had incurred concussions from those who had not.

175. Randic Connectivity Indices for Decagonal Graphs

Kateryna Kaplun Montclair State University
Advisor(s): Aihua Li, Montclair State University

In this research project, we investigate graphs made of n regular decagons and their Randić Connectivity Index (RCI) values. These graphs, called decagonal graphs, come from biology and chemistry applications. We give an explicit formula for the RCI value of each decagonal graph without interior vertices. The graphs with maximum or minimum RCI among this group are identified. We further show that a symmetric cycle of decagons must be of size 4, 5, or 10. We give an explicit formula for symmetric cycles of decagons.

176. Randić Connectivity Index Values of Trees with Maximum Degree at Least 3

Giancarlo Labruna Montclair State University
Advisor(s): Aihua Li, Montclair State University

The Randić Connectivity Index, or RCI, was introduced in 1975 by Milan Randić. It has been used as a molecular descriptor in quantitative structure-activity relationship and quantitative structure-property relationship studies. We

consider graphs that are derived from biology and chemistry. We first investigate trees with maximum degree at least 3. For certain such trees, we give explicit formulas for the RCI values. We then determine among all the trees with maximum degree at least 3 which ones admit the maximum RCI. Similar results are obtained for monocyclic graphs that are derived by adding one edge to such a tree.

177. Avalanche Polynomial of the Complete Bipartite Graph $K_{m,n}$

Drisana Mosaphir Harvard University
Karlie Elliott Humboldt State University
Maleek Richardson North Carolina A&T State University
Advisor(s): Luis David Garcia-Puente, Sam Houston State University

The sandpile model on a graph is a classical example of dynamical system exhibiting self-organized criticality. Given a graph G, this model can be visualized by dropping grains of sand onto the vertices of G. When the amount of sand on a vertex v exceeds the degree of v, that vertex topples, sending one grain of sand along an edge to each of its neighbors. Such a toppling may trigger new vertices to topple resulting in an avalanche. The dynamics of these topplings are recorded by the multivariate avalanche polynomial, which encodes the size, frequency and large scale structure of the avalanches on the graph. Formulas for avalanche polynomials have been computed for complete graphs, wheel graphs, cycles, and trees. We build off of these examples as well as the work of Dukes and Le Borgne to calculate a general form of the multivariate avalanche polynomial for the case of complete bipartite graphs.

178. Domination in the Hierarchical Product and Vizing's Conjecture

Shriya Nagpal Trinity College
Advisor(s): Kirsti Wash, Trinity College

Given a graph G, a set $S \subseteq V(G)$ is a dominating set of G if every vertex of G is either in S or adjacent to a vertex in S. The domination number of G, denoted $\gamma(G)$, is the minimum cardinality of a dominating set of G. Vizing conjectured in 1968 that $\gamma(G\Box H) \geq \gamma(G)\gamma(H)$ where $G\Box H$ represents the Cartesian product of G and H. In 1995, Hartnell et al. identify a class of graphs, called Type χ graphs, for which the conjecture is true. We identify another class of graphs for which the conjecture holds. We also study domination in the hierarchical product $G \sqcap H$, which is a generalization of the Cartesian product, and give lower bounds on $\gamma(G \sqcap H)$ that show a trend to Vizing's conjecture.

179. Local Moves on Meanders

Isabella Nang Georgia State University
Ida De Vierno Georgia Institute of Technology
Advisor(s): Heather Smith, Georgia Institute of Technology

A meander of order n is a non-self-intersecting single closed curve in the plane which crosses a horizontal line in $2n$ points. While the study of meanders dates back to Poincare (1912), exact enumeration of meanders remains an open problem. In an effort to estimate the number of meanders via MCMC sampling methods, we define a local move on meanders and study properties of the resulting state space graph. While our local move is a restriction of the move studied by Heitsch and Tetali (2011), their techiques do not carry over to our setting. In an effort to prove that the graph is connected, we explore a class of meanders formed by Kreweras complementation. We prove that the subgraph induced on this set of exponentially-many meanders is connected. We are hopeful that this discovery will lead to a proof that the entire graph is connected.

180. Maximizing the number of homomorphisms into V_k

Andrew Pallotto Montclair State University
Kevin Weatherwalks Montclair State University
Advisor(s): Jonathan Cutler, Montclair State University

A graph homomorphism is an edge-preserving mapping from the vertex set of a graph G to the vertex set of an image graph H. Let $\hom(G, H)$ be the number of homomorphisms from G to H. Much work has been done to understand which graphs maximize $\hom(G, H)$ when G is restricted to a certain class of graphs and H is some fixed graph. Recently, Engbers studied the problem of maximizing $\hom(G, H)$ when G is a connected graph on n vertices with minimum degree δ and H is not a regular graph. We consider a specific 2-regular image graph V_k, a path on k vertices

with looped endpoints. (In this case, loops contribute one to a vertex's degree.) We derive several formulas for the number of homomorphisms from a particular graph on n vertices to V_k. We also show which graph is extremal for $\hom(G, V_k)$ when G is a graph on n vertices with minimum degree one or two, giving a different proof of a special case of a result of Engbers. Lastly, we investigate this problem when G is connected.

181. Algebraic Properties of Labeled Graphs Joined by j Edges

Shahriyar Roshan Zamir Georgia Gwinnett College
Advisor(s): Daniel Pinzon, Georgia Gwinnett College

Joining any two labeled graphs with j undirected edges can be viewed as a binary operation on the set of labeled graphs. We also define the following relation: two labeled graphs, G_1 and G_2, are j-related if and only if for any labeled graph H, the determinant of the adjacency matrix of G_1 j-operated with H is the same as G_2 j-operated with H. The paper, *The Determinant of Graphs Joined by j Edges, [Gyurov,Pinzon]* gives the determinant of the adjacency matrix of G j-operated with H as a sum of of the determinants of of the adjacency matrices of variations of G and H, for any two labeled graphs G and H. This expression allows us to explore the j-relation equivalence classes for the j-operations and their algebraic structure.

182. Optimal Density of the Open-Locating-Dominating Sets of Snub Trihexagonal Tilings

Jeffrey Shi Jamestown High School
Advisor(s): Gexin Yu, College of William and Mary

The Open Locating Dominating (OLD) sets are sets of vertices on a graph where each point has at least one neighbor (adjacent vertex) and no point in the set has the same neighbors within the set. The optimal density of the OLD sets has been found for the Infinite Triangular tiling and bounds have been found for the Infinite Hexagonal tiling. In this work, we have obtained partial results for the OLD sets of the Snub Trihexagonal tiling.

183. Prime Labelings of Hypercube Graphs

Giana Solviletti Providence College
Kayla Johnson Providence College
Michelle Cruz Providence College
Advisor(s): Cayla McBee, Providence College

A prime labeling on a hypercube graph, Q_k, with 2^k vertices is a labeling of the vertices its by the numbers $1, 2, 3, \ldots, 2^k$ in such a way that the labelings of any two adjacent vertices are relatively prime. Determining whether a hypercube graph has a prime labeling for a given value of k is a challenging question. Exhaustive search algorithms are not feasible for even relatively small values of k given the large number of possible labelings. This project focuses on the development of a more efficient algorithm that utilizes the mathematical structure of the hypercube graph to determine whether or not Q_k has a prime labeling for a specified value of k. Original proofs that Q_k is not prime for certain k values as well as specific prime labelings for other values of k will also be presented.

184. 3×3 Rook's graph: the unique smallest graph requiring 3 lazy cops

Nikolas Townsend Emmanuel College
Mikayla Werzanski Emmanuel College
Advisor(s): Brendan Sullivan, Emmanuel College

The pursuit-evasion game of *cops & robbers* on graphs has been studied extensively since its introduction in the 1980s. A recently-proposed variant, *lazy cops & robbers*, allows just one cop to move per round. In both variants, we seek the *cop number* of a graph G (denoted $c(G)$ or $c_L(G)$) which is the minimum number of cops required to guarantee victory. Beveridge et al. have shown that the Petersen graph is the unique smallest structure which requires 3 ordinary cops. We have adapted this result to the lazy cops variant, showing that the 3×3 Rook's graph ($R_3 = K_3 \square K_3$) is the unique smallest structure which requires 3 lazy cops. In general, we conjecture that R_n is the unique smallest structure with $c_L = n$. We will share a proof of the $n = 3$ case which is based on general facts about lazy cops and arguments invoking the maximum degree of a graph. We will also share some partial results towards proving the general conjecture.

185. Spanning Tree Modulus and Homogeneity of Undirected Graphs

Sarah Tymochko College of the Holy Cross
Derek Hoare Kenyon College
Advisor(s): Nathan Albin, Kansas State University

The p-modulus of a family of objects on a discrete graph provides a method for quantifying the "richness" of the family. When applied to the family of spanning trees of a simple, undirected graph, modulus has a particularly interesting probabilistic interpretation. Among all possible probability mass functions (pmfs) on the set of spanning trees, modulus selects those that most evenly distribute the usage of graph edges. If a graph admits a pmf such that all edges are equally likely to appear in a random spanning tree, the graph is called homogeneous. If the uniform distribution on spanning trees is optimal, the graph is called uniform. We present a necessary and sufficient condition for a graph to be both uniform and homogeneous. Numerical experiments suggest large, well-connected, non-homogeneous graphs are rare. We present a sufficient condition for the homogeneity of d-regular, connected graphs. This condition suggests that as d gets large, d-regular graphs are almost surely homogeneous. Since any graph can be decomposed into homogeneous components using a process called deflation, understanding homogeneous graphs is the primary focus of this project.

186. Small Graphs with Generalized Quaternion Automorphism Group

Lillian Webster Grinnell College
Kripa Khanal University of Texas at Dallas
Samuel Edwards Gettysburg College
Advisor(s): Stephen Graves, University of Texas at Tyler

For a finite group G, the value $\alpha(G)$ denotes the minimum number of vertices of a graph Γ such that $\operatorname{Aut}\Gamma \cong G$. Given an integer m, $e(G, m)$ denotes the minimum number of edges of a graph Γ on m vertices such that $\operatorname{Aut}\Gamma \cong G$. We investigate edge minimal graphs with automorphism group isomorphic to the generalized quaternion group Q_{2^n}. We will determine the value of $e(Q_{2^n}, m)$ for $m = \alpha(Q_{2^n}) + k$ and $k \leq 3$, and in the special case of $n = 3$, we also determine the value of $e(Q_8, \alpha(Q_8) + 4)$.

187. On the Secure-Domination Number of Full Balanced Binary Trees with 2^n Leafs

John Weeks Lee University
Advisor(s): Peter Johnson, Auburn University

The secure-domination number $\gamma_s(G)$ of a finite simple graph G is the smallest size of a set of vertices in G which is both secure and dominating in G. It is elementary that $\frac{\gamma_s(G)}{|V(G)|} \geq \frac{1}{2}$. A currently unsolved problem: Find the largest number $g \in (\frac{1}{2}, 1]$ such that there is a sequence (H_n) of distinct connected graphs such that $\lim_{n\to\infty} \frac{\gamma_s(G)}{|V(H_n)|} = g$. In early work on this problem the full balanced binary trees G_n (which has 2^n leafs, each a distance n from the root vertex) were of interest. They are no longer, but the unexpected difficulty of determining $\gamma_s(G_n)$ has made this determination of interest in itself. In this session we show that $\liminf_{n\to\infty} \frac{\gamma_s(G_n)}{|V(G_n)|} \geq \frac{8}{15}$ and give a construction of a secure-dominating set $S_n \subseteq V(G_n)$ such that $\lim_{n\to\infty} \frac{|S_n|}{|V(G_n)|} = \frac{11}{20}$. However, we find that S_n is not a minimum secure-dominating set in G_n for $n \geq 6$.

188. Graph Properties of Blockade Games

Yolanda (Yaodan) Zhang Beloit College
Advisor(s): Darrah Chavey, Beloit College

Blockade games are a class of games where the players alternate turns moving their pieces along edges of a graph from one vertex to an unoccupied vertex, where you lose the game if you have no legal move to make on your turn. Our research attempted to identify some properties of a graph that make the associated blockade game "interesting." Our team approached this from both a mathematical viewpoint of identifying and proving properties of graphs that generate good games, and a computer simulation viewpoint, simulating the play of the game for candidate graphs. I was responsible for the mathematics aspect of our research. Several "real-life" versions of these games exist, all on graphs with high degrees of connectivity. The focus of my research was on "maximal blockade games" where the two players have as many pieces as possible, so that only 1 or 2 vertices are initially unoccupied. My research showed that good games with 1 unoccupied vertex must not contain vertices of degree 1, and good games with 2 unoccupied vertices

must not contain an edge whose removal disconnects the graph. Part of my work was to do initial investigations of some of the many types of graph properties that might affect the playability of the game, and to provide the computer science student with conjectures on some of the other properties, on which he could then run simulations to support or invalidate those conjectures. Focusing on smaller graphs, I also analyzed alternatives for the graphs used in such "real-life" games.

189. A Statistical Model for Detecting Concussion

Tianyuan (Patty) Zhang University of Richmond
Sinong Li University of Richmond
Harrison Wenzel University of Richmond
Advisor(s): Joanna Wares, University of Richmond

To date, doctors have used patients self-report of injury and symptoms to diagnose concussion. This poster explains our use of quantitative electroencephalography (qEEG) data to build a statistical model that can aid diagnosis by providing physiological evidence of concussion. To build the model, we first used Graph Theory to translated EEG coherence data, measured from combat exposed Veterans at rest, into numerical measures of aspects of brain networks. We then used statistical analysis, including logistic regression, to build a model to predict the probability of concussion based on these numerical measures. To be effective predictors in a logistic regression model, variables must be good individual predictors of concussion as well as explain unique aspects of a concussion's physiological effects. We explain how we chose our predictors to accomplish this. We then tested our method on a data set consisting of qEEG output of combat-exposed veterans, some with concussions and some without concussions.

190. 3D Printing in Mathematics Education

Lewis Istok Augsburg College
Advisor(s): Matthew Haines, Augsburg College

With the advent of cheaper 3D printers and user-friendly computer aided design (CAD) software, digital fabrication is becoming more prevalent in mathematics education. This paper looks at literature on incorporating 3D printing into mathematics education as well as literature regarding the role of 3D visualizations in mathematics education. The synthesis of the literature indicates potential next steps for effective use and development of 3D printers in the mathematics classroom. The poster also provides examples of lessons utilizing 3D printed models and the design process in connection with middle school mathematics and Calculus 3.

