Abstracts for the MAA Undergraduate Poster Session

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Organized by

Joyati Debnath
Winona State University

Organized by the MAA

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 about 273 posters and 492 presenters, record numbers, once again. 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 PhD.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 the National Science Foundation.

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 Julia Dills and Maia Henley for their 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.

There are many details of the poster session that begin with putting out the advertisement in FOCUS in February, ensuring students have travel money, and organizing tables in the room we are in today that are attributed to Gerard Venema (MAA Associate Secretary), Linda Braddy (MAA), and Donna Salter (AMS).

Zsuzsanna Szaniszlo (Valparaiso University) rallied volunteers to judge the session and coordinated the judge assignments. Angel R. Pineda (California State University, Fullerton), James P. Solazzo (Coastal Carolina University), and Dora Ahmadi (Moorehead State University) organized an orientation for the judges and authored the judging form. Thanks to all the students, judges, volunteers, and sponsors. I hope you have a wonderful experience at this years poster session!

Joyati Debnath
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Titles, Authors, Advisors and Abstracts

1. Tight Frame Structure and Scalability

Rachel Domagalski Central Michigan University
Hong Suh Pomona College
Xingyu Zhang Pennsylvania State University
Advisor(s): Yeonhyang Kim, Central Michigan University

In $\mathbb{R}^n$, a frame is defined to be a spanning set. A collection $F = \{f_i\}_{i=1}^k \subseteq \mathbb{R}^n$ is a λ-tight frame if there exists $\lambda 0$ such that for every $f \in \mathbb{R}^n$, $\lambda \| f \|^2 = \sum_{i=1}^k |\langle f, f_i \rangle|^2$. We examine the structure of frames through factor posets and scalability. A factor poset for a frame $F = \{f_i\}_{i=1}^k$ is the set $P = \{J \subseteq \{1, \ldots, k\} : \{f_j\}_{j \in J}$ is a tight frame$\}$, partially ordered by set inclusion, $\emptyset \in P$. This definition leads to the question: given a poset P, when is P a factor poset? We call this problem the *inverse factor poset problem* (IFPP). The IFPP was solved in $\mathbb{R}^2$ in 2013. In our goal of solving the IFPP in $\mathbb{R}^n$, we discovered combinatorial properties of tight frames and explored constructions of frames from posets. Next, we examine the scalability of frames. For a frame $F = \{f_i\}_{i=1}^k$, a scaling is a vector $w = (w(1), \ldots, w(k)) \in \mathbb{R}^k_{\geq 0}$ such that $\{\sqrt{w(i)} f_i\}_{i=1}^k$ is a 1-tight frame in $\mathbb{R}^n$. We establish results on the structure of the scalability polytope and its connection to the factor poset. This research completed at Central Michigan University's 2014 REU.

2. Classifying Seven-Dimensional Solvable Lie Algebras with Six-Dimensional Abelian Niradical

Kyle Ferguson Grand Valley State University
Advisor(s): Firas Hindeleh, Grand Valley State University

This poster is the first 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. They were completely classified up to dimension six. A general theorem asserts that if $\mathfrak{g}$ is a solvable Lie Algebra of dimension n, then the dimension of 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. In this project we focus on the class where the nilradical is six-dimensional abelian, i.e isomorphic to $\mathbb{R}^6$.

3. Isomorphy classes of trivolutions of $SL_2(K)$

Fernando Betancourt Velez University of Puerto Rico
Ontario Stotts Wake Forest University
Joyce Yang Harvey Mudd College
Advisor(s): Aloysius Helminck, North Carolina State University

Involutions of real matrix groups have been used to construct real symmetric spaces for more than a 100 years. Using automorphisms of order n of matrix groups defined over an arbitrary field k one can construct spaces similar in nature. These are called generalized symmetric spaces. This area has a strong connection to physics. As a first step in the study of these generalized symmetric spaces we consider trivolutions of $SL_2(K)$. Trivolutions are group automorphisms of order 3. $SL_2(K)$ is the group of 2-by-2 matrices with determinant 1. In this paper we will give a characterization for the isomorphy classes of trivolutions of $SL_2(K)$ with K any field of characteristic not 2 or 3. This work is analogous to work by Helminck and Wu on automorphisms of order 2.

4. Common Algebraic Errors: Interesting Math Problems

Luis Ortiz Universidad Metropolitana
Advisor(s): Luis F. De La Torre, Universidad Metropolitana

The algebra is a branch of mathematics where students have difficulties. In this research, a list of common algebraic errors were selected and studied. These errors become interesting mathematical problems when are treated as multivariate equations. It means, each error is related to a mathematical problem associated, where a solution set is required to be found. These solutions were initially found in the set of integers (Z) and then in the field of real numbers (R). Most of these associated problems were solved using only algebra; in some cases it was necessary to use calculus,

number theory and numerical analysis. In this research 20 problems associated with the most common algebraic errors were solved. Some of these problems have unique solutions while some other of these problems have infinite solutions. Algebraic errors are well discussed in the literature. However, to visualize these errors as mathematical problems are an important tool to help our students to establish the differences and do not make these kind of mistakes.