191. Cluster Analysis: A Pedagogical Investigation

Kallie Simpson Slippery Rock University
Advisor(s): Dil Singhabahu, Slippery Rock University

In recent years, there has been a debate in the education field regarding the success of using "flipped" classrooms as a new teaching pedagogy. Flipped learning is defined by flippedlearning.org to be, "a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment. . . ." The lack of published literature regarding this topic is hindering the improvement of the learning process. The primary purpose of our study is to perform statistical, and more specifically, cluster analysis using complete-linkage clustering and k-means algorithm on the final grades from students that took Elementary Statistics 1 taught in regular and flipped classroom settings by a single professor at Slippery Rock University to identify clusters that might give insight into the two different teaching pedagogies. The original data collection took place from Fall of 2013 to Spring of 2015, where each class spanned a single semester. These classes include a variety of majors, class status , genders, and evaluation methods. This study will be expanding the quantity of data and analysis of a project completed last semester. This project concentrates on Hierarchical Clustering and K-Means Clustering through the use of R software. We hope the results will contribute towards better understanding the advantages/disadvantages of flipped teaching.

192. The Role of Cronbach's Alpha Coefficient in Analyzing the Reliability of a Testing Instrument

John Yannotty Slippery Rock University
Advisor(s): Dil Singhabahu, Slippery Rock University

In order for a testing instrument o be considered valid, it must be proven to be reliable. The concept of reliability refers to the internal consistency of the test results over a period of time. One method to quantify reliability is Cronbach's Alpha coefficient, which was developed by Lee Cronbach in the early 1950 s. Cronbach's Alpha is derived from The Classical Test Theory which states any observed test score is comprised of a true and an error score. The true score represents the actual knowledge of the test taker, while the error variable accounts for any potential mistakes that influence the final observed scores. Cronbach's Alpha coefficient is derived from manipulation of the principles outlined by the Classical Test Theory to calculate reliability. Once the reliability coefficient is computed, it can then be used to estimate the true score and determine the consistency of the test itself. The purpose of our study is to develop a tool that will test the reliability of an instrument for comparing flipped teaching pedagogy to traditional teaching. Our reliability test tool is inspired by the Cronbach's Alpha coefficient. The first part of the study was to mathematically derive Cronbach's Alpha coefficient. Going forward, the coefficient will be used to ensure the testing instrument is reliable and can be depended upon in order to find a conclusion. In the poster we will discuss the mathematical derivation, adaptation to our study, and the results from using the tool on tests to measure its reliability.

193. Factorizations, elasticity, and Frobenius numbers of numerical monoids generated by a double arithmetic sequence

Vanessa Aguirre University of Hawaii at Hilo
Seneca Cox University of Hawaii at Hilo
Advisor(s): Brian Wissman, University of Hawaii at Hilo

Much is known about numerical monoids with two generators as well as those with generators forming an interval or an arithmetic sequence. When the generators are not of these forms, numerical monoids exhibit more complicated behavior. We introduce a monoid generated by a double arithmetic sequence or the numerical monoid $\langle a, b, a+s, b+s\rangle$, and we assume that $s|a$ and $a < b$. We give a general expression for the Frobenius number of these numerical monoids and provide a proof for when $b = a + 1$ and $s \geq a/s$. In this case, the Frobenius number for monoids generated by a double arithmetic sequence is equal to the Frobenius number of $\langle b, s\rangle$, the monoid generated by b and s. In addition, we compare the elasticity of elements in $\langle a, b\rangle$ with those in a monoid generated by a double arithmetic sequence $\langle a, b, a + s, b + s\rangle$. While it is known that the overall elasticity of the monoid generated double arithmetic sequence is larger than that of the monoid $\langle a, b\rangle$, we explore their differences in elasticity element-wise.

194. Some complexity results in the theory of normal numbers

Dylan Airey University of Texas at Austin
Advisor(s): Bill Mance, IMPAN

Let $\mathcal{N}(b)$ be the set of real numbers which are normal to base b. A well known result of H. Ki and T. Linton is that $\mathcal{N}(b)$ is $\mathbf{\Pi}^0_3$-complete. We show that the set $\mathcal{N}^\perp(b)$ of reals which preserve $\mathcal{N}(b)$ under addition is also $\mathbf{\Pi}^0_3$-complete. We use a characterization of $\mathcal{N}^\perp(b)$ given by G. Rauzy in terms of an entropy-like quantity called the noise. It follows from our results that no further characterization theorems could result in a still better bound on the complexity of $\mathcal{N}^\perp(b)$. We compute the exact descriptive complexity of other naturally occurring sets associated with noise. One of these is complete at the $\mathbf{\Pi}^0_4$ level. Finally, we get upper and lower bounds on the Hausdorff dimension of the level sets associated with the noise.

195. Strong Accessibility: Forging a Link Between Accessible and Large Sets

Monica Busser Youngstown State University
Sarah Cooney Saint Joseph's University
Maria Macaulay St. Olaf College
Advisor(s): Bruce Landman, University of West Georgia

A D-diffsequence is defined as a sequence $x_1, x_2, \ldots, x_k$ of positive integers where $x_i - x_{i-1} \in D$ for all $i \in [2, k]$. We then define $\Delta(D, k; r)$ to be the least positive integer such that when $[1, \Delta(D, k; r)]$ is colored with r colors

there is a k-term D-diffsequence in one of the colors. We call the set D r-accessible if $\Delta(D, k; r) < \infty$ for all k. Similar concepts are defined for arithmetic progressions, where $R(A_D, k; r)$ and largeness for arithmetic progressions are equivalent to $\Delta(D, k; r)$ and accessibility for diffsequences. The concepts of largeness and accessibility of sets have been well researched by Ramsey Theorists. Here we will define and explore a concept that we named strong accessibility, defined to be between accessibility and largeness. We call a D-diffsequence whose first three terms form an arithmetic progression a β-sequence and define $\beta(D, k; r)$ and strong accessibility to be the equivalents of $\Delta(D, k; r)$ and accessibility for diffsequences. We will present our results regarding strong accessibility in relation to the sets $T = \{2^i \mid i \geq 0\}$, the Fibonacci Numbers, the positive integers, and $V_m = \{x \in \mathbb{Z}^+ \mid m \nmid x\}$.

196. Leading Digit Distribution, Continued Fractions, and Probabilistic Diophantine Approximation

Zhaodong Cai University of Illinois at Urbana-Champaign
Matthew Faust University of Illinois Urbana Champaign
Yuan Zhang Uiuc
Advisor(s): Hildebrand, University of Illinois Urbana-Champaign

It has long been known that sequences such as $\{2^n\}$, $\{F_n\}$ satisfy Benford's law. That is, the frequency of leading digits is not uniform but given by the Benford distribution, $P(d) = \log_{10}(1+1/d)$, for $d = 1, 2, \ldots, 9$. In our research, we focus on the distribution of the error between the Benford prediction and the actual count for each digit for certain classes of arithmetic sequences. Empirical evidence suggests that the distribution of the error is in some cases normal with slowly increasing standard deviation, while in other cases it is uniform over a fixed interval. We try to explain this behavior in light of recent work by Beck on probabilistic Diophantine approximation, and formulate conjectures based on this work and connections with continued fractions.

197. Decrypting the Link Between Elliptic Primes and Twin Primes

Devin Ferri Renaissance High School
Javier Hernandez Nampa Senior High School
Anthony Luo Boise High School
John Elizarraras Treasure Valley Mathematics and Science Center
Isabel Swafford Boise High School
Advisor(s): Liljana Babinkostova, Boise State University

The increase in computational efficiency over the past few years has lead to the need for stronger encryption systems, catalyzing the growth in cryptography research. A curve of the form $y^2 = x^3 + Ax + B$, where A, $B \in \mathbb{Z}$ is known as an elliptic curve. Elliptic curves are increasingly prevalent in modern cryptosystems. Our research focused on the notion of elliptic primes, some of their properties, their relationship with a variety of elliptic curve characteristics, as well as some of their applications in cryptography. Through the exploration of a formula of Euler, prior work on elliptic primes and elliptic six-cycles, and elliptic gaps, we were able to analyze aspects of the elliptic curves.

198. Some Variations of Fibonacci Sequence

Dominique Forbes Coastal Carolina University
Tyler Sullivan Coastal Carolina University
Advisor(s): David Duncan, Coastal Carolina University

We determine a family of recursively defined sequences, determine their growth rates, and describe how they arise by modifying the assumptions of the rabbit population used by Fibonacci in motivating his famous sequence.

199. Enumerating Analogous Carmichael Numbers

Anthony Gurovski Butler University
Advisor(s): Jonathan Webster, Butler University

Our goal is to enumerate sets of pseudoprimes described by Hugh Williams as analogous to Carmichael Numbers. These composite numbers pass primality tests for Lucas Sequences in the same way that Carmichael Numbers pass primality tests using Fermat's Little Theorem. We enumerate these numbers using a new algorithm that is similar to Richard Pinch's tabulation method for Carmichael Numbers.

200. Slopes of Some Newton Polygons

Vanshika Jain PROMYS
Advisor(s): Glenn Stevens, PROMYS

We analyze the slopes of Newton polygons, the lower convex hull of a set of points, to explore the behavior of $\rho_i(\nu)$, a function, as ν goes to infinity. The sequences we study inform us about power series. We show that the first three sets of points satisfy a linear recurrence while the final set does not. As one of our main results, we prove a necessary and sufficient condition for a set of points to be in a recurrence, applying this to the the newton polygon of points we were studying.

201. Unique Integers on the Catalan Triangle

Eric Jovinelly Muhlenberg College
Nathan Benjamin Kutztown University
Edgar Jaramillo University of California, Berkeley
Advisor(s): Eugene Fiorini, Muhlenberg College

The Catalan Triangle is the number triangle whose entries, denoted $c_{n,k}$, give the number of strings with n X's and k Y's, where $n, k \in \mathbb{N}$, such that no initial segment has more Y's than X's. While it is easy to show that every positive integer appears at least once on the Catalan Triangle, very little is known about which integers appear uniquely. This poster investigates the sequence of integers that appear uniquely on the Catalan Triangle. In doing so, we present an algorithm to determine whether a given integer is unique on the triangle. Together with this algorithm, we have submitted the sequence of unique integers on the Catalan Triangle to the OEIS for review. Furthermore, we present conditions that guarantee uniqueness if met. Specifically, we we will show that all the primes appear uniquely on the Catalan Triangle except for 2,5. Additionally, for all primes p and integers $i \geq 2$, p^i does not appear in the Catalan Triangle whenever $p^i \notin \{3^2, 3^3\}$ and k is composite or equal to 2.

202. Ramification of Wild Automorphisms of Laurent Series Fields

Kenz Kallal Boston University - PROMYS
Hudson Kirkpatrick Boston University - PROMYS
Advisor(s): Laurent Berger, cole Normale Sup rieure de Lyon

We study the structure of the Nottingham group $\mathcal{N}(\mathbb{F}_p)$ of power series $f \in X \cdot \mathbb{F}_p[[X]]$ with $f'(0) = 1$ where $p > 2$ is prime, which is isomorphic to the group of wild automorphisms of $\mathbb{F}_p((X))$. We concern ourselves with power series $g \in \mathcal{N}(\mathbb{F}_p)$ with $g^{\circ m} \neq X$ for all $m \geq 1$ (that is, power series of infinite order in $\mathcal{N}(\mathbb{F}_p)$), and we determine a necessary and sufficient criterion for such $g \in \mathcal{N}(\mathbb{F}_p)$ having ramification type $i_n(g) = 3(1 + \cdots + p^n)$ given a finite number of coefficients of g. We also conjecture analogous results for higher ramification based on the results of a computer program, generalizing Fransson's 2016 theorem on 2-ramified power series, as well as the work on minimally ramified power series used in a 2013 result of Lindahl and a 2015 result of Lindahl–Rivera-Letelier.

203. On Consecutive Primitive nth Roots of Unity Modulo q

Siddarth Kannan Pomona College
Matthew Litman The Pennsylvania State University
Thomas Brazelton The Johns Hopkins University
Advisor(s): Joshua Harrington, Cedar Crest College

Given $n \in \mathbb{N}$, we study the conditions under which a finite field of prime order q will have adjacent elements of multiplicative order n. In particular, we analyze the resultant of the cyclotomic polynomial $\Phi_n(x)$ with $\Phi_n(x+1)$, and exhibit Lucas and Mersenne divisors of this quantity. For each $n \neq 1, 2, 3, 6$, we prove the existence of a prime q_n for which there is an element $\alpha \in \mathbb{Z}_{q_n}$ where α and $\alpha + 1$ both have multiplicative order n. Additionally, we use algebraic norms to set analytic upper bounds on the size and quantity of these primes.

204. Improved error bounds for the Fermat primality test on random inputs.

Jared Lichtman Dartmouth College
Advisor(s): Carl Pomerance, Dartmouth College

We investigate the probability that a random odd composite number passes a random Fermat primality test, improving on earlier estimates in moderate ranges. For example, with random numbers to 2^{200}, our results improve on prior estimates by close to 3 orders of magnitude.

205. Recurrence relation for rook placement on Genocchi boards in 4 and higher dimensions

Stephanie Loewen Grand Valley State University
Vasily Zadorozhnyy Grand Valley State University
Advisor(s): Feryal Alayont, Grand Valley State University

The two-dimensional rook theory can be generalized to three and higher dimensions by assuming that rooks attack along hyperplanes. Using this generalization, Alayont and Krzywonos defined two families of boards in any dimension generalizing the triangular boards of two dimensions whose rook numbers correspond to Stirling numbers of the second kind. One of these families of boards is the family of Genocchi boards whose rook numbers are the Genocchi numbers. This combinatorial interpretation of the Genocchi numbers provides a new triangle generation of the Genocchi numbers. In our project, we investigate whether such a similar triangle generation exists for the generalized Genocchi numbers in four and higher dimensions.

206. Infinite Product Exponents for Modular Forms

Nitya Mani Stanford University
Asra Ali MIT
Advisor(s): Ken Ono, Emory University

Recently, D. Choi obtained a description of the coefficients of the infinite product expansions of meromorphic modular forms over $\Gamma_0(N)$. Using this result, we provide some bounds on these infinite product coefficients for holomorphic modular forms. We give an exponential upper bound for the growth of these coefficients. We show that this bound is also a lower bound in the case that the genus of the associated modular curve $X_0(N)$ is 0 or 1.

207. Anomalous Primes and the Elliptic Korselt Criterion

Eric Neyman Princeton University
Jackson Bahr Carnegie Mellon University
Yujin Kim Columbia University
Gregory Taylor College of William & Mary
Advisor(s): Liljana Babinkostova, Boise State University

We define a Bachet anomalous number to be any prime power q such that there is an elliptic curve $y^2 = x^3 + B$ of order q over the field of q elements. We show that, conditional on a special case of the Tijdeman-Zagier conjecture, the Bachet anomalous numbers are exactly the prime powers of the form $3n^2 + 3n + 1$. This result has been proven unconditionally for $q = p^r$ where $r = 1$; we prove the result unconditionally when r is 2 or a multiple of 3. We then examine Type I elliptic Korselt numbers, a class of pseudoprimes introduced in a paper by Joseph Silverman. We generalize a result of Silverman that sets conditions on when a Type I elliptic Korselt number must be a product of anomalous primes. Finally, we establish a probabilistic result that, conditional upon a conjecture, almost all Type I elliptic Korselt numbers that are a product of two distinct primes are a product of anomalous primes.