5. On the Cohen-Macaulayness of S_n-Invariant Subspace Arrangements

Aaron Brookner Massachusetts Institute of Technology
Advisor(s): Pavel Etingof, Massachusetts Institute of Technology

In this paper, we define a family of algebraic varieties, $X_\lambda \subset \mathbb{C}^n$, where λ is an integer partition of n and X_λ is a union of subspaces of $\mathbb{C}^n$. We are specifically interested in which X_λ satisfy the Cohen-Macaulay (CM) property, which roughly states that the singularity of X_λ at the origin is "not too bad." We give examples, prove several results, and make several conjectures about for which λ these X_λ satisfy this property, both facilitated by computer calculations done in the Macaulay2 program. The motivation for this work comes from representation theory, which provides the only other known proofs that these X_λ satisfy the CM property. Throughout this presentation, we highlight that X_λ is not CM "by chance." That is, X_λ seems to be CM only when there is a reason from representation theory and integrable systems for it to be.

6. Reduced τ_n Irreducible τ_n Factor Graphs

Michelle Rosado University of Puerto Rico in Mayaguez
Advisor(s): Reyes M. Ortiz, University of Puerto Rico in Mayaguez

A nonzero nonunit integer x has a τ_n-factorization if $x = \pm x_1 \cdot x_2 \cdots x_k$, where for each $i \neq j$, $n \mid x_i - x_j$. We also say that x is a τ_n-product of the x_i and each x_i is a τ_n-factor of x. We called x a τ_n-irreducible, if $k = 1$. In 2011, Ortiz and Lucena defined a τ_n-irreducible τ_n-factor graph of x, as a graph in which the vertices represents the τ_n-irreducible τ_n-factor (up to associates) and two vertex are connected if there is an τ_n-factorization into τ_n-irreducible where the τ_n-irreducible τ_n-factor associated with such vertex appear in such τ_n-factorization. We defined, the reduced τ_n-irreducible τ_n-factor graph, in a similar manner the only difference from the τ_n-irreducible τ_n-factor graph is that associates of a reduced τ_n-irreducible τ_n -factor cannot be represented by the same vertex. We present preliminary results of a characterization for such graphs when $n = 0, 1, 2, 3$. They are distinct with respect to the ones Lucena and Ortiz characterized in 2010.

7. Methods of Relating Types of Canonical Algebraic Curvature Tensors

Elise McMahon Ave Maria University
Advisor(s): Corey Dunn, California State University San Bernardino

We relate canonical algebraic curvature tensors that are built from a self-adjoint (R_A^S) or skew adjoint (R_A^Λ) linear map A. By Nash's imbedding theorem, an algebraic curvature tensor built from a self-adjoint operator is realizable as the curvature tensor of an embedded hypersurface in Euclidean space. We develop an identity to relate the skew-adjoint canonical algebraic curvature tensor to the self-adjoint canonical tensors, which will allow us to employ previous methods to solve new problems. We compute the structure group of R_A^Λ, and develop methods for determining the linear independence of sets which contain both builds of algebraic curvature tensors. We consider cases where the operators are arranged in chain complexes and we find this case to be highly restrictive. Moreover, if one of the operators has a nontrivial kernel, we develop a method for reducing the bound on the least number of canonical algebraic curvature tensors that it takes to write an algebraic curvature tensor.

8. Leamer Monoids and the Huneke-Wiegand Conjecture

Sara Stover Mercer University
Dalton Worsnup Arizona State University
Advisor(s): Roberto Pelayo, University of Hawaii- Hilo

The Huneke-Wiegand Conjecture has earned much attention in commutative algebra; once a theorem was developed connecting the Huneke-Wiegand Conjecture to numerical monoids, the study of arithmetical sequences in numerical monoids was sparked. In our research, we restricted ourselves to characterizing numerical monoids with consecutive generators (intervals). In particular, we focus on determining when a numerical monoid $\Gamma=\langle m, m+1, \ldots m+k\rangle$

has an irreducible sequence of the form $\{x, x+s, x+2s\}$ for $s \in \mathbb{N}\backslash\Gamma$. We discovered and proved a theorem for finding an irreducible sequence of this form when Γ has two generators, thus satisfying the Huneke-Wiegand Conjecture for monomial ideals generated by two elements. This lays the groundwork for finding conditions when $\{x_0, x_0+s, x_0+2s\} \subset \Gamma$ for any number of generators.

9. A dynamic algorithm for compution of ω-primality in numerical monoids

Thomas Barron University of Kentucky
Advisor(s): Christopher O'Neill, and Roberto Pelayo, Texas A&M, and University of Hawaii - Hilo

In a numerical monoid S (a cofinite additive submonoid of $\mathbb{N}$), the ω invariant assigns to each element n of S a positive integer $\omega(n)$ which measures how far n is from being prime. Existing algorithms for computing $\omega(n)$ for a given n become prohibitively slow as n grows large. By using an extension of ω from S to the whole of $\mathbb{Z}$, we develop a dynamic algorithm (one which re-uses prior computations to speed up new queries) for computing $\omega(n)$ which provides drastic improvements in computation times. We also give an improved description of the asymptotic behavior of ω, which in combination with our algorithm, allows for very efficient computation of the complete behavior of ω for a given numerical monoid. Our algorithm has been included in the NumericalSgps package in GAP, a popular computational algebra system.