208. Units in Quadratic and Multi-Quadratic Fields

Adam Pratt Birmingham-Southern College
Advisor(s): Maria Stadnik, Birmingham-Southern College

We investigate multi-quadratic fields, looking for those that contain units of norm -1. We prove explicit results concerning the existence of units of norm -1 in fields of the form $\mathbb{Q}(\sqrt{2p})$ for prime $p \equiv 1 \mod 4$. We also prove that if the quadratic field $\mathbb{Q}(\sqrt{2p})$ has a unit of norm -1, then so does the multi-quadratic field $\mathbb{Q}(\sqrt{2}, \sqrt{p})$ if $(\frac{2}{p}) = -1$.

209. On A Modification of the Collatz Problem

Miguel Quime Los Angeles Mission College
Michelle Orozco Los Angeles Mission College
Advisor(s): Werner Horn, California State University, Northridge

The Collatz problem deals with the patterns that arise from a map,

$$T(n) = \begin{cases} \dfrac{n}{2} & \text{if } n \equiv 0 \bmod 2 \\ \dfrac{3n+1}{2} & \text{if } n \equiv 1 \bmod 2 \end{cases}$$

as it iterates even and odd integers. This conjecture states that iterating any positive integer n will eventually lead to the value 1. In our research, the following modification will be investigated:

$$T_p(x) = \begin{cases} \dfrac{x}{p} & \text{if } x \equiv 0 \bmod p \\ \dfrac{(p+1)x - r(x)}{p} & \text{if } x \not\equiv 0 \bmod p \end{cases}$$

where $p > 2$ is prime, $0 < r(x) < p$, such that $(p+1)x - r(x)$ is divisible by p. We will provide some probabilistic results that indicate for any prime p and any positive integer x, the sequence $T(x)$ either converges to some $n \in \{1, 2, \ldots, p-1\}$, or lapses into a closed loop of integers. Indeed, our preliminary results indicate probabilistic properties such as $P(T^{n+1}(x) < T^n(x)) = \dfrac{1}{p}$ and $P(T^{n+1}(x) \geq T^n(x)) = \dfrac{p-1}{p}$, which indicates there are at least $(p-1)$ limit behaviors.

210. Discerning New Patterns in the Generalized Collatz Function Utilizing Big Data Analysis

Shyam Sai Illinois Mathematics and Science Academy
Advisor(s): James Choi, Sabio Research

The Collatz Conjecture has eluded mathematicians for decades. It is widely conjectured that any initial integer n, when recursively inputted to $f(n) = \begin{cases} \frac{n}{2} & n \equiv (0 \bmod 2) \\ 3n+1 & n \equiv (1 \bmod 2) \end{cases}$, creates a hailstone sequence that converges to 1. However, the Generalized Collatz Function, a variable form of the Collatz function, is a relatively new function that is not studied by many since its first proposition by Zhongfu and Shiming. In our research, we consider this function, using the logic $f(n) = \begin{cases} \frac{n}{d} & n \equiv (0 \bmod d) \\ mn+1 & n \neq (0 \bmod d) \end{cases}$, where d is a list of consecutive positive primes until the dth prime. We use Mathematica to run this Generalized Collatz function for $n \in [1, 100]$, $m \in [1, 100]$ and $d \in [1, 100]$, creating 1 million data sequences. We use big data analysis to discern three new patterns from these sequences. One, that all numbers divisible by any p^2, where p is any prime number, can be set to n, so that, when $m = n - 1$, the function creates a hailstone sequence ending in $\{4, 2, 1\}$. Two, that all generalized Collatz sequences with $m = n - 1$ will converge to 1, for any divisor, in three cycles of the function. Three, that all Mersenne numbers, when set to m, will, for any divisor and for any initial number, cycle into an infinite recursive sequence. This project was able to find never before seen patterns in a thought-to-be unpredictable function, the Generalized Collatz Function. These patterns have application in proving the Collatz Conjecture, a feat we are currently working on.

211. Generalized Frobenius partitions with non-zero row difference

Kelsey Scott Grand Valley State University
Advisor(s): Brian Drake, Grand Valley State University

We extend the theory of generalized Frobenius partitions to include arrays whose rows differ in length. We focus on uncolored partitions in which no integer appears more than k times and on k-colored generalized partitions. We show that when enumerated these arrays satisfy a number of congruences analogous to those which arise when counting ordinary generalized Frobenius partitions whose rows are of equal length. In particular, we present a result about a congruence modulo k, and show that with an additional restriction on the row difference, we can establish a stronger congruence modulo k^2.

212. M-Gapped Progressions

Alexander Stoll Clemson University
Daniel Lewitz Carleton College
Advisor(s): Bruce Landman, West Georgia University

In this poster, we discuss what we call m-gapped progressions. An m-gapped progression is a generalization of an arithmetic progression in which the gaps in the progression only need to belong to a set of m elements, rather than all be the same. In the same way that arithmetic progressions pertain to the Van der Waerden numbers, $W(k;r)$, m-gapped progressions pertain to what what we denote as $B_m(k;r)$. This paper examines the values of $B_m(k;r)$ and provides characterizations for several k and r.

213. The Relation Between Permutable Prime's Infiniteness And Public key Exchange

Papa Sylla Borough of Manhattan Community College
Advisor(s): Fatima Prioleau, Borough of Manhattan Community College

Papa T. Sylla and Fatima Y. Prioleau (mentor), Mathematics Hans-Egon Richert, a twentieth century German mathematician, defined a permutable prime as a prime number which, in a given base, can have some or all of its digits' positions switched through any permutation and still be a prime number. The idea of permutable prime has always been relevant in the fields of discrete mathematics and cryptography; however many questions are still raised when it comes to permutable primes infiniteness and its applications. In our research, we seek to answer the question, "Are there infinitely many permutable primes and how permutable primes infiniteness can improve the security developed by Public Key Exchange?" Our research is restricted to permutable primes of base-10. We focus at first in describing the subtypes of permutable primes followed by experiments about a permutable prime subset. Experimenting with reversible primes will help us to determine the validity of our conjecture, as the specificity of permutable primes increases. In those experiments, we used methods suggested by mathematicians Jean Bevis and Jan Boal. Proving the number of permutable primes is infinite led us to a discussion about the relation between its infiniteness and Public key exchange. This talk is intended for a general audience.

214. Ergodic Properties of Heisenberg Continued Fractions with Applications in Hyperbolic Geometry

Nina Anikeeva Massachusetts Institute of Technology
Advisor(s): Jayadev Athreya, University of Washington

We give an overview of how to construct continued fractions on the Heisenberg group H, the projective and planar Siegel models of the group, and how to perform computations on the group using matrices. We discuss and work with some recent results from on the classification of which elements of the Heisenberg group have eventually periodic continued fraction expansions.Then we examine and work with major theorems in ergodic theory to explore results concerning growth of denominators and digit frequency, relating the results to hyperbolic geometry.

215. Numerical Solutions of the Radiosity Equation by the Galerkin Method for the Spherical Rhombus

Qiuyang Deng Roger Williams University
Advisor(s): Yajni Warnapala, Roger Williams University

The Radiosity of a surface is the rate at which energy leaves that surface. It includes the energy emitted by a surface as well as the energy reflected from other surfaces. In this proposal, a global Galerkin method is used to solve the Radiosity Equation for the Spherical Rhombus as the particularly designed spherical shape. This research is based on the study of the Radiosity equation for occluded surfaces using the Collocation Method by Atkinson and Chein. The study of Spherical Rhombus is extended from previous research for a sphere, perturbation of the sphere, ellipsoid and the oval of Cassini. The results of convergence errors for different reflectivity values will be presented.

216. Positron Emission Tomography Image Reconstruction with Fast Projection Gradient Method

Samuel Jugus George Mason University
Advisor(s): Igor Griva, George Mason University

Positron Emission Tomography (PET) is an important medical tool used to discover abnormalities in the body such as cancer. Our aim is to increase the speed of the algorithms conventionally used in PET. We pursue this by replacing

most instances of the Hessian with the Fast Projection Gradient, which only requires the Lipschitz constant of the gradient. The algorithms are tested using a data generator we created that simulates varying 2D PETs as well as the emission rates of cancerous areas. We compare the given emission rates created by the generator with the emission rates reconstructed by our algorithm to test for accuracy.

217. A Spectral Subgradient Algorithm of Non-Smooth Optimization

David Kotval University of Tennessee at Chattanooga
Yiting Xu University of Washington, Bothell
Advisor(s): Milagros Loreto, University of Washington, Bothell

Unconstrained minimization problems with non-differentiable convex objective functions, are usually solved by using the subgradient method, whose convergence is guaranteed if the optimal value of the objective function is known. In this work, we combine the subgradient method with the spectral step length, which does not require either exact or approximated estimates of the optimal value. Since subgradient methods are not descent methods, we add a non-monotone globalization strategy to ensure sufficient progress is made. This work also presents numerical results on a set of non-differentiable test functions. These numerical results indicate that using the spectral step length furnishes significant improvement over other subgradient methods.

218. Numerical Solutions of the Radiosity Equation via the Galerkin Method for the Dirichlet Condition: Mars Project

Hien Ngo Roger Williams University
Advisor(s): Yajni Warnapala, Roger Williams University

This research project is focused on finding the true solution of the exterior Dirichlet problem for the Radiosity equation to determine the convergence of a Spherical Quatrefoil in three dimensions at its boundaries, using the Galerkin Method. A mathematical model, based on the Radiosity equation will be utilized to investigate the role of incoming light waves for different surfaces with different emissivity and reflectivity functions. Theoretical and computational details of the method will provide sufficient information for designing proper lighting of an interior space inside a spacecraft that can ultimately be used for future endeavors of Mars exploration.

219. A convergence study of the augmented lagrangian method applied to the filtration problem

Yesom Park Ewha Womans University
Youngjoo Moon Ehwa Womens University
Hankyul Kim Ehwa Womens University
Advisor(s): Chohong Min, Ewha Wowens University

We discuss the filtration problem which estimates the free boundary of the wet area in a rectangular dam. We review the variational-inequality formulation of the free boundary, and show that the formulation is equivalent to a constrained minimization. In this research, we utilize the Augmented Lagrangian method to solve the minimization and analyze its convergence. At the end, numerical tests are provided to validate the convergence analysis.

220. Pattern Avoidance and Fiber Bundle Structures on Schubert Varieties

Timothy Alland Oklahoma State University
Advisor(s): Edward Richmond, Oklahoma State University

We give a permutation pattern avoidance criteria for determining when the projection map from the flag variety to a Grassmannian induces a fiber bundle structure on a Schubert variety. In particular, we introduce the notion of a split pattern and show that a Schubert variety has such a fiber bundle structure if and only if the corresponding permutation avoids the split patterns $3|12$ and $23|1$. Continuing, we show that a Schubert variety is an iterated fiber bundle of Grassmannian Schubert varieties if and only if the corresponding permutation avoids (non-split) patterns 3412, 52341, and 635241. This extends a combined result of Lakshmibai-Sandhya, Ryan and Wolper who prove that Schubert varieties whose permutation avoid the "smooth" patterns 3412 and 4231 are iterated fiber bundles of smooth Grassmannian Schubert varieties.

221. On the G-Rule for Ancient Egyptian Fractions and Its Extensions

Nicholas Baker Lee University
Advisor(s): Debra Mimbs, Lee University

The purpose of this research is to expand both the existing research on the mathematical prowess of the ancient Egyptians and the existing research on the properties of the system of fractions employed by the ancient Egyptians. In order to reach this goal, we have done three primary things. First, we searched through the two extant papyri containing computations with fractions done by ancient Egyptian scribes, searching for patterns in the way that they computed them in order to find evidence that there were certain rules, so to speak, about their fractional system of which the ancient Egyptian scribes were aware. Secondly, we attempted to discover extensions of what is commonly known as the G-Rule, a property of the ancient Egyptian fractional system first discovered by MIT mathematical historian Richard Gillings. Thirdly, we attempted to discover properties of the ancient Egyptian fractional systems related to prime numbers. This poster will present, among other expository things related to the Ancient Egyptians, two new theorems which extend the G-rule and three new theorems governing prime denominators in ancient Egyptian fractions.

222. Completing Partial Latin Squares Arising from Latin Arrays

Stacie Baumann West Virginia Wesleyan College
Kevin Akers Concord University
Sarah Gustafson Davis and Elkins College
Advisor(s): Michael Schroeder, Marshall University

Completing partial Latin squares has been studied since the 1940s. Recently, Kuhl and Schroeder looked at a specific problem where an $r \times r$ Latin array A is copied n times down the diagonal of a blank array. Call this partial Latin square nA. In 2015, they proved that if $n > r$, then nA is completable for any $r \times r$ Latin array A, and if $n < r$, there exists an $r \times r$ Latin array A such that nA is not completable. They failed to resolve the case when $n = r$. At the Summer 2016 Marshall University REU, we improved upon their techniques. In this work, we show that rA is completable for every $r \times r$ Latin array A.

223. Complexity and Characterization of Set Splitting

Peter Bernstein Tufts University
Cashous Bortner University of Nebraska - Lincoln
Connor Simpson Cornell University
Shuni Li Macalester College
Advisor(s): Samuel Coskey, Boise State University

A collection of sets is called splittable if there is a set S such that for each set B in the collection, the intersection of S and B is half the size of B. Splittability is a generalization of graph colorability, which is an active area of research with numerous applications such as scheduling and matching. We show that the problem of deciding whether a collection is splittable is NPcomplete. Nevertheless we characterize splittability for some special collections. At the same time we study a further generalization called p-splittability, in which the splitter S is required to contain a given fraction of each set B. The project described was supported by the REU Program in Mathematics through the National Science Foundation under Grant No. DMS-1359425, Department of Mathematics, College of Arts and Sciences, and Division of Research and Economic Development at Boise State University.

224. Geometric Limits of Julia Sets of Multiple Variables

Micah Brame Butler University
Advisor(s): Scott Kaschner, Butler University

In 2011, Boyd and Schulz proved for the family of polynomials $z \mapsto z^n + c$ with $|c| < 1$ that the limit as $n \to \infty$ of the Julia sets is the unit disk. We generalized this result to higher dimensions, focusing on filled Julia sets for maps of two complex variables and their convergence to the bidisk, $\overline{\mathbb{D}} \times \overline{\mathbb{D}}$.