10. Hall-Littlewood Polynomials and a Twisted Six-Vertex Model

Roger Van Peski Princeton University
Vineet Gupta Stanford University
Uma Roy Boston University - PROMYS
Advisor(s): Daniel Bump, Stanford University

The six-vertex or ice-type model of statistical mechanics, originating with Linus Pauling's attempt to calculate the residual entropy of ice, has seen much work since its inception from both physical and pure combinatorial viewpoints. In particular, Tokuyama's deformation of the Weyl character formula, which expresses the Schur polynomial (of Cartan type A) in terms of combinatorial data from Gelfand-Tsetlin patterns, has been rephrased in terms of partition functions of six-vertex systems. In recent work, the presenters generalized Tokuyama's original result to the Hall-Littlewood polynomials, suggesting that there should be a analogous formula expressing the Hall-Littlewood polynomial as a six-vertex partition function divided by the deformed Weyl denominator. Here we provide such a generalization, expressing the type A Hall-Littlewood polynomial in terms of a partition function of a column-twisted six-vertex model. We also present progress on a generalization of our formula to the type C Hall-Littlewood polynomials.

11. Characters of $GL_2(K)$ with K a Finite Field

Aura Salazar Cardona University of Texas at Brownsville
Advisor(s): Ju-Lee Kim, Massachusetts Institute of Technology

Characters of group representations are fundamental tools for performing calculations in representation theory. The entries of the character table of a group G are the values of each irreducible character on the conjugacy classes of G. From the character table of a group we can obtain important group theoretical information, most notably we can deduce all the irreducible representations of this group. In his paper "The Characters of the Finite General Linear Groups," J.A. Green provides a method to compute the character table for $GL_n(F_q)$, the group of $n \times n$ non-singular matrices with entries coming from the field F_q. However, Green's methods rely heavily on finite group theory, thus they can hardly be used to find the irreducible representations of $GL_n(F)$ with F a local field. Our goal is to provide a method to construct the character table of $GL_2(K)$ without explicitly using the finiteness of K, allowing future work to expand this method to the case of $GL_n(K)$ where K is a local field.

12. Random Groups at Density 1/2

Shelby Kilmer Bucknell University
Advisor(s): Moon Duchin, Tufts University

Random groups in the density model (with density $0 < d < 1$) have presentations with a random set of $(2m-1)^{dk}$ relators of length k on m generators. The classic theorem in the density model states that for $d > 1/2$, random groups are asymptotically almost surely trivial or isomorphic to $\mathbb{Z}/2\mathbb{Z}$, while for $d < 1/2$, random groups are asymptotically

almost surely infinite hyperbolic. This summer our research group studied random groups at $d = 1/2$ and found both infinite hyperbolic groups and trivial groups are generic, depending on how we tuned certain parameters. This is the report of a research project completed at Tufts University, Summer 2014, as a part of an NSF research cluster.

13. A Combinatorial Model for Rational Base Representations of Natural Numbers

Hailey Olafson Pacific Lutheran University
James Van Alstine Pacific Lutheran University
Advisor(s): Tom Edgar, Pacific Lutheran University

We investigate representation of natural numbers in terms of rational bases and some of the associated properties. We then define a collection of combinatorial data associated with a rational number and study the properties of these sequences. Finally, we use this combinatorial data to construct an infinite, labeled, rooted tree that describes many of the interesting features of the relevant rational base representations of natural numbers, and we explore some of the combinatorics of these trees.

14. Representing Finite Fields using Fibonacci Cycles mod p

Jeremy Porche Angelo State University
Shelby Robertson Angelo State University
Caitlyn Conaway Angelo State University
Advisor(s): John Smith, Angelo State University

Finite fields can be represented in various ways. Generally, they are most easily understood when represented as vectors. This representation poses serious computational issues when considering the multiplicative operation. Several methods have been devised to deal with this problem. Holger Schellwat presented a simple slide rule and William Wardlaw simply circumvented the problem of dealing with vectors, by modeling finite fields using square matrices. This research project used the work done by Wardlaw to represent finite fields using Fibonacci cycles mod p. This new approach also yields a vector representation where the multiplication is somewhat transparent, and may even be extended to obtain a simplification of the vector and slide rule problem.

15. Special Values in Leamer Monoids

Jackson Rebrovich Angelo State University
Nico Rojina University of North Carolina at Chapel Hill
Advisor(s): Roberto Pelayo, University of Hawaii at Hilo

A numerical monoid Γ generated by an arithmetic sequence with step size identical to the distance between the generators is called an arithmetical Leamer monoid. Much is known about the factorization theory for arithmetical Leamer monoids. For every numerical monoid of embedding dimension two it is generated by the arithmetic sequence {a, a+d}. However, much is still unknown about Leamer monoids when the step size does not equal the distance between the generators. The ultimate goal is to prove that the Huneke-Wiegand conjecture holds for embedding dimension 2 numerical monoids for any $s \notin \Gamma$. One approach is to attempt finding a closed form for x_0. In this paper,we found a formula to calculate the last step size before $x_0 = x_f$ consecutively. In addition, we found a formula to find x_0 and x_f, for the last time $x_0 \neq x_f$ for that particular step size. As a result, we found a closed form for x_0, which involves Apery sets and modular arithmetic.

16. Toward a Generalization of the Newton–Girard Formulae

Emily Scott William Jewell College
Advisor(s): Azadeh, Samuel, Rafizadeh, Chamberlin

A symmetric polynomial is a polynomial in n variables such that any permutation of the variables leaves the polynomial unchanged. An example of a symmetric polynomial in two variables is $x_1 + x_2$. This poster will present our progress towards proving a conjectured generalization of the Newton–Girard formulae, which relate two types of symmetric polynomials: the elementary symmetric polynomials and the power sum symmetric polynomials. These formulae have applications in Galois theory, invariant theory, group theory, combinatorics, and general relativity. The conjectured generalization we are trying to prove relates two other types of symmetric polynomials: the monomial symmetric polynomials (which are a generalization of the elementary symmetric polynomials) and the power sum symmetric polynomials. Our progress thus far has been to prove the conjecture in n variables in several cases.

17. On the Kronecker Product of a Hook and a Box

William Hallahan College of the Holy Cross
Advisor(s): Cristina Ballantine, College of the Holy Cross

The algebra of symmetric functions is the collection of functions such that taking any permutation of their arguments does not change the function. This collection is endowed with the operations of addition and multiplication. One basis of this algebra consists of the Schur functions, which correspond to partitions. The Kronecker Product of Schur functions is an operation which produces a symmetric function. There is no simple combinatorial rule for writing the Kronecker Product in the basis of the Schur functions. Jonah Blasiak gives a combinatorial interpretation for the coefficient of a given Schur function in the decomposition of the Kronecker product of two other Schur functions when one of the corresponding Young diagrams is a specific shape, a hook. We are attempting to find a simpler rule for the special case when the other shape is a box. We prove a simpler rule for coefficients of some of the Schur functions appearing in the decomposition. We also give some stability results for the coefficients in the Kronecker product of Schur functions indexed by a hook and a box.

18. Permanents of Random $(0, 1)$ — Square Matrices over $\mathbb{Z}_P$

Alexander Wilson The University of Texas at Tyler
Advisor(s): Kristen Stagg, The University of Texas at Tyler

Calculating permanents of $n \times n$ matrices is impossible to compute in polynomial time for large values of n. Our aim is to examine the permanents of random $(0, 1)$ - square matrices over the field $\mathbb{Z}_P$. We utilized Burnsides' Theorem in an effort to condense the 2^{n^2} cases. We begin with 2×2 and 3×3 matrices and applied this technique to larger matrices. We also hope to comment on the open problem of finding the probability that an $n \times n$ random matrix has permanent 0 over the field $\mathbb{Z}_p$ as n approaches infinity. It is hypothesized that this probability is is $1/p$.

19. On the divisibility and valuations of the Franel numbers

Samantha VanSchalkwyk Mount Holyoke College
Adela Yang Bowdoin College
Abraham Schulte Northwestern University
Advisor(s): Herbert Medina, Victor Moll, Loyola Marymount University, Tulane University

The Franel numbers are the sum of cubes of binomial coefficients. The set of primes may be partitioned with respect to the p-adic valuations of Franel numbers as follows: those whose valuation is 0 for all Franel numbers, those whose valuation is equal to the number of occurrences of a particular digit in the base-p representation of the index of the Franel numbers, and those which fall into neither category. One of the goals of this project is to classify as many primes as possible into these three types. Furthermore, the 2-adic valuations of the Franel numbers have interesting properties that are explored in more detail.

20. Exploration into Birkhoff's Algebraic Structure Problem

Jessica Young Westfield State University
Advisor(s): Maureen Bardwell, Westfield State University

In a book originally published in 1940, Garrett Birkhoff posed the problem of classifying all partially ordered sets whose group of order automorphisms $(f, \cdot, \leq)$ is a lattice ordered permutation group. As part of my project, I examined original French manuscripts in abstract algebra and obtained a copy of the annals of the 1900 World Congress of Mathematicians where background for Birkhoff's book was originally given. Although many have attempted to solve this problem, there is currently no general solution. My project outlines the problem and explores specific examples of partially ordered sets with their corresponding automorphism groups. I use these examples as building blocks for a general example of my own which I classify and which can be used to generate a multitude of other examples.

21. Distance Between Finite Groups: Formulae, Bounds, and the Triangle Inequality

Kim Pham University of California Irvine
Weiwei Li University of California Irvine
Advisor(s): Alessandra Pantano, University of California Irvine

The distance, **d**, between two finite cyclic groups $\mathbb{Z}_m$ and $\mathbb{Z}_n$, is a function that describes how close these groups are to being isomorphic. The smaller the distance, the closer these groups are to being isomorphic. This notion of closeness has been made precise by a concept known as matching pairs. We prove Mark Lewers' hypothesized upper bound for

the distance. That is, If $m \mid n$, then the following holds: If m is odd, then $\mathbf{d}(\mathbb{Z}_m, \mathbb{Z}_n) \leq n^2 - \frac{(m^2+1)}{2}$. If m is even, then $\mathbf{d}(\mathbb{Z}_m, \mathbb{Z}_n) \leq n^2 - \frac{(m^2)}{2}$. We discover a necessary condition to obtain the distance, and give explicit formulae for the distance between finite cyclic groups of small order. Our results also suggest that this distance function has all the properties of a metric except the Triangle Inequality. However, we are able to show that the Triangle Inequality holds for certain cases. We have discovered multiple lower bounds for the distance between the groups. However, our lower bounds are not sufficient enough to verify the other cases of the Triangle Inequality. So, we plan to look for better bounds for the distance in order to verify the Triangle Inequality and better approximate the distance.