225. Seeing Curvature on Specular Surfaces

David Broaddus Wheaton College
Dawson Miller Wheaton College
Advisor(s): Stephen Lovett, Wheaton College

Reflections on specular surfaces distort their surrounding environments in ways that give visual clues about their principal and Gaussian curvatures. This project examines this phenomenon by introducing a calibrated environment and using standard photography to record the distortions of that environment on the specular surface. We provide a novel approach to this examination which ultimately succeeds in demonstrating the availability of this curvature information in the reflections.

226. Considering Qualitative Preferences on Regression Analysis Using the Analytical Hierarchy Process

Caleb Bugg Morehouse College
Advisor(s): Robert Hampshire, University of Michigan Transportation Research Institute (UMTRI)

In this project, we seek to synthesize the priorities gained from the well-known decision making tool, the Analytic Hierarchy Process (AHP), and the output produced by regression analysis on models related to pedestrian and bike safety. The AHP falls into the category of Multiobjective Programming and Planning, a distinct discipline in Operations Research which has great use for the public sector. We hypothesize that a successful synthesis will increase the effectiveness of countermeasure practices for non-motorized safety by considering both the quantitative factors and qualitative judgments that affect the model. Therefore, an approach similar to the well-developed ridge regression will be employed, which systematically decreases the error common to regression analysis through the use of qualitative bias. Results thus far are formed from a system of linear differential equations that can be solved for optimum regression parameters. A benefit to this approach, then, would be the ability to analytically amend the regression in order to meet the main concerns of a chosen local, state, or federal government.

227. Side-Channel Attacks and Countermeasure Characterization

Lucius Bynum Harvey Mudd College
Sneha Kudugunta Indian Institute of Technology, Hyderabad
Tram Pham University of California, Berkeley
Advisor(s): Alejandro Morales, UCLA

The hardware of a cryptographic device can leak physical information while it runs an encryption algorithm. This leakage can allow attackers to gain secret information about a device without needing to directly exploit the encryption algorithm itself. These attacks can be performed on several types of devices, from servers to chip cards and smartphones. We explore these side-channel attacks and analyze countermeasures against them with a mathematical approach. We focus on power consumption data for devices running AES-128 encryption. We propose mathematical characterizations of different countermeasures effects on power consumption data and quantify the effectiveness of these countermeasures by (1) experimentally testing their resistance to side-channel attacks and (2) theoretically predicting their resistance to side-channel attacks. We predict resistance to attacks by calculating a lower bound on the number of traces required for an attack to be successful, using techniques from Mangard (2005). The side-channel attack we focus on is Correlation Power Analysis, an extension of Differential Power Analysis, put forward in the late 1990s by Kocher, Jaffe, and Jun. Typically, countermeasures against power analysis attacks are implemented in hardware, and the effects of those countermeasures on power consumption and side-channel leakage are analyzed after performing specific hardware modifications. Instead, we approach a study of countermeasures by directly manipulating power consumption data, mimicking the effects of several known hardware modification techniques and proposing some countermeasures that currently have no direct hardware analog. In this way, we simulate countermeasures that would in practice be implemented with hardware modifications by manipulating power data directly instead of modifying hardware. Countermeasures we simulate and analyze include filtering, introducing amplitude noise, introducing temporal noise, and power balancing. In addition to proposing specific mathematical characterizations of several countermeasures, we demonstrate a nontraditional means of studying countermeasures against power analysis attacks: one that uses a mathematical, data-oriented approach.

228. A Survey of Game Theory through Examples and Applications

Adam Carty Lee Univeristy
Austin Wheeler Lee University
Austin Wheeler Lee University
Advisor(s): Debra Mimbs, Lee University

Game theory is a reasonably new field of mathematics. It emerged in the 20th century, mainly from the works of John von Nuemann, Oskar Morgenstern, and John Nash, the subject of the 2001 biography A Beautiful Mind. The name game theory might suggest that it studies recreational children's games. For the purposes of this paper, consider a provisional definition: a game is a group activity with pre-determined rules, an end-goal or goals, and a clear winner and loser. With this definition, the study of game theory becomes much more broad. As people seek to fill their needs and desires with limited resources, games emerge in many aspects of life. Retail shopping, wars, and negotiations all have an element of give-and-take. Any rational person wants to maximize the good and minimize the bad in their life. The primary focus of game theory is to model real-world problems and develop optimal solutions. Some highly practical applications include economics, computer science, and logic. This paper provides a brief introduction to the field and then considers the applications of game theory to popular board games including Checkers, Connect Four, and Chess. This study of these popular board games include analyzing the set up of the game, finding the optimal strategy for winning, and allowing variations to the rules of the game.

229. On k-fold intersections of convex sets

Ryan Chen Princeton University
Advisor(s): Florian Frick, Cornell University

A theorem of Tverberg states that if $n \geq (r-1)(d+1)+1$, any n points in $\mathbb{R}^d$ can be partitioned into r sets whose convex hulls all contain a common point of intersection — this bound is tight. Reay's relaxed Tverberg conjecture is an open problem asking whether the necessary number of points can be lowered if one only requires any k of the convex hulls to contain a common point of intersection, where $2 \leq k \leq r$. Letting $T(d,r,k)$ denote this minimum number of points necessary, Reay conjectured that $T(d,r,k) = (r-1)(d+1)+1$ as well; this has been resolved in a few special cases but is open otherwise. Furthermore, lower bounds on $T(d,r,k)$ in the traditional literature are independent of d. In this project, we show the improved lower bounds $T(d+1,r,k) \geq T(d,r,k)+k-1$ and $T(d,r,k) \geq r(\frac{k-1}{k} \cdot d+1)$ and prove a colorful version of Reay's conjecture for $k > \lceil \frac{r}{2} \rceil$.

230. Euler characteristic of Hilbert schemes via colored Young diagrams

Shelby Cox University of Massachusetts, Amherst
Amal Mattoo Sidwell Friends School
Advisor(s): Amin Gholampour, University of Maryland, College Park

We are interested in finding a generating function for the Euler characteristic of the Hilbert scheme of points in the (singular) variety $\mathbb{C}^2/\mathbb{Z}_n$, and the Hilbert scheme of points in the (smooth) orbifold $[\mathbb{C}^2/\mathbb{Z}_n]$. For the former case, the problem reduces to finding a generating function for all 0-generated Young diagrams which contain a certain number of 0 colored squares i.e. those in correspondence with ideals generated by monomials trivially acted upon by the group action. We found a theorem which greatly simplifies the problem, and in some cases it reduces the problem into already solved ones. For the orbifold case, the problem reduces to finding a generating function for all Young diagrams with a given coloring. We developed a procedure which results in the desired generating function, as well as closed form generating functions for some cases. We also explored the method of vertex operator algebras, which had previously been applied to prove MacMahon's formula counting plane partitions.

231. Mates of the Latin Square C_2^3

Tyler Davis Fairmont State University
Rylee Shell Mount Vernon Nazarene University
Advisor(s): Carl Mummert, Marshall University

We classify and enumerate mates of powers of cyclic latin squares. Our overall goal is to produce a combinatorial enumeration of the mates of the latin square C_2^3, which is obtained by taking the Kronecker product of the cyclic square C_2 with itself. C_2^3 is known to have $70{,}272 \cdot 8!$ mates. We obtain results on the structure of these mates, which

allows us to divide them into four classes. We produce a combinatorial enumeration of one of these classes, which is composed of $6,144 \cdot 8!$ mates of C_2^3.

232. Regular Mates of Power Squares

Christopher DeFiglia UNC Chapel Hill
Advisor(s): Carl Mummert, Marshall University

We study the number of mates of latin squares which are powers of cyclic squares. For $k > 1$ the cyclic square C_k is the Cayley table of Z_k. The power square C_k^n is obtained by taking a repeated Kronecker product of C_k with itself. In this work, we consider the power squares C_k^n for $k > 2$ and $n > 1$. For each of these squares, we enumerate a family of mates of a particular form. This gives an asymptotic lower bound for the number of mates that a latin square can have in terms of its size.

233. A Comparison of Young Tableaux under Jeu de Taquin

Ellie Demuth Butler University
Advisor(s): Amber Russell, Butler University

A Young tableau is a collection of boxes, or cells, with a number filling each box. The two types of tableaux we explored were standard and row-standard tableaux. A standard tableau is a Young tableau whose entries are increasing across each row and down each column. In comparison, a row-standard tableau has increasing entries across each row, but not each column. For our research, we explored a combinatorial relationship between standard and row-standard tableaux that comes from a 2010 paper of Lucas Fresse. This relationship relies on a comparison between subdiagrams determined using the jeu de taquin method and one we call Fresse's method. We proved results in two cases for two-row tableau — the case where there is one box on the second row and the case where there are two boxes on the second row. We use these theorems and additional computations as evidence for a conjecture about the relationship defined by Fresse in the two-row case.

234. What do UNC Asheville Alumni Think About Their Undergraduate Research Experiences?

Emily Diaz-Loar University of North Carolina at Asheville
Advisor(s): Leah Mathews, UNC Asheville

Many universities offer undergraduate research (UR) opportunities for students in mathematics and across disciplines. Nationwide, 33% of undergraduates complete research projects. UR experiences can be improved by understanding alumni perceptions of their undergraduate research. UNC Asheville is nationally recognized for opportunities in UR, yet alumni perceptions of research have not been previously studied. This study uses statistical methods to report on a 2014 survey of UNC Asheville alumni that prompted them to describe their UR experiences and the overall perceptions of their undergraduate education. The data were analyzed in aggregate and by academic division (Natural Sciences, Social Sciences, and Humanities) in order to determine whether there are distinct differences in alumni perceptions across academic disciplines. Overall, alumni responses were positive amongst the divisional cohorts. The responses of alumni from the mathematics department were extracted and compared to the responses from the social sciences. Identifying how mathematics alumni view their research experiences could aid in distinguishing what the strengths and weaknesses of UR are at UNC Asheville. By determining the perceived benefits of UR at UNC Asheville, the university and its mathematics department can improve how research is conducted to provide mathematics students with more beneficial research opportunities that encourage further engagement in educational activities during, and after, their undergraduate careers.

235. A Fundamental Theorem and Forms of the Dyck Path

William Dula Morehouse College
Advisor(s): Leon Woodson, Morgan State University

A Dyck Path is a path of $2n$ steps, where $n \in \mathbb{N}$ in the *xy*-plane, above the line $y = x$. The path is constructed by taking unit length steps in either the positive x or y-direction such that it touches $y = x$ at (n, n). The length of a path, n, is equal to the number of steps taken in the y-direction. The Dyck Path has three statistics associated with it. The Area is the number of unit squares that fit between the path and the diagonal. The Bounce is a number created by tracing path from its terminal point and summing the x values at each section where the path turns towards the origin. The

Diagonal Inversion (Dinv) is determined by creating ordered pairs out of the Area in each row of the path. The purpose of this research was to find the bijection between the multisets of Bounce values and Dinv values for paths of a given area. By turning the area of each individual row in to a string we then get words, called Dinv words, which uniquely express each path. We can turn these Dinv Words into Dyck vectors by allowing one parameter to represent each unit of area and set each value equal to the row of that unit. The Fundamental Theorem of Dyck Paths characterizes the set of all paths of a given area and length, represented by their vectors, and equates it to a family of transformations applied to each vector in the set of paths of the given area minus one. Now it is possible to express these sets and connections between them as a planar tree, where each level represents the area of the paths.

236. An Investigation of Polygonal Numbers Using Elliptic Curves

Evelyn Easdale California State University, Fullerton
Advisor(s): Christopher Lyons, Califonia State University, Fullerton

The study of polygonal numbers is a classical topic in number theory. One interesting question is: Which integers may be written as a polygonal number in three different ways? For instance, which integers are simultaneously triangular, square, and pentagonal? Motivated by the search for such integers, we derive a related family of elliptic curves and investigate their ranks and torsion subgroups.

237. Sufficient Conditions for a Linear Operator On $\mathbb{R}[x]$ to be Monotone

Kelly Emmrich University of Wisconsin-La Crosse
Leah Buck Muskingum University
Advisor(s): Tamas Forgacs, California State University, Fresno

We demonstrate that being a hyperbolicity preserver does not imply monotonicity for infinite order differential operators on $\mathbb{R}[x]$, thereby settling a recent conjecture in the negative. We also give several conditions, some necessary, some sufficient, for such operators to be monotone.

238. Billiard Dynamics on Surfaces of Revolution

Isaac Garfinkle Carleton College
Advisor(s): Daniel Visscher, University of Michigan

We explore integrability in billiard dynamics on surfaces of revolution. On the sphere, wedges (regions bounded by two great circles) serve as an example of integrable billiards. Surfaces of revolution, unlike the sphere, do not in general have constant Gaussian curvature. We generalize these wedges to biangles, billiard tables bounded by two geodesics. Unlike wedges on the sphere, these sometimes appear to be non-integrable. We examine these biangle billiard tables by computing phase portraits and visualizing orbits in Mathematica. Finally, we identify some conditions on these tables that seem to be associated with integrability.

239. Potential Stability of Matrix Sign Patterns

Christopher Hambric College of William and Mary
Advisor(s): Chi-Kwong Li, College of William and Mary

A square matrix with real entries is said to be stable if each eigenvalue of the matrix has a real part that is strictly negative. We consider matrix sign patterns which may be realized by a stable matrix, and we investigate necessary and sufficient conditions for a sign pattern to be potentially stable, as well as a lower bound for the number of nonzero entries in such a sign pattern. Our approach uses a combination of graph and matrix theory in order to examine the structure and properties of these sign patterns, and we provide results which restrict the structure of a potentially stable pattern.

240. Slopes: A Differential Equations Graphing Environment

Joshua Haug Pepperdine University
Advisor(s): Timothy Lucas, Pepperdine University

We have designed a new app for the iPad entitled “Slopes” that will allow students to plot solutions, tactically explore slopefields and phase planes as well as construct numerical approximations of differential equations. No such app currently exists. The poster will focus on the issues involved in developing such an app and the collaborations with faculty

and students in mathematics, computer science, and graphic design that have enhanced the project. Key issues include lexically analyzing and parsing equations, performing efficient evaluations in Swift (for iOS), optimizing numerical algorithms, visualization, and handling errors. Slopes consists of five activities. We have designed each activity to empower students to investigate various concepts in differential equations. "Slopefields" and "Phase Planes" both plot vector fields and solutions corresponding to multiple initial conditions. "Systems" dynamically solves arbitrarily large systems of equations. "Waves" animates the solution of a spring-mass system. "Methods" interprets equations supplied by the user and constructs numerical approximations using Euler's method as well as Second and Fourth Order Runge-Kutta methods.