22. The catenary degree of elements in numerical monoids of embedding dimension 3

Gautam Webb Colorado College
Reuben Tate University of Hawaii at Hilo
Advisor(s): Vadim Ponomarenko, San Diego State University

The catenary degree is an invariant that arises in the study of non-unique factorization theory. Given an element in a numerical monoid, its catenary degree is an integer that gives a measure of the overall spread of that element's factorizations. Define the catenary set to be the set of possible catenary degrees of elements in a numerical monoid. For numerical monoids of embedding dimension 2, the catenary set is well understood. We investigate the catenary sets of numerical monoids of embedding dimension 3 and we present some results characterizing these sets for certain monoids. In particular, we show that catenary sets can be arbitrarily large and we give conditions that determine when catenary sets have exactly two elements. We also give a proof of a conjecture regarding the minimum nonzero catenary degree of elements in a numerical monoid.

23. Towards the classification of unital 7-dimensional commutative algebras

Alexandria Yu MIT Primes and University School of Nashville
Advisor(s): Sherry Gong, MIT

We study the problem of determining how many unital commutative algebras exist in a given dimension and to find all of these algebras.The motivation for this classification problem comes from number theory and algebraic geometry. For dimension less than or equal to 6, Poonen has completely classified all unital commutative algebras up to isomorphism. For dimension greater than or equal to 7, the situation is much more complicated due to the fact that there are infinitely many algebras up to isomorphism. An algebra is called local if there exists a unique maximal ideal M. Local algebras are basic building blocks for general algebras as any finite dimensional unital commutative algebra is isomorphic to a direct sum of finite dimensional unital commutative local algebras. In this work, we classify all unital 7-dimensional commutative local algebras up to isomorphism with the exception of the special case $k(1) = 3$ and $k(2) = 3$, where, for each positive integer i, $M(i)$ is the subalgebra generated by products of i elements in the maximal ideal M and $k(i)$ is the dimension of the quotient algebra $M(i)/M(i+1)$. When $k(2) = 1$, we classify all finite-dimensional unital commutative local algebras up to isomorphism.

24. Omega Primality and Length Sets of Arithmetic Congruence Monoids

Bruce Zheng Texas A&M University
Advisor(s): Scott Chapman, Sam Houston State University

For positive integers a,b where $a \leq b$ and $a^2 \equiv a \mod b$, we define the Arithmetic Congruence Monoid (ACM) $M(a,b) = \{x \equiv a \mod b : x \in \mathbb{N}\}$. $M(a,b)$ is an commutative, cancellative, atomic monoid. For an ACM M and nonunit x, we define that $\omega_M(x)$ is the smallest positive integer n such that whenever $x \mid a_1 \cdots a_t$ for atoms a_i, there exists a $T \subset \{1, \ldots, t\}$ with $|T| \leq n$ such that $x \mid \prod_{k \in T} a_k$. The omega function of M may be viewed as a measure of how close x is to being prime. We give a formula for the omega function of any ACM. For any nonunit x of an ACM M, we may describe the length set $\mathcal{L}(x)$ of x, which is the lengths of all possible atomic factorizations of x. We present some new results on the structure of the lengths sets of an ACM $M(a,b)$ when $\gcd(a,b)$ is prime.

25. n-dimensional semi-hypercubes and the algebras associated with their Hasse graphs

Mitchell Lemons University of Wisconsin-Eau Claire
Austin Riedl University of Wisconsin-Eau Claire
Advisor(s): Colleen Duffy, University of Wisconsin-Eau Claire

The primary goal of our project is to determine the structure of a graded algebra, $A(\Gamma_n)$, that is associated to the Hasse graph, Γ_n, of an n-dimensional semi-hypercube. We can consider a unit n-cube with one vertex at the origin, keep

only those vertices with an even number of 1's in its coordinate positions, and form new simplex and semi-hypercube facets. The symmetry group of the semi-hypercube, and thus the automorphism group of the graph, is isomorphic to $S_n \ltimes \mathbb{Z}_2^{n-1}$. Each symmetry of the n-dimensional semi-hypercube can be thought of as acting on the coordinates of the vertices. For each symmetry, we consider the Hasse subgraph consisting of fixed k-faces of the semi-hypercube under the action. From each Hasse subgraph, we determine the graded dimension of the subalgebra of $A(\Gamma_n)$ by counting the directed paths between each pair of levels in the graph. We have determined the generating functions that describe $A(\Gamma_n)$ under the action of elements from $S_n \ltimes [0]_2^{n-1}$, and have a conjecture on the generating functions for the remaining symmetries. This defines the complete structure of $A(\Gamma_n)$.

26. Of Maximal Bullets of the Generators of a 3-Generated Numerical Monoid where $\omega(n_1)\omega(n_3)$

Loren Anderson North Dakota State University
Advisor(s): Scott T. Chapman, Sam Houston State University

We examine the omega function for a 3-generated numerical monoid in a few general cases. For an element x in a numerical monoid, $\omega(x)$ measures how far x is from being prime in the monoid. Unless the values of the generators are known, it is difficult to compute $\omega(x)$ because the factorization of x is not necessarily unique. One way to ease the calculation of $\omega(x)$ is to identify a $maximal\ bullet$ of x. Here, we identify the possible sets of maximal bullets of the generators of a 3-generated numerical monoid where $\omega(n_1)\omega(n_3)$. Some sets are unique to the $\omega(n_1)\omega(n_3)$ case, while others are not. Throughout, we determine if knowing the factorizations of maximal bullets is sufficient to establish whether $\omega(n_2) = \omega(n_3)$ or $\omega(n_2)\omega(n_3)$ both when $\omega(n_1)\omega(n_3)$ is known and unknown. Additionally, we place bounds on $gcd(n_2, n_3)$.