241. The Mathematical Physics and the Technical Mechanics of Time Travel

Brandon Hoogstra Arizona State University
Advisor(s): Sergei Suslov, Arizona State University

The project analyzes both the mathematical physics and the technical mechanics associated with the theory of relativity as it applies to temporal distortion. More specifically, the research addresses the influence of relativistic time dilation and gravitational time dilation upon a point mass within a theoretical model of interplanetary travel throughout the universe. The model provides an account of the influence of a black hole upon the passage of time, including such factors as mass, angular momentum, and electrical charge. Equations are provided for calculating the discrepancy in time between that experienced by a terrestrial observer and that experienced by the traveling point mass. Examples of the empirical observations of the effects of gravitational factors and time delay are discussed. The project proposes future research into such topics of relevance as the influence of gravitational waves upon time dilation, the utilization of wormholes for purposes of time travel, and the existence of tachyons within the universe.

242. Bijecting Recurrent Configurations on an Eulerian Digraph and its Reverse

Tafari James Haverford College
Casandra Monroe Princeton University
Advisor(s): Luis Garcia-Puente, Sam Houston State University

An Eulerian digraph is a directed graph where the in-degree of each vertex is equal to the out-degree. After designating a single vertex of an Eulerian digraph as a sink, the set of recurrent sandpiles on the graph forms a finite abelian group whose isomorphism class can be calculated based on the Laplacian matrix of the graph. Given an Eulerian directed graph, we can also construct its 'reverse graph' by reversing the direction of each edge. In general, there is no relationship between the group of recurrent sandpiles of a directed graph and its reverse. However, in the case of Eulerian digraphs we have the salient property that the Laplacian of the reverse graph is equal to the transpose of the Laplacian of the original graph. This allows us to conclude the two groups of recurrent sandpiles are isomorphic. While this isomorphism shows that the number of recurrent sandpiles on an Eulerian digraph and its reverse are equal, the two sets of sandpiles can look quite different (e.g., differing on which vertex the most sand is placed). Further, the isomorphism does not provide an explicit bijection between these two sets. We discuss progress towards producing a combinatorial bijection, including a proof that the number of recurrents with K grains of sand on the forward is the same as on the reverse.

243. Reduction of ETRU to NTRU

Floyd Johnson Michigan Technological University
Advisor(s): Jie Sun, Michigan Technological University

The NTRU cryptosystem is a ring based public key cryptosystem developed in 1998 by Hoffstein et al. based over an integer modulus. The NTRU cryptosystem is faster than other popular encryption techniques such as RSA or DES and is believed to be resilient to quantum computing attacks, but has the drawback of possible decryption failure (See: Jarvis and Nevins, ETRU: NTRU over the Eisenstein integers(2015)). The ETRU cryptosystem is NTRU over the Eisenstein Integers with an Eisenstein Prime modulus of q, which are $\mathbb{Z}[\omega]/\langle q\rangle$ where ω is the third root of unity. Some attacks to find the private key include brute force, meet in the middle, and most strongly lattice methods. Traditionally ETRU is more resilient than NTRU for lattice methods and hence is considered to be stronger (Jarvis and Nevins). Presented here is the possibility of reducing the ETRU lattice to a smaller version of the NTRU lattice by constructing an explicit isomorphic mapping from $\mathbb{Z}/\langle |q|^2\rangle$ to $\mathbb{Z}[\omega]/\langle q\rangle$ then reversing this process. This mapping has

restrictions on which Eisenstein prime q can be used. The repercussions of this reduction including decryption failure rate, combinatorial security, and lattice attacks will then be discussed.

244. Chaos and Integrability in Mushroom Billiards

Emily Joslin Baylor Universtiy
Samuel King Boston University
Michael Vavala Fairfield University
Advisor(s): Mark Demers, Fairfield University

Mathematical billiards are simple mechanical models of systems of particles colliding with a fixed boundary. While chaotic and integrable billiards are well understood, much less is known about systems with mixed phase space, in which chaotic and integrable components coexist. We present a numerical study of a class of mushroom billiards with mixed phase space. We classify the phase space for a family of billiard tables depending on several parameters by deriving explicit formulas for periodic orbits that correspond to the principal elliptic islands. We also formulate and provide evidence to support an original conjecture. In an effort to quantify the hyperbolicity of the billiard table, we present data from a newly created add-on to the billiard simulation software that computes the Lyaponov exponent along a given orbit. This work was done as part of the Fairfield University 2016 REU.

245. Broad Support in Voting

Sunny Kim Gordon College
Luke Cui Gordon College
Advisor(s): Karl-Dieter Crisman, Gordon College

The majority rule is a universally popular voting system, at least for two candidates. But it does not resolve all situations, such as when there are multiple groups, one of which is much bigger than other groups. In such a case, a candidate who is affiliated with the largest group of voters will always win, which is not quite fair. This paper examines how broad support could be achieved by looking at several different methods including a two-step plurality, quota system, and a weighted system.

246. The Four Curves of Alexis Clairaut

Taner Kiral Wabash College
Jonathan Murdock Wabash College
Advisor(s): Colin McKinney, Wabash College

Alexis Clairaut, born in 1713 to mathematician and teacher Jean-Baptiste Clairaut and mother Catherine, was a mathematician who showed promise from a very young age. In 1726, Alexis presented on four new families of curves and their properties to the Royal Academy of Sciences. In 1734, Clairaut published these findings in Quatre Probl mes sur de Nouvelles Courbes. His paper, published in French, has not yet been translated to English. We present a dual language edition - French and English - to make Clairaut's paper readable by a modern audience. Clairaut investigates four families algebraic curves, each partly motivated by the classical Greek problem of finding mean proportionals between two given line segments. Clairaut also investigates the analytic properties of his curves by finding tangents, inflection points, and quadratures.

247. Combinatorial Diameters and Automorphisms of Gelfand-Tsetlin Polytopes

Benjamin Krakoff Yale University
Yibo Gao Massachusetts Institute of Technology
Lisa Yang Massachusetts Institute of Technology
Advisor(s): Victor Reiner, University of Minnesota Twin Cities

For any partition $\lambda = (\lambda_1, \ldots, \lambda_n)$, one can construct the Gelfand-Tsetlin polytope GT_λ associated to λ. These convex polytopes arise in the study of representations of $GL_n(\mathbb{C})$ and in algebraic combinatorics. This paper focuses on the combinatorial geometry of Gelfand-Tsetlin polytopes. Specifically, we determine the diameter of the 1-skeleton and the combinatorial automorphism group of any Gelfand-Tsetlin polytope.

248. Number Sequences for Birectified Cross Polytopes

Wei-En Lu Grove City College
Joseph Swanson
Matthew Peffer
Advisor(s): Michael Jackson, Grove City College

Polytope numbers are non-negative number sequences constructed from the geometry of polytopes. Birectification is the process of truncating the vertices of a polytope to the midpoint of each face. We expand upon previous research to determine a formula for the nth polytope number of a birectified cross polytope. We use Dr. H.K. Kim's process to sum the difference between the nth bi-rectified cross polytope number and the $n-1$th number to obtain the nth polytope number of a d-dimensional birectified cross polytope.

249. Dynamics of Cyclic Systems

Kayleigh McCrary Agnes Scott College
Advisor(s): Rachel Bayless, Agnes Scott College

We study finite cyclic dynamical systems generated by the function f_r defined by Adamaszek, Adams, and Motta (2016). In particular, we are interested in relating the structure of a system to its dynamics. The authors proved that equidistant, "regular" systems are at the base of all cyclic dynamical systems. That is, the core (or union of all periodic points) of any cyclic dynamical system is isomorphic to a "regular" system. We further show that, given a unique orbit on an equidistant arrangement, adding a finite number k points into $(x_j, x_{(j+1) \mod \ell})_{S^1}$ where $x_j, x_{(j+1) \mod \ell}$ are two consecutive points of the arrangement, produces $(k+1)^2$ possible systems, each of which must be isomorphic to one of two regular systems.

250. (q,t) Symmetry in Macdonald Polynomials

Joanna McKinney SUNY Oswego
Matthew Jones Virginia Tech
Jacob Coleman West Virginia Wesleyan College
Advisor(s): Elizabeth Niese, Marshall University

We examine (q,t) symmetry in the Macdonald polynomial $F_\mu(q,t)$ using combinatorial methods. We present two maps between subsets of the standard fillings of a Ferrers diagram of an integer partition μ and the set of μ-sub ballot words to obtain (q,t) symmetry for some shapes. Our first bijection maps fillings with zero comajor index into the μ-sub ballot words, encoding information about the inversion number of the filling. The second function maps between certain integer partitions with zero inversions and the μ-sub ballot words. We also present some conjectures and questions to guide future work on this topic.

251. The Perceptron: An Introduction to Machine Learning

Karen Medlin Borough of Manhattan Community College
Advisor(s): David Allen, Borough of Manhattan Community College

Considered the world's first learning machine, The Perceptron was developed by Frank Rosenblatt in 1957, seven years after Alan Turing introduced the Turing test in a paper asking, "Can machines think?" and 14 years after Warren McCullogh and Walter Pitts introduced the Linear Threshold Unit, a computational model of a biological neuron. An investigation into the Linear Threshold Unit and Perceptron Convergence Theorem, including ideas from linear algebra such as $\mathbb{R}_n$ space, Cauchy-Schwarz Inequality, and dot product, reveals how The Perceptron is a powerful linear classifier. Coding The Perceptron in $\mathbb{R}$ provides a 2-D rendering of machine "learning" — The Perceptron moving itself by adjusting linear coefficients according to its Update Rule that matches outputs with training data. An understanding of The Perceptron, a single-layer neural network operating with supervised training, provides insight into how humans began and are continuing to mimic their own ability to think using computational machines.

252. Boom-and-Bust Dynamics in Financial Systems

Zhusong Mei George Mason University
Advisor(s): Harbir Lamba, George Mason University

Geometric Brownian motion is often used to simulate assets price paths but this model does not represent the 'boom-and-bust' nature of actual financial markets. I shall describe two closely-related, previously developed, agent-based

models. Each of them is based upon a realistic and different source of non-rationality or efficiency, but only one of them has an analytically tractable solution. It is therefore of interest to try and quantify any statistical differences between the price outputs of the two models. The problem of choosing comparable pairs of parameters will be explained and our results suggest that the statistical similarities between the models may be good enough for many applications (eg. Monte Carlo simulations).

253. Living on the Edge: Improved Reconstruction of Fourier Series using Jump Information with Applications to MRI

Angela Morrison Albion College
Alison Radgowski Goucher College
Joseph Tobin University of Virginia
Advisor(s): Mark Iwen, Michigan State University

Magnetic Resonance Imaging (MRI) is a critical non-invasive tool used by medical professionals to take images of the human body. MRI machines work by returning the Fourier Coefficients corresponding to the patient being imaged which are then used to reconstruct a picture of the patient. The imaging process is error prone due to, e.g., instrumentation limitations as well as motion by the patient during the scanning process. Additionally, due to the presence of multiple tissues and organs in patients' bodies, the underlying images tend to have a piecewise-smooth structure, resulting in imaging errors that distort the boundaries between tissues due to the Gibbs Phenomenon. We propose a highly effective method of detecting edges from Fourier data in order to produce more accurate reconstructions by mitigating Gibbs artifacts. We describe several advanced sampling and reconstruction methods supported by numerical results that produce quicker and more accurate reconstructions relative to the modern standard.

254. Classifying All k-Isotoxal, Equilateral, Convex Tiles

Kayla Neal University of Washington Bothell
Rebecca Claxton Stockton University
Toryn Avery Ithaca College
Advisor(s): Casey Mann, University of Washington Bothell

In this poster, we intend to fully complete a problem initially presented by Ruby Chick and Dr. Casey Mann in their paper Equilateral k-Isotoxal Prototiles: Find all equilateral and convex tiles that admit only edge-to-edge, edge-k-transitive monohedral tilings. We investigate quadrilaterals, pentagons, and hexagons that tile the plane by restricting their edges to congruent S-, C-, or J-curves, as defined in the previous paper.

255. Using Image Analysis and Machine Learning Techniques for Classification of Harmful Algal Blooms

Maria Ruwe Northern Kentucky University
Rachel Zieverink Northern Kentucky University
Advisor(s): Michael Waters, Northern Kentucky University

Reports of toxic cyanobacterial blooms, also known as Harmful Algal Blooms (HABS) have increased in recent years. HABS impact human health by causing conditions ranging from mild allergies to liver damage and death. Northern Kentucky University is developing a smart device application that will permit accurate and quick identification of potential HABS from an image of the surface of a body of water. This new application HAB APP will be useful in assisting identification of HABS in recreational and drinking water supplies. Using supervised machine learning algorithms, the smart device extracts a color histogram from an image and compares it with a trained model of images for classification. More specifically, the algorithm distinguishes between relatively harmless green algae and potentially harmful blue-green algae. Further, the algorithm may be applied to images taken by cameras to act as an early warning system for HABS. The mathematics and computer processing involved in this feature recognition software will be demonstrated.

256. Generalized Algorithm for Wythoff's Game with Basis Vector $(2^m, 2^m)$

Shuvom Sadhuka PROMYS
Jared Geller PROMYS (Boston University)
Max Yu PROMYS (Boston University)
Advisor(s): Paul Gunnells, University of Massachusetts Amherst

Wythoff's Game is a variation of Nim in which players may take an equal number of stones from each pile or make the valid Nim moves. W. A. Wythoff proved the set of P-Positions (losing positions) is given by $\{(\lfloor k\phi \rfloor, \lfloor k\phi^2 \rfloor), (\lfloor k\phi^2 \rfloor, \lfloor k\phi \rfloor) : k \in \mathbb{Z}_{\geq 0}\}$. An open Wythoff problem remains when players may make the valid Nim moves or remove ka stones from each pile, $k \in \mathbb{Z}$ and a a fixed integer–we denote this as the (a, a) game. Duchene and Gravier (2009) proved an algorithm to generate the P-Positions for the $(2, 2)$ game by exploiting the cyclic nature of the differences of stones between the two piles (mod 4). We observe similar cyclic (mod a^2) behavior when a is a power of 2, and construct a similar algorithm to generate the set of all P-positions for this game. We prove this by first showing our algorithm works for the first a^2 terms in the (a, a) game, then constructing an ordered multiset for the $(2a, 2a)$ game from the a^2 terms. Moreover, we conjecture that all cyclic games require a to be a power of 2, suggesting that there is no similar structure in the generalized (b, b) game where b isn t a power of 2. Future directions for generalizing the result would likely use numeration systems, particularly the PV numbers.

257. On the Accessibility Numbers in the Sandpile Monoid of a Graph

Cecily Santiago Mount Holyoke College
Dominika Palinko University of California - Berkeley
Advisor(s): Luis Garcia-Puente, Sam Houston State University

The sandpile model [Bak, Tang, Wiesenfeld (1987)] exists at the intersection of combinatorics, graph theory, and algebra. It models systems with the property of self-organized criticality. We consider a simple graph, and to each vertex, v, we assign a number of grains of sand denoted by a non-negative integer. If the amount of sand on the vertex is greater than or equal to $deg(v)$, then v is unstable, so v topples by sending exactly one grain of sand along each of its edges to its adjacent vertices. A sandpile is stable when every vertex is stable. Our object of study is the collection of all stable sandpiles on a given graph, which forms a monoid under the operation stable addition. Stable addition of sandpiles c, d, denoted $c \oplus d$ adds grains of c, d vertex-wise then topples until the sandpile is stable. A sandpile c can access another sandpile, m, if $c \oplus d = m$. The number of sandpiles that access m is called the accessibility number of m. The two highest possible accessibility numbers have already been characterized. In this work, we find the third highest possible accessibility number. We give conditions for its existence based on the structure of the graph. We also provide formulae for the sandpiles with this accessibility number when they exist.

258. Quantifying CDS Sortability of Permutations Using Strategic Piles

Meghan Shanks Texas A&M University
Marisa Gaetz Massachusetts Institute of Technology
Bethany Molokach Western Carolina University
Advisor(s): Marion Scheepers, Boise State University

The special purpose sorting operation, `context directed swap` (**CDS**), is an example of the block interchange sorting operation studied in prior work on permutation sorting. Moreover, this sorting operation has been postulated to model certain molecular sorting events that occur in the genome maintenance program of certain species of ciliates. We investigate the mathematical structure of permutations not sortable by the **CDS** sorting operation. Our main findings include two enumeration results for permutations with equal degree of **CDS** non-sortability. By quantifying this aspect of non-sortable permutations, we seek to better understand the **CDS** operation and its relationship to ciliate genomes.

259. Origami and Optimization

Cynthia Sixco Ramirez City College of New York
Advisor(s): Shenglan Yuan, LaGuardia Community College

In recent years, the application of origami in different areas of study such as mathematics and engineering has increased. In this poster we are investigating the way certain geometrical shapes can be folded so that the maximum area of two-dimensional shapes can be achieved. Then, we show an approach to three-dimensional optimization of

the volume of geometrical shapes followed by a similar process for a two-dimensional case. Finally, applications to engineering problems are presented with the latter optimization approach.

260. Modeling Tsunami Run-Up and Draw-Down on the Beach

Dylan Smith University of Connecticut
William Noland North Central College
Advisor(s): Sergei Fomin, University of California at Chico

Previous literature has investigated the run-up and draw-down of tsunami waves on a one-dimensional, constant-sloped beach, but the existing solutions are complex and computationally unwieldy. Our research aims to establish a simpler model while still obtaining accurate results. We do so using a quasi-linear theory derived from the nonlinear shallow-water wave equations. These equations are considered over a linear beach, with properly imposed initial and boundary conditions. The main difficulty in solving this problem is the moving boundary associated with the shoreline motion. To eliminate this difficulty, we apply an appropriate substitution to the spatial variable, and thus replace the moving boundary of the computational domain with a stationary boundary. A key feature of our tsunami problem is the presence of the small parameter , where is the characteristic amplitude of the wave and is the characteristic depth of the ocean. Due to the presence of this small parameter, the problem can be essentially linearized using the method of perturbations and then solved analytically via an integral transformation. This explicit solution enables us to swiftly predict the behavior of the wave using an essentially linear model. We test the accuracy of our model against the numerical solution obtained using Mathematica, and find minimal discrepancy. Finally, we extend our results to a modified beach configuration that more accurately reflects real-world shoreline topography. This project is supported by the NSF award DMS-1559788.

261. Numerical Analysis of the Inverse Free Boundary Problems for Parabolic PDEs via Gradient type Methods in Besov-Sobolev Spaces

Taylor Spino North Central College
Carlos Seda Damiani University of Puerto Rico at Mayaguez
Advisor(s): Ugur Abdulla, Florida Institute of Technology

In this work we propose and validate a computational method for solving the inverse Stefan type free boundary problem to reconstruct constitutive relations, such as the diffusion, convection and reaction coefficients, along with the density of the heat sources, boundary heat flux and the free boundary itself. This optimal control problem is solved as PDE-constrained optimization using a gradient-based technique in the optimize-then-discretize framework. A key element of this approach is the gradient of the cost functional which is computed based on a suitably-defined adjoint system. The gradient structure is supported by the recently proved formula for the Frechet differential under minimal regularity assumptions on available data. We will discuss a number of computational issues arising in the solution of such optimal control problems including proper regularization and gradient projection techniques. We will also present some computational results obtained for 1D model problem.

262. String duplication histories with no-breakpoint-reuse

Audrey Steinman University of Wisconsin - Eau Claire
Mitchell Paukner University of Wisconsin - Eau Claire
Advisor(s): Manda Riehl, University of Wisconsin - Eau Claire

We model genes as strings of letters, and between any two adjacent letters is a breakpoint. We use the duplication mutation model, which copies a portion of the string and inserts it anywhere not within the original substring copied. Three important breakpoints are: the two positions that mark the ends of the duplicated portion and the third position where the copy was inserted. The no-breakpoint-reuse condition forbids the use of these three breakpoints more than once, even if that breakpoint was copied to another place in the string. Given a string with repeated letters, a history is a sequence of duplications that creates that string from a permutation. In 2013, Brejov a et al. explored algorithms for calculating a string duplication history under no-breakpoint-reuse. We demonstrate the longest string achievable with k duplications beginning with a permutation of length n. We derived formulas for the number of strings achievable with 1 or 2 duplications from a starting permutation of length n, and we present data calculated using a Python program we wrote for 3 duplications. We also present data on how strings are distributed based on length and number of

duplications. Finally, we extend some of these results to a multichromosomal version of the model which is a new extension.

263. Permutation Statistics in the Hyperoctahedral Group

Ryan Stodola University of Wisconsin-Eau Claire
Rita Post University of Wisconsin-Eau Claire
Jingtai Liu University of Wisconsin-Eau Claire
Advisor(s): Aba Mbirika, University of Wisconsin-Eau Claire

We study a variety of permutation statistics in the hyperoctahedral group $G(2, 1, n)$, including the involutory elements and their corresponding conjugacy classes. Also, by analyzing the cycle structures of positively and negatively signed cycles of varying lengths, we derive formulas for calculating the sizes of each involutory conjugacy class and for calculating the number of involutory conjugacy classes in $G(2, 1, n)$ for all n values. In particular we explore some combinatorial aspects of the analogue of the alternating subgroup contained in $G(2, 1, n)$—namely, the orientation-preserving symmetries, which we denote $A(2, 1, n)$.

264. Effect of variation in life history strategies on long term population trajectories of eelgrass

Stephanie Thurner Albion College
Advisor(s): Sylvia Yang, Shannon Point Marine Center

Contemporary declines in seagrass habitats worldwide warrant understanding factors that may allow managers to predict change and recovery in these habitats. In the Pacific Northwest, eelgrass (Zostera marina) forms these critically productive meadows and has experienced instances of localized population decline. Eelgrass reproduces using two different life history strategies, asexual and sexual reproduction, with varying life history strategies between populations. It is unknown how variation in life history strategy affects the long term population trajectories of eelgrass. In this study we develop a stage-based matrix population model and analyze populations with variations in sexual and asexual reproduction. We see that the model is a highly conservative estimate for solely sexually reproducing populations, and an over estimate for populations with asexual reproduction. We also see that recovery of a population back to initial population levels after a disturbance is different when density is determined spatially rather than by looking at the entire area. Further data collection and refinement of vital rates as well as the addition of other environmental conditions will increase the accuracy of the model and help inform management and conservation strategies.

265. Dynamics of piecewise translations

Sang Truong University of California, Irvine
Advisor(s): Anton Gorodetski, University of California, Irvine

In this poster session, we discuss piecewise translations on a compact set Ω in the Euclidean space. For each such map, we partition the set into smaller regions, with the property that the restriction of the map to each region is a translation. To each piecewise translation $F : \Omega \to \Omega$, we consider the non-empty compact set $A = \cap_{n=1}^{\infty} F^n(\Omega)$ (called the *attractor* of the map F). If $A = F^N(\Omega)$ for some integer N, then the map F is said to be of finite type. We present a proof of a special case when we always get finite type maps. We will talk about the topological properties and the semi-continuity of the attractor in this case.

266. Folding Strips by Binary Expansion

Maria Vazquez Alonso Lehman College
Advisor(s): Shenglan Yuan, LaGuardia Community College

The research entails folding origami strips into nth strips with equal length by binary expansion. The process was to examine the binary representations of unit fractions and to analyze the connection between the binary and the folds. With this presentation I will show how the binary expansion is related to the exact fold necessary to create nth strips with equal length.

267. Comparing the extent to which closure methods recover the knot type of a closed knot from open subarcs

Emily Vecchia University of Saint Thomas
Advisor(s): Eric Rawdon, University of Saint Thomas

Traditional knot theory studies knotting in closed curves. To understand physical systems such as proteins and DNA that contain knotting in open curves, a rigorous mathematical definition of open knotting is needed. Many methods to close open knots have been proposed. This study focuses on two prominent methods, the Random Equilateral Arc method and the Uniform Closures method. Given a closed, equilateral, and polygonal knot, the behavior of each closure method is analyzed as length and starting vertex of the subarcs of the closed knot vary. We compare the ability of the two methods to recover the closed knot type given an open subarc.

268. Existence of Some Signed Magic Arrays

Nathan Wagner Bucknell University
Advisor(s): Abdollah Khodkar, University of West Georgia

We consider the notion of a signed magic array, which is an $m \times n$ rectangular array with the same number of filled cells s in each row and the same number of filled cells t in each column, filled with a certain set of numbers that is symmetric about the number zero, such that every row and column has a zero sum. We attempt to make progress toward a characterization of for which (m, n, s, t) there exists such an array. This characterization is complete in the case where $n = s$ and in the case where $n = m$; we also characterize three-fourths of the cases where $n = 2m$. This work was completed as part of an REU at the University of West Georgia during the summer of 2016.

269. Algebra for Higher Rings

Karthik Yegnesh Ursinus College
Advisor(s): Nicholas Scoville, Ursinus College

There have been several approaches to developing the foundations of a 2-categorical analog of algebraic geometry, notably by Balmer, Rosenberg, and Chirvasitu/Johnson-Freyd. These approaches differ mainly in their notion of a "commutative 2-ring." For example, Balmer uses tensor triangulated categories, while Rosenberg builds his theory of non-commutative algebraic geometry via local abelian categories. On the other hand, Chirvasitu and Johnson-Freyd roughly define a commutative 2-ring as a suitable symmetric monoidal locally presentable category. Familiar examples of 2-rings include Grothendieck topoi and the category of quasicoherent sheaves on an affine scheme. We use the 2-rings in the sense of Chirvasitu/Johnson-Freyd to categorify several constructions in classical commutative algebra and sheaf theory. On the "algebraic" side, for instance, we generalize the notion of a free ring on a set via constructing the free 2-ring on a category. On the sheaf-theoretical end, we define stacks (higher categorical sheaves) of 2-rings, which can be seen as a vertically categorified sheaves of rings. We show that stacks of 2-rings provide an appropriate setting for generalizing fundamental notions in the theory of ringed sites.

270. Probabilistic Change Point Analysis on Bond Liquidity

Richard Bielak Jr. College of the Holy Cross
Advisor(s): Eric Ruggieri, College of the Holy Cross

The role of primary dealers in the bond market has changed with the passage of the Volker Rule (the Rule) in 2014. An unintended consequence of the Rule may be that primary dealers no longer provide an adequate level of market liquidity through large intermediate bond holdings in their own accounts, and instead are more active in matching buyers and sellers. Bid-ask spread data can be used to measure bond market liquidity, since in times of high market liquidity the bid-ask spread has historically been narrow with the inverse also true. In order to determine whether passage of the Rule has materially affected bond market liquidity, a Probabilistic Change Point algorithm was developed in R to analyze historical bid-ask spreads relative to primary dealer net bond positions from 2001 to the present. Change point models allow a piecewise function to be fit to a data set that is expected to require more than one linear regression model and Bayes Rule is invoked to create a probability distribution on the unknown number of change points and their best-fit locations. Due to the size of the data set, a solution cannot be obtained through brute force methods and a recursive solution to the multiple change point problem was used instead. From our analysis, we found that implementation of the Rule and the subsequent change in dealer inventory had very little effect on bond liquidity. We thank the National Science Foundation (DMS-1407670) for financial support.

271. Modeling Metabolic Outcomes and Symptom Severity Based on Genetic Risk Factors in Patients with Schizophrenia: An Exploratory Use of Tree-Based Algorithms

Grace Cavanaugh College of the Holy Cross
Advisor(s): Shannon Stock, College of the Holy Cross

Schizophrenia is a psychiatric illness characterized by psychotic symptoms, cognitive impairment, and social dysfunction. Unfortunately, antipsychotic medications used to treat schizophrenia have severe metabolic side effects. It is unclear whether metabolic risk genes established in the general population are also associated with poor metabolic outcomes among antipsychotic-treated patients. Furthermore, this established comorbidity raises the possibility of shared genetic vulnerability pathway(s). To explore these questions we used tree-based data mining algorithms to model both metabolic outcomes and schizophrenia symptom scores based on metabolic risk genes. Genetic risk factors emerged as important variables in both analyses, suggesting that genetic screening may prove useful for personalized decision making in treatment that manages both metabolic risk and symptom severity.

272. Modelling Thrombus Growth Relative to Hemodynamic Factors

Antonia Chacon-Taylor Arizona State University
Advisor(s): Yiannis Kamarianakis, Arizona State University

The goal of the project is to generate a regression model that captures the relationship between the following explanatory variables: time averaged wall shear stress(TAWSS), oscillatory sheer stress(OSI), and relative residence time(RRT) to intraluminal thrombus growth by year(ILTgrBY) and verify the empirical results of published academic literature on the subject. The models were fitted and tested from data sets generated from four patients with spatial auto-correlation of observations taken into account as indicated by Moran's I. Preliminary models were tested using methodologies such as Akaike Information Criterion and Maximum Likelihood Estimate to determine the validity of a single model for a patient. Results thus far have agreed with results from academic literature pertaining to the relationship of our explanatory and response variables.

273. Modelling Thrombus Growth Relative to Hemodynamic Factors

Ernest Reginald Dela Cruz Arizona State University
Advisor(s): Ioannis Kamarianakis, Arizona State University

This talk will discuss the process of generating a regression model that captures the relationship between intraluminal thrombus growth by year(ILTgrBY) to the following explanatory variables: time average wall shear stress(TAWSS), oscillatory sheer index(OSI), and relative residence time(RRT) with spatial autocorrelation taken into account by estimating alternative spatial-autoregressive specifications. Models were fitted and tested using data from four patients whose vascular topographies were captured with the variables generated through computational fluid mechanics. Results thus far have agreed with results from academic literature pertaining to the relationship of explanatory and response variables: (Arzani *et al.,* 2014) and (Rayz *et al.,* 2010).