27. Some Sums on Additive Abelian Groups

Abraham Bekele University of Colorado Denver
Benjamin Wright Providence College
Katie Rosenberg Austin Peay State University
Advisor(s): Baginski, Paul, Fairfield University

The well studied classical Davenport constant of an additive finite abelian group, G, is the least natural number, ℓ, such that every sequence of length ℓ in G is guaranteed to have a nontrivial zero sum subsequence. The Davenport constant arises naturally when studying nonuniqueness of factorization in algebraic number rings. The plus-minus weighted Davenport constant is a variant of the classical Davenport constant, which allows weighting the elements of a sequence by -1 or 1. A sequence $S = s_1, s_2, \ldots, s_\ell$ in G has a nontrivial plus-minus weighted zero sum if $\sum_{i=1}^{\ell} a_i s_i = 0$ for some choice of $a_i \in \{-1, 0, 1\}$, with not all a_i zero. The plus-minus weighted Davenport constant of G, $D_{\pm}(G)$, is defined as the least integer ℓ such that every sequence of length ℓ has a nontrivial plus-minus weighted zero sum. Like the classical Davenport constant, the plus-minus Davenport constant arises in factorization problems, but it is also used to construct dissociated sets in additive combinatorics. With this poster, we will introduce the general bounds on the plus-minus weighted Davenport constant, describe the scientific process of computing Davenport constants, and present the results of the Fairfield University REU.

28. Deformations of 5-Dimensional Associative Non Nilpotent Complex Algebras

Thao Tran University of Wisconsin-Eau Claire
Austin Riedl University of Wisconsin-Eau Claire
Hengzhou Liu University of Wisconsin-Eau Claire
Zach Forster University of Wisconsin-Eau Claire
Advisor(s): Michael Penkava, University of Wisconsin-Eau Claire

We have been studying the deformation theory of non nilpotent complex 5-dimensional associative algebras. By computing the miniversal deformation of an algebra, we can determine precisely to which algebras it deforms. This information tells how the moduli space of such algebras is glued together. In this poster we will explain some of the methods we have used to carry out the computations. There are 285 isomorphism classes of algebras, including 16 1-parameter families. Each of these families is parametrized by a 1-dimensional projective orbifold, which is given by $\mathbb{CP}^1$, modulo an action by the permutation group Σ_2. We have computed versal deformations for all of these algebras, and have completed the study of these deformations for almost all of the algebras. We will present some highlights of our results.

29. Groups with Context-free Co-word Problem and Embeddings into Thompson's Group V

Heather Mathews Miami University
Rose Berns-Zieve Hamilton College
Dana Fry Mount Holyoke College
Johnny Gillings Morehouse College
Advisor(s): Reza Akhtar, Miami University

A conjecture of Lehnert states that a group has context-free co-word problem if and only if it is a finitely generated subgroup of Thompson's group V. Given a finite group G and a homomorphism $\theta : G \to G$, one may define a group $V(G, \theta)$ which generalizes Thompson's group V. We prove that $V(G, \theta)$ has context-free co-word problem by constructing a pushdown automaton and showing that the co-word problem of $V(G, \theta)$ is the cyclic shift of the language accepted by the automaton. Since there does not seem to be an obvious embedding of $V(G, \theta)$ into V, our construction is a candidate for a counterexample to Lehnert's conjecture.

30. The Toppling Polynomial of a Graph

Megan Chambers Youngstown State University
Advisor(s): Luis Garcia-Puente, Sam Houston State University

Let G be a directed graph with a global sink. A sandpile c is a vector of nonnegative integers indexed by the non-sink vertices of G, where $c(v)$ represents the number of grains of sand at vertex v. A sandpile c is stable if, for all vertices v, $c(v)$ is less than the number of edges incident to v; otherwise, c is unstable. In the latter case, the unstable sandpile c may be stabilized by a sequence of vertex topplings where an unstable vertex v topples sending one grain of sand through each edge incident to v. The process of adding sand and toppling creates a Markov chain. It is of great interest to study properties of the recurrent elements in this Markov chain. A principal avalanche is the sequence of topplings that occurs when one grain of sand is added to a particular vertex on a recurrent sandpile of a graph. In 2004, Cori, Dartois, and Rossin introduced the avalanche polynomial, which encodes the sizes of all principal avalanches of a graph. We introduce the toppling polynomial, which encodes the specific toppling sequences of the principal avalanches. This polynomial encodes more information than the avalanche polynomial. We provide general formulas for the toppling polynomials of trees, cycles, wheels, and complete graphs.

31. Generalization of AES-Based Ciphers

Jeff Schreiner-McGraw Willamette University
Kevin Stubbs University of Maryland
Advisor(s): Liljana Babinkostova, Boise State

For the last three decades hash functions have been an essential element of the cryptography that is used for securing computers and electronic communications. Their use is vital and the need to understand them in depth is crucial. The Advanced Encryption Standard (AES), adopted by the US National Institute of Standards and Technology in 2001, is the current symmetric key encryption standard and has widespread use in industry and government, from internet banking and wireless communications to data storage on hard drives. Several hash functions have been designed using modified versions of AES internally. Our research centered on determining the algebraic structure of the sets of encryption functions of AES-based ciphers used in these hash functions. We focused specifically on investigating certain algebraic properties which have been proven to imply significant security weaknesses. Moreover, we define almost translation based ciphers over an arbitrary finite field and study the permutation groups generated by the round functions of such ciphers. We show that under certain cryptographic conditions this group is primitive, which generalizes some previous results. The class of almost translation based ciphers includes the ciphers of several well-known hash functions.