274. Hot or Not: Statistical Analysis of Gender Representation Within Printed Media

Emily Gentles University of Arkansas
Katelyn Heath University of Arkansas
Advisor(s): Chaim Goodman-Strauss, University of Arkansas

Sex sells. At least, that's what the entertainment industry tells us. However, with the rising rhetoric of gender equality as well as the growing impact of media in our everyday lives, we must consider the consequences that accompany sexualized marketing. How prominent is sexual objectification and does it vary with the gender of the intended viewer or the gender of the seller? Are there differences in the ratio of implied promiscuity between genders and if so, by how much? All of these questions and more will be statistically analyzed with data drawn primarily from magazine advertisements. We all have our prejudices, but are they really statistically significant?

275. Non-asymptotic Bounds for the Mean Square Error of Markov Chain Monte Carlo Approximations

Ethan Gwaltney Baylor University
Shane Lubold Arizona State University
Advisor(s): Jorge Rom n, San Diego State University

When estimating intractable integrals using MCMC methods, we are often interested in knowing the closeness of our estimation given a particular number of iterations of the Markov Chain. In the past, the sharpness of an estimate was determined asymptotically by defining a function that yielded a Rosenthal Drift Condition. We show that the Rosenthal Drift Condition is equivalent to a Tweedie Drift Condition. We then exploit this equivalence using results from Latusynzki et al (2013) to obtain non-asymptotic bounds on the mean square error of the estimation in the one sample model with proper priors and the regression model with normal priors. We present several different upper bounds on the mean square error. We also provide numerical results for both models.

276. Vehicular Traffic Forecasting

John House Arizona State University
Thomas Valente Arizona State University
Advisor(s): Ioannis Kamarianakis, Arizona State University

The goal of this project is to develop a time-series model of traffic flow which can successfully predict occupancy and volume over short and long term periods of time. This has significant utility for local economies, businesses, governmental organizations, and more making it a worthwhile endeavor. We started with data from seven locations along a busy road in Athens. The data we received was the volume and occupancy measured every 90 seconds for the months of April and May of 2000. We analyzed the data chronologically using the April data for training the model and May data for testing it. To account for periodicity in the data, 3360 sine and cosine functions were used as predictors in a linear regression model. Linear regression with such a large number of predictors yielded several issues, creating too much estimation uncertainty and complexity, which are undesirable. To alleviate the aforementioned issues, we implemented a method called Adaptive Lasso. Adaptive Lasso is a penalized estimation method that is based on the Lasso method; the purpose of this technique is to reduce complexity in the model by squeezing insignificant coefficients to zero. With Lasso, a penalty term is used to gauge the complexity of a model by summing each coefficient and multiplying it by a tuning parameter. We then adapted this method by using varying penalties for each coefficient based on the values determined by standard linear regression. This model was useful, but not completely satisfying because it did not use all the data available. Traffic varies greatly with factors that are not associated with time (e.g. weather, accidents, traffic control malfunction) and ways that we cannot measure or predict. However, we can apply a method known as ARIMA (Auto Regression Moving Average) to use recent measurements to slightly change the predictions of the model. We applied this model to the residuals of the adaptive lasso model, to obtain a model which was approximately 20% more accurate (based on root mean square error) when tested. Overall, we ended up with a standard error (RMSE) of 8.62 cars per 90 seconds on our predictions across the month of May when we trained the model on the month of April. Values of the actual data vary between 10 and 60, so the error is generally approximately 20%. Further improvements to the model would include consideration of data from the other sensors to create a better, more accurate model. To accomplish this, methods to reduce variance of these coefficients must be used in order to avoid over-fitting the data.

277. Applications of Statistics to determine Business Relationships

Jie Lan Borough of Manhattan Community College
Jieying Li Borough of Manhattan Community College
Advisor(s): Lina Wu, Borough of Manhattan Communtiy College

The statistics analysis method is widely used in business. The statistical relationship is classified into two different categories: correlation and causality. In this research, we use two business models (Mattel, US Major Airline stock and oil price) to explain how two relationships work. Correlation is a statistical measure that describes size and direction of a relationship between two or among more variables. Causation indicates that one event is the result of the occurrence of the other event. Statistical methods of regression analysis, Hypothesis-test, and T-test were applied in this project. By analyzing data of Delta, Southwest, American Airline associated with the oil price (during 2010 thru 2016) in the regression method and SPSS Software, we have determined that the oil price is the common factor closely correlated

with these 3 major US airline stocks. By analyzing data of Mattel in Hypothesis-test and T-test methods, we have discovered the cause of Mattel going down suddenly in 2014.

278. Determining the Statistical Significance of Success Clusters in Professional Bowling Performances using the Exact Distribution of the Multiple Window Scan Statistics

RaQuedra Lee Philander Smith College
Advisor(s): Deidra Coleman, Philander Smith College

An abundant amount of attention has been given to what is known as the hot hand phenomenon. A player is considered "hot" if he or she has had a majority of successes on most of his or her attempts in a designated time frame. An algorithm was developed that computes the exact distribution of the multiple window scan statistic for higher-order, multi-state Markovian sequences. With this distribution, we are able to obtain the probability that clusters that follow the higher-order, multi-state Markovian sequences are statistically significant. However, the method has the weakness of limited usage documentation in the literature. Usage documentation is important for knowledge of unusual clusters. Therefore, we analyzed the success clusters of the performances of bowlers in the Professional Bowlers Association. Hence, we will report our findings. The method was useful because it allowed us to examine clusters of various sizes simultaneously across the entire data series.

279. Upper and lower bounds on the speed of an excited random walk

Owen Levin University of Minnesota
Jacob Smith Franklin College
Advisor(s): Jonathon Peterson, Purdue University

Excited random walks (ERWs) are a self-interacting non-Markovian random walk in which the future behavior of the walk is influenced by the number of times the walk has previously visited its current site. We study the speed of the walk, defined as $V = lim_{n\to\infty}\frac{X_n}{n}$ where X_n is the state of the walk at time n. While results exist that indicate when the speed is non-zero, there is no explicit formula for the speed. It is difficult to solve for the speed directly due to complex dependencies in the walk since the next step of the walker depends on how many times the walker has previously visited the current site. We derive the first non-trivial upper and lower bounds for the speed of the walk that agree very closely with numerical simulation for some model parameters.

280. Exploring Modular Arithmetic and Stochasticity to Understand Latent Variables

Robert Padgett University of Wisconsin - Whitewater
Advisor(s): Meg Waraczynski, University of Wisconsin - Whitewater

Evaluating responses from attitudinal assessments that use ordinal force choice items such as a Likert-type response to create estimates of a latent variable is common practice in psychology and education research. A common method is a sum score by adding the coded responses (Strong Agree = 5, Agree = 4, etc.). Other methods such as alternative least squares optimal scaling, item response theory, and a few other algorithms are available to rescale ordinal scores to interval/ratio level of measurement. Most of the methods developed have numerous assumptions underlying their use such as generalizability and response patterns. We present a novel method, tentatively called stochastic modular scaling (SMS), for rescaling based on modular arithmetic and stochasticity to limit the assumptions, thus developing a more pragmatic rescaling method. A key benefit is that SMS takes into account individual differences in attitude for each item despite the forced response, and also defines the space for attitude. We compare scores on multiple rescaling methods on two conceptually related scales, and comparing correlations between end scores to identify the method for obtaining a better approximation of the latent variable. We expect SMS to have broader applicability compared to existing rescaling methods.

281. Predictors of Long-Term School-Based Behavioral Outcomes in the Multimodal Treatment Study of Children with Attention-Deficit/Hyperactivity Disorder

Margot Reed College of the Holy Cross
Advisor(s): Dr. Michael H. Bloch, Yale School of Medicine Child Study Center

Children with attention-deficit/hyperactivity disorder (ADHD) often experience significant school-based challenges. Previous studies reviewing school-based outcome findings of the Multimodal Treatment Study of Children with

Attention-Deficit/Hyperactivity Disorder (MTA) demonstrated that improvements in negative/ineffective parental discipline were associated with decreased disruptive behavior at school. Behavioral intervention was also found to greatly reduce homework problems during the initial 12 months of treatment. We examined potential baseline predictors of school-based behavioral outcomes in children who completed the 8-year follow-up in the MTA. Stepwise logistic regression and Receiver Operating Characteristic (ROC) analysis identified baseline predictors associated with higher risk of truancy, school discipline and in-school fights. Stepwise regression analysis explained between 8.1% (in-school fights) to 12.0% (school discipline) of the total variance in school-based behavioral outcomes. Logistic regression identified several baseline characteristics associated with school-based behavioral difficulties eight years later including sex, race, increased Conduct Disorder symptoms, decreased parental affection, ADHD severity and study site. ROC analyses identified the most discriminative predictors of truancy, school discipline and in-school fights, to be Aggression and Conduct Problem Scale Total score, family income and race, respectively. Future research might target higher paternal involvement and parental knowledge of behavioral principles and reducing use of physical punishment in order to improve school-based behavioral outcomes in children with ADHD.

282. Categorical Prediction: Classifying Crime in San Francisco

Samantha Runnels Arizona State University
Advisor(s): Yiannis Kamarianakis, Arizona State University

This work evaluates alternative statistical models for classification, including logistic regression, linear discriminant analysis, and K-nearest neighbors. Models are trained using a large database of crimes in San Francisco and aim to predict the type of crime committed. Predictors of interest include police district, day of the week, month, year, and hour of the day. A predictor's significance is determined through stepwise methods and model accuracy is assessed through cross-validation.

283. Examining Apparent Slumps in National Basketball Association (NBA) Player Free Throw Shooting

Craig Steele Philander Smith College
Advisor(s): Deidra Coleman, Philander Smith College

In sports statistics research, the "hot hand" phenomenon has received a great deal of attention with free throwing shooting as a typical event of interest, specifically streaks of made free throws. In recent years, streaks of missed free throws have been receiving more attention in the media; however, very little has been done to determine if streaks of unsuccessful free throw attempts or slumps are truly unusual. This work is an examination of a subset of the 2015–2016 free throw data of the NBA. Here the Multiple Window Scan Statistic is used to investigate the statistical significance of slumps in free throw shooting by a select group of NBA players during the 2015–2016 season.

284. Mathematical Analysis of Lottery Voting

Stephanie Thrash St. Edward's University
Nicole Buczkowski Jacksonville University
Advisor(s): Jonathan Hodge, Grand Valley State University

Standard voting methods rely on deterministic social choice functions to aggregate voter preferences and determine a winner or set of winners. In contrast, lottery voting determines winners by randomly selecting voter ballots. In this presentation, we will investigate lottery voting from a mathematical perspective. In particular, we will provide insight into the effects of varying the size of the set of winners and potential strategies for political parties within the lottery voting system.

285. Modeling Emergency Department Arrivals using Non-Homogeneous Poisson Processes

Rachel Wagner Coastal Carolina University
Advisor(s): Lindsey Bell, Coastal Carolina University

The purpose of this research is to determine a function that describes the rate at which people arrive in the emergency room at a local hospital. We assume that the rate of patient arrivals follows a repeating trend. The cyclic rate function has the form $\lambda(t) = e^{h_\theta(m,z)}$ where $h_\theta(m, z)$ consists of two components. The components are a trigonometric

component to capture the cyclic behavior. The second component is a polynomial of degree m which represents the general behavior over time. Additionally, θ is the vector consisting of all unknown parameters that will be estimated using parameter estimation techniques. The data obtained includes arrival times from randomly selected days at the local hospital. The rate function will then be applied to the Non-Homogeneous Poisson Process in order to obtain the expected number of arrivals in a day or certain time interval and predict when the arrivals will occur. Such information is important for hospitals aiming to efficiently allocate resources.

286. Forecasting Electricity Demand

Paige Weisman Arizona State University
Advisor(s): Yiannis Kamarianakis, Arizona State University

Since electricity cannot be economically stored, supply and demand must be kept in balance. Thus, forecasting electricity load is important for the designing and planning of power plants. The electricity demand data analyzed is from Salt River Project. Exploratory analysis suggested that the series is dominated by trends and seasonal effects such as, weekdays versus weekends, summer versus winter, and daytime versus nighttime. Sine and cosine functions are used to capture seasonal variation and a penalized estimation method, namely lasso, is used to estimate the coefficients of a baseline predictive model. The goal of this project is to relate profile-deviations for load and temperature and determine if a satisfactory predictive model for load-deviations can be based on temperature-deviations.

287. A Comparison of the Permutation Approach and the Multiple Window Scan Statistic Approach for Identifying Streaks of Strikes in Professional Bowlers Data

Jhai West Philander Smith College
Advisor(s): Deidra Coleman, Philander Smith College

Streaks are frequently researched in sports; in particular, streaks of strikes in bowling have become of interest. Two researchers, Gur Yaari and Gil David, have focused on the streaks of strikes by using a permutation approach. In this research, we investigate streaks in bowling by comparing streaks of bowling performances as identified or unidentified by Yaari and David to those that are identified or unidentified by using the exact distribution of the multiple window scan statistic and its probability distribution to identify statistically significant streaks.

288. Mixing Times for the Generalized Rook's Walk

Ana Wright Willamette University
Benjamin Savoie University of Michigan-Flint
Renjun Zhu University of California-Berkeley
Advisor(s): Peter Otto, Willamette University

Our work focuses on using path coupling, a powerful probabilistic tool, to find bounds on the mixing times of a class of Markov chains. The mixing time of a Markov chain measures the rate of convergence to its stationary distribution. This mixing time is of interest for sampling and simulations of random processes. The Markov chains we are investigating are restrictions on the random rook's walk on a d dimensional chessboard, which can also be considered random walks on the Cartesian powers of certain groups of circulant graphs. We prove bounds on the mixing times of these Markov chains, extending and generalizing previous results for the unrestricted case of the rook's walk.

289. Analysis of Historical Stock Price for Facebook, Twitter, and LinkedIn through Change Point Detection

Fan Wu College of the Holy Cross
Advisor(s): Eric Ruggieri, College of the Holy Cross

In statistics, linear regression is an approach for modeling the relationship between a scalar dependent variable y and independent variable x. Based on the fact that stock prices frequently rise and fall, a simple linear regression model is not an effective way to represent the relationship between stock price and time. Change point analysis is used in situations where the parameters of the regression model are expected to change through time and the model is able to determine whether a change has taken place and the location of the change. Through the statistical computing language R, an efficient change point algorithm was created which generates the number of change points and their location for any data set in three steps, including: a) calculate the minimum sum of squared error for every possible substring of

the data set; b) recursively piece these substrings together; and c) work backwards through the recursive calculations to determine the optimal placement of the change points. The location of change points corresponds with important events within each company, such as launching new products, acquisitions, and lawsuits.