32. Invariants of Generalized Arithmetic Numerical Semigroups

Sarah Hillier Lawrence University
Casey Fu Massachusetts Institute of Technology
Josiah Banks Youngstown State University
Julia Getsos Fordham University
Advisor(s): Vadim Ponomarenko, San Diego State University

A generalized arithmetic numerical semigroup is a numerical semigroup of the form $S = \langle a, ah + d, \ldots, ah + xd \rangle$ where the $\gcd(a, d) = 1$ and $a x$. Much is known for the arithmetic numerical semigroup (the case when $h = 1$), since

for those semigroups there is a complete characterization of the length sets. Therefore, we explore various invariants of the generalized arithmetic numerical semigroup. Specifically, we give an exact description for the following three invariants: Specialized Elasticity, a measure of the maximum length of factorization of an element given its shortest length of factorization, Omega-Primality, a measure of how far an element is from being prime, and Delta Sets, a measure of how far apart factorizations are in length.

33. Computing the Hilbert series of invariant polynomials

Lauren Cowie Rhodes College

Advisor(s): Christopher Seaton, Rhodes College

Let G be a compact subgroup of $\mathrm{GL}(\mathbb{C}^n)$, the group of invertible $n \times n$ matrices with complex entries, and then G permutes the polynomials in the ring $\mathbb{C}[x_1, \ldots, x_n]$. Under this group action, there is an invariant polynomial ring, the set of polynomials that are mapped to themselves under the actions. It can be quite simple to produce a polynomial that is invariant under a group action, and knowing all of the invariants provides a lot of information about the action; however, it can be computationally challenging to "count" the number of invariants of each degree. One technique is to compute the Hilbert series, the power series whose nth coefficient is the dimension of invariants of degree n. This talk will discuss computations of the Hilbert series in the case that G is isomorphic to a circle. In this case, we can describe G in terms of a weight vector, an element of $\mathbb{Z}^n$, and the computation will be in terms of this weight vector.

34. Error-Correction of Linear Codes via Colon Ideals

Benjamin Anzis University of Idaho

Advisor(s): Stefan Tohaneanu, University of Idaho

In this presentation, we show how errors in a received message can be thought of as codewords of minimum weight in a new linear code. We then use techniques such as finding the primary decomposition of the saturation of a homogeneous ideal associated with a code to find codewords of minimum weight and hence perform error-correction. Finally, we show the equivalence, in this case, of saturating to coloning by the power of a variable, and how, in the case of a unique error, finding the primary decomposition of the associated homogeneous ideal becomes superfluous.

35. An Outside Analysis of the Mandelbrot Set

Dante Gates Rowan University

Advisor(s): Hieu D. Nguyen, Rowan University

Due to its fractal nature, much about the Mandelbrot set remains to be understood. While a series formula has been proven to calculate the area of the Mandelbrot set, to date the exact value of this area remains unknown. The challenge lies in computing the series coefficients which are recursively defined by a two dimensional sequence. We present new approximations concerning the 2-adic valuation of the series coefficients. Moreover we use these coefficients to generate high resolution plots of the Mandelbrot set to give an outside perspective of its fractal boundary.

36. A comparison of several algorithms of multidimensional continued fractions

Baudry Metangmo Montana State University Billings

Advisor(s): Saroj Aryal, Montana State University

Finding the most accurate algorithm to express a multivariate function as a generalized continued fraction stands as an important problem until today. Generalization of a regular continued fraction algorithm to higher dimensions is not trivial and has been studied for decades already. There are several algorithms available for expressing functions in two variables as continued fractions, but their accuracy largely depends on a particular set of conditions. In this work, we compare some of these algorithms, both analytically and numerically, with an attempt to find the one that works best in most general situations. We primarily study the errors in the approximants of the continued fraction expansions of some two-variable functions. We further explore convergence properties of the approximants.

37. Infinite Products Arising in Paperfolding

Hadrian Quan University of California, Santa Cruz
Fernando Roman Kansas State University
Michole Washington Georgia Institute of Technology
Advisor(s): Victor Moll, Tulane University

The work here develops methods to evaluate certain infinite products in closed-form. These are finite products of values of the gamma function. Presented here are infinite products of rational functions R(n) raised to the power of some sequence M_n. The sequences satisfy certain regularity conditions as either a ℓ-periodic or k-automatic. Of particular interest is the Regular Paperfolding sequence considered by J. P. Allouche. We include a closed form expression for Infinite Products to the power of an ℓ-periodic sequence, and for a class of k-automatic sequences.