290. A Bayesian Approach to Predicting the Outcome of Endovenous Laser Ablation

Michelle Yu College of the Holy Cross
Aaron Pinkerton Sterling College
Hunter Rehm University of Wisconsin - La Crosse
Advisor(s): Steve Chung, California State University, Fresno

Varicose veins affect more than 40 million people in the United States. Endovenous Laser Ablation (EVLA) is a common and highly effective treatment method for varicose veins. The success of EVLA may depend on several key variables: laser power, time, length of vein, laser energy, and linear endovenous energy density (LEED), as well as combinations of these variables. In this study, we consider the Bayesian and parametric logistic regression models to predict the treatment outcome from these key variables. We use the Monte Carlo cross validation to assess the models. Our finding indicates that the Bayesian logistic regression is a better predictive model than the parametric logistic regression.

291. Statistical Analysis of Weather Forecasts: Accuracy of Internet Weather Forecasts vs. Statistical Models

Yayu Zhou University of Illinois at Urbana-Champaign
Sijia Huo University of Illinois at Urbana-Champaign
Yantong Zheng University of Illinois at Urbana-Champaign
Yunxin Zhang University of Urbana-Champaign
Advisor(s): A J Hildebrand, University of Illinois

When a meteorologist says that it is going to be sunny and 80 degrees 10 days from now, how well can we rely on this prediction? This project analyzes the accuracy of weather forecasts obtained from online sites and compares these to predictions based on historical climate data using different statistical models such as the persistence, climatology, and time series models. The analysis is based on over 10 million individual predictions from wunderground.com, and historical weather data from over 10000 locations in the U.S.

292. The Colorability of Rational Tangles and Their Closures

Jonah Amundsen University of Wisconsin Eau Claire
Dawn Paukner University of Wisconsin Eau Claire
Advisor(s): Carolyn Otto, University of Wisconsin Eau Claire

Our research team researched the colorability of rational tangles. The colorability of a rational tangle and the rational number of a tangle are invariants of the tangle. We investigate the relationship between these two invariants. We develop formulas for the determinant of certain types of rational tangles. We also explore the relationship between the colorability of the tangle and the tangle's closures.

293. Hexagonal Mosaic Knots

Selina Foster Westmister College
Malachi Alexander California State University Monterey Bay
Gianni Krakoff University of Washington
Advisor(s): Jennifer McLoud-Mann, University of Washington Bothell

In their 2008 paper, Quantum Knots and Mosaics, Lomonaco and Kauffman introduce mosaic knots on square tilings of the plane. This paper generalizes the tiles, terms, and theorems from square tilings to hexagonal tilings. Additionally, we develop further constructions with properties unique to hexagonal mosaic knots, including minimal hextile number and algebraic saturation diagrams.

294. Topological Data Analysis of Ballistic Deposition

Kate Heenan College of the Holy Cross
Advisor(s): David Damiano, College of the Holy Cross

In this project we adapt a method developed by MacPhearson-Schweinhart that utilize persistent homology (PH), and apply them to analyze the void structure of ballistic depositions. Their method uses PH to calculate a topological analogue of fractal dimension for one-dimensional complexes generated by probabilistic processes. The ballistic depositions model porous granular media. We consider depositions that depend on a probability p in a novel matter. We compute their PH and fractal dimensions for varying sizes and probabilities, and obtain a relation between them. The PH is computed using a filtration of the void space by maximum radii permitted within the closed voids.

295. A Polynomial for Unoriented Links

Janet Huffman Indiana Wesleyan University
Advisor(s): Sandy Ganzell, St. Mary's College of Maryland

The Jones polynomial is an invariant of oriented links with $n \geq 1$ components. When $n = 1$, the choice of orientation does not affect the polynomial, but for $n > 1$, changing orientations of some (but not all) components can change the polynomial. Here we define a version of the Jones polynomial that is an invariant of unoriented links, i.e., changing orientation of any sublink does not affect the polynomial. This invariant shares some, but not all of the properties of the Jones polynomial. The construction of this new invariant also reveals new information about the original Jones polynomial.

296. Knot Fertility and Lineage

Elsa Magness Seattle University
Kayla Perez Evergreen State College
Advisor(s): Allison Henrich, Seattle University

Is your favorite knot fertile? We define a knot K to be a parent knot of a knot H if some number of crossings in a minimal crossing projection of K can be resolved to produce a diagram of H. We say that K fertile if it is a parent knot of every knot with a smaller crossing number than itself. In this talk, we will explore families of knots and their relative fertility. We also explore ways to find the trefoil in every knot.

297. Modeling the Topology of Non-Trivial Space

Thayer Meyer Virginia Military Institute
Advisor(s): Jessica Libertini, Virginia Military Institute

What is the shape of the universe? Is it finite yet unbounded, like the multi-connected topologies studied by cosmic crystallographers, like Jean-Pierre Luminet? And, if it is, how could we use mathematics to determine the feasibility of measuring the size and shape of the universe? How much of the sky would we need to search to see a replication of ourselves? These questions have been answered for a toy 2D model universe, and in this research, we seek to extend these results to 3D. We begin by assuming the most basic topological structure, the 3-torus, creating a 3D lattice of repetitions of galaxy super-clusters. We then apply a set of mathematical tools, including spherical projection and Delaunay triangulations on the sphere, with the goal of developing a mathematical conjecture which, given the ratio between the maximum visible distance and the length scale of the universe, will provide the minimum cone-angle needed to guarantee that at least one lattice point will always be in view. We also discuss future work, including alternative gluing of the cube, temporal effects due to a finite speed of light and relative motion, and the expansion of the universe.

298. The Effect of Doubling Operators on Colorability of Knots and Links

Molly Petersen University of Wisconsin-Eau Claire
Advisor(s): Carolyn Otto, University of Wisconsin-Eau Claire

Our research team has looked at patterns in the colorability of knots and links. The colorability, which is given by a link's determinant, is a specific invariant that is useful when distinguishing between two links. Specifically, we have looked at doubling operators, the bing double and pure double, and their formation through satellite construction. Using several different methods to find a knots determinant and Alexander Polynomial, we found patterns in a knots

determinant between framings. Recently, we have proven our conjectures for the patterns of a knots determinant between framings using Skein Relations and induction.

299. Volume Preserving Surgeries on Hyperbolic 3-Manifolds

Peter Rudzis University of Washington
Advisor(s): Rolland Trapp, California State University - San Bernardino

We investigate two types of surgeries, the parallel surgery and the series surgery, on finite-volume hyperbolic 3-manifolds. A paper by Harnois and Trapp shows that these surgeries preserve hyperbolicity and volume when performed on the complement of a special type of link, known as a fully augmented link. Using methods based on those of Adams, in his work on hyperbolic 3-manifolds, we prove that the parallel and series surgeries preserve hyperbolicity and volume when performed on any finite-volume hyperbolic 3-manifold.

300. A Combinatorial Characterization of Curves On the n-Punctured Sphere

Joe Suk Stony Brook University
Brian Matvey Stony Brook University
Advisor(s): Moira Chas, Stony Brook University

The group of components of the homeomorphism group of a surface, the mapping class group, acts on the set of free homotopy classes of curves on the surface (i.e., the set of closed oriented curves on the surface, up to continuous deformation). We study the number of orbits of curves with k self-intersections on the sphere with n disks removed. We present two algorithms to determine the exact number of orbits for a given k: a topological one and a graph theoretic one. In the topological method, we decompose the curve into a product of simple loops and study the number of ways of arranging the intersections of these loops. In the graph theoretic method, we use a ribbon graph to encode both the complement of the curve and the instructions for gluing the discs back together. We plan to extend these methods to higher genus surfaces, and also explore other applications of configuration graphs.

301. A Radically Simple State Sum Invariant for Compact Oriented n-manifolds

Levente Szabo University of North Carolina Asheville
Advisor(s): David Peifer, University of North Carolina Asheville

A statistical mechanical model is defined on an oriented compact n-manifold equipped with a vertex ordered triangulation. State variables are located on edges and the analog of Boltzmann weights are assigned to top dimensional simplexes according to the Ansatz $\prod f(\lambda(xy))^{\epsilon_{xy}}$ where f is a complex valued function on the edge states. The powers ϵ_{xy} depend only on the position of the edge within the ordered simplex and the combinatorial orientation of the simplex relative to the ambient orientation. Conditions are determined for which the resulting partition function is invariant under Pachner moves, thereby determining an invariant of PL manifolds. Instances of such invariants can differentiate between S^3, $S^2 \times S^1$ and the lens space $L(5, 2)$.

302. Generalization's of Conway's Thrackle Conjecture

Zoe Wellner Cornell University
Advisor(s): Florian Frick, Cornell University

A thrackle is a graph that can be drawn in the plane such that any pair of distinct edges intersects precisely once, either at a common vertex or a transverse intersection point. Conway conjectured that for any thrackle the number of edges does not exceed the number of vertices. We prove convex-geometric analogs of Conway's conjecture and establish bounds on the number of facets for higher-dimensional generalizations of thrackles. In the convex planar setting, we conjecture that a bound as in Conway's conjecture holds whenever the pairwise intersections admit a transversal set.

303. Determining a Twisted Torus Link's Number of Components

Emily Winn College of the Holy Cross
Advisor(s): Brandy Doleshal, Sam Houston State University

A link is a smooth embedding of a finite number of disjoint copies of S^1 into S^3. Links of one component are known as knots. Links that can be embedded on the surface of a torus are called torus links. Further, a twisted torus link is the concatenation of two or more torus links. While torus links have been studied extensively, no complete classification

of twisted torus links currently exists. We examine finding easy ways to determine the number of components that a twisted torus link has and look for special cases when it has one component and is therefore a knot. We find that there exist various patterns in the parameters of a twisted torus link that reveal general information about the number of components.

304. The Turaev Genus of Torus Knots with Small Braid Index

Eli Polston Vassar College
Yanjie Zheng Vassar College
Advisor(s): Adam Lowrance, Vassar College

A knot invariant is a property defined for all knots such that the invariant will be the same for equivalent knots. In particular, we looked at an invariant known as the Turaev genus. Essentially, the Turaev genus of a torus knot is a measure of complexity on the torus associated with the knot. In this project, we wanted to know the Turaev genus of torus knots, knots that lie flat on a torus. A torus knot is characterized by a pair of coprime integers, p and q. The (p, q)-torus knot intersects a cross section of the torus p times and wraps around the core circle of the torus q times. The braid index of the (p, q)-torus knot is said to be p. Previous research discovered the Turaev genus of torus knots with braid index two and three. The Turaev genus of torus knots with braid index four or greater was previously unknown. To find the Turaev genus of torus knots with greater braid index, we looked at the diagrams of the knots. A diagram of a knot is a projection of a knot onto the plane. The Turaev genus of a diagram gives the upper bound of the Turaev genus of a knot. We calculated the width of another knot invariant called knot Floer homology to get the lower bound of the Turaev genus of the knots. We transformed the diagram through braid moves to lower the upper bound so it equaled the lower bound given by the width of knot Floer homology. By this technique, we found the Turaev genus of the family of torus knots with braid index 4 and subsets of torus knots with braid index 5 and 6. We also developed some new techniques that will hopefully help further research determine the Turaev genus of torus knots with greater braid index.

305. Predicting Major Dropout Rates for Undergraduate Students in Mathematics

Ritvik Kharkar University of California, Los Angles
Jessica Tran University of California, Los Angles
Advisor(s): Mason Porter, University of California, Los Angles

In this work, we aim to predict whether or not a given mathematics student will drop out of their mathematics major. Switching majors or dropping out of specific subject tracks are prevalent issues which are often necessary for student success but which also often lead to lost time and money for university level students. For many students, it is highly predictable whether or not they will drop out of their current major within a specified time range such as within the next quarter or within the next year. Given models which accurately identify such students, universities can take action by either sending precious academic resources to these at-risk students in order to boost their chances of retaining their major, or make the transition to a new major or track much easier for the student. We build models in two flavors. First, we construct models designed to assign a binary score to each student predicting whether or not s/he will drop out of their major in a predetermined time range. Second, we construct models designed to assign more nuanced risk scores ranging between 0 and 1 to each student. This risk score will tell the department how much to prioritize a particular student when considering the allocation of university resources.

306. Astronomical Image Deblurring for Optical Navigation

Liam Coulter University of St. Thomas

This project focuses on image deblurring and centerfinding for astronomical optical navigation. Optical navigation (OPNAV) has been in use in multiple spacecraft for many years, and is an important component of spacecraft navigation. However, OPNAV deals with images which are blurry and contain noise, so image processing is an integral part of OPNAV. This project seeks to solve traditional OPNAV problems with a new approach: deblurring using inverse matrix linear algebra, paired with centerfinding techniques. To accomplish this we use filtering, regularization, and sparse inversion methods. A discussion of both visual results and quantitative results is given, and of which methods perform best in each category. Then, possible conclusions, as well as future directions are discussed.

307. Radio Labeling of Odd Cycle Graphs

Stephania Ortiz California State University, San Bernardino
Sifat Khan California State University, San Bernardino
Amber Olson California State University, San Bernardino
Advisor(s): Min-Lin Lo, California State University, San Bernardino

For a connected graph G, let $d(u,v)$ denote the distance between vertices u and v of G. The diameter of G, denoted by $\mathrm{diam}(G)$, is the maxium distance between any two vertices u and v of G. A radio labeling of G is a function f that assigns each vertex a non-negative integer (label) such that the inequality $|f(u)-f(v)| \geq \mathrm{diam}(G)-d(u,v)$ holds for any two distinct vertices u and v of G. The span of a labeling f, denoted by span f, is the difference between the largest and smallest label assigned. The radio number of G, denoted by $rn(G)$, is the minimum span of all radio labeling of G. An optimal radio labeling of G is a radio labeling f of G such that span $f = rn(G)$. In this presentation, we will discuss a new pattern we found for an optimal radio labeling of C_n (cycle graph with n vertices) where $n \equiv 1 \pmod 4$.

308. Radio Labeling of Odd Cycle Graphs

Esther Morales California State University, San Bernardino
Shantanue Tavkar California State University, San Bernardino
Advisor(s): Min Lin Lo, California State University, San Bernardino

For a connected graph G, let $d(u,v)$ denote the distance between vertices u and v of G. The diameter of G, denoted by $\mathrm{diam}(G)$, is the maxium distance between any two vertices u and v of G. A radio labeling of G is a function f that assigns each vertex a non-negative integer (label) such that the inequality $|f(u)-f(v)| \geq \mathrm{diam}(G)-d(u,v)$ holds for any two distinct vertices u and v of G. The span of a labeling f, denoted by span f, is the difference between the largest and smallest label assigned. The radio number of G, denoted by $rn(G)$, is the minimum span of all radio labeling of G. An optimal radio labeling of G is a radio labeling f of G such that span $f = rn(G)$. In this presentation, we will discuss a new pattern we found for an optimal radio labeling of C_n (cycle graph with n vertices) where $n \equiv 1 \pmod 4$.

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