38. A Morphological Classification of the Arithmetic Sum of Two-Parameter Affine Cantor Sets with $C_{1/3}$

Sharat Chandra University of California, Irvine
Advisor(s): Anton Gorodetski, University of California, Irvine

It has been shown the sum of two affine Cantor sets either contains an interval or does not. Further it has been shown that given parameters $(\lambda, \gamma) \in [0, 1] \times [0, 1]$ corresponding to middle-λ Cantor set, C_λ, and middle-γ Cantor set, C_γ, the arithmetic sum of $C_\lambda + C_\gamma$ is a Cantor set if (λ, γ) is close to the origin, while the sum contains an interval if (λ, γ) is far away from the origin. However, there exists a mysterious region in the parameter space, R where the morphology was unknown. Boris Solomyak showed that for almost every point in R, the sum of the corresponding Cantor sets contained an interval. Generalizing to more complex Cantor sets, and extending Solomyak's argument, we consider two-parameter affine Cantor sets $C_{(\alpha,\beta)}$: Cantor sets where the thicknesses of the two generating sets are α and β respectively. We analyze the morphology of the sum of the standard $1/3$ Cantor set with $C_{(\alpha,\beta)}$ and find in the $\alpha - \beta$ parameter space, there again exists a mysterious region where the morphology is unclear. We show for a.e point in the parameter space, the sum does contain an interval.

39. Emergent Gastrointestinal Diagnoses and Procedures: A Nationwide Longitudinal Study of Emergency Department and Inpatient Stays

Kimberly Siegler University of Milwaukee-Wisconsin
Advisor(s): Peter Tonellato, University of Wisconsin-Milwaukee

We performed a meta-data analysis of emergent gastrointestinal (GI) diseases and GI procedures from 2006-2010. GI diseases contribute significantly to mortality, morbidity and healthcare spending in the United States. Anecdotal evidence suggests that the 2008 recession affected emergent GI diseases, GI procedures and their associated costs. We targeted 7 GI diseases and 4 GI procedures for analysis. We used the two largest publically available patient record databases, totaling over 150 million patient records. Data was normalized to 2006 population and adjusted for inflation. Using linear regression and ANOVA, our results show a change in the frequency of emergent GI diseases, the frequency of selected GI procedures and related healthcare costs (p0.03) during the height of the recession. These results suggest the recession may have influenced individuals decision in emergent healthcare use.

40. Low regularity local solutions to the generalized Magneto-Hydrodynamics Equations

Benjamin Schmachtenberger Creighton University
Lucia Magos Creighton University
August Hagen Creighton University
Advisor(s): Nathan Pennington, Creighton University

The incompressible magnetohydronynamics (MHD) system governs the dynamics of the velocity and magnetic fields in electrically conducting fluids such as plasmas and liquid metal. The generalized magnetohydrodynamic (GMHD) system differs from the standard MHD system by replacing the viscosity terms $(-\triangle)$ by the generalized operator $(-\triangle)^\alpha$. Besides their mathematical interest, this allows the GMHD system to model more complex interactions than the MHD system. In this paper, we prove the local existence of a unique short-time solution to the GMHD system with initial data in non-$L^2(\mathbb{R}^n)$ based spaces. These solutions are the first step toward establishing unique global solutions in $L^p(\mathbb{R}^n)$ based spaces for $p2$.

41. Towards a Stability Theory for Feynman's Operational Calculus in the Purely Discrete Setting — A Direct Approach

William Graft Creighton University
Joshua Trebbien Creighton University
Advisor(s): Lance Nielsen, Creighton University

In this poster, we illustrate an abstract formulation of Feynman's operational calculus which was originated by B. Jefferies and G. W. Johnson. This formulation of the operational calculus allows Feynman's heuristic 'rules' for the formation of functions of several noncommuting operators to be applied in a mathematically rigorous fashion. Consider a nicely behaved function, f of bounded linear operators $A_1, \ldots, A_n$ on a Banach space X. The operator $f_{\mu_1,\ldots,\mu_n}(A_1, \ldots, A_n)$ is called the disentangling of the function f. Given continuous Borel probability measures $\mu_1, \ldots, \mu_n$ on $[0, T]$, select sequences $\{\nu_{j,k}\}_{k=1}^{\infty}$, $j = 1, \ldots, n$, of purely discrete finitely supported probability measures on $[0, T]$ which converge weakly to μ_j. Using Feynman's operational calculus for purely discrete measures, compute the disentangled operator $f_{\nu_{1,k},\ldots,\nu_{n,k}}(A_1, \ldots, A_n)$. We are working to establish, in a direct way,

$$\lim_{k\to\infty} f_{\nu_{1,k},\ldots,\nu_{n,k}}(A_1, \ldots, A_n) = f_{\mu_1,\ldots,\mu_n}(A_1, \ldots, A_n).$$

Knowing how to compute such limits directly should lead to insights into the operational calculus and related evolution equations.

42. Dynamics of Folds with Boundary Dependent Ratios

Nicolas Hyde St. Edwards
Advisor(s): Michael Saclolo, St. Edwards

We examine the behavior of a linear system of difference equations generated from the process of "folding" between two smooth curves. Take an arbitrary transversal of these two curves. Then use the following rule: to create a new transversal, take the angle between the most recently constructed transversal and the corresponding curve and let the new transversal be alternately folded by two separate ratios, depending on which curve the transversal originates. We then examine the sequence of angles that these transversals create and discover what they converge to. We use analytical and as well as linear algebraic techniques to analyze the system and to generate the solutions.

43. Ergodicity and Conservativity of Products of Infinite Transformations and their Inverses

Isaac Loh Williams College
Advisor(s): Cesar Silva, Williams College

Weak mixing for finite measure-preserving transformations has many interesting equivalent characterizations, among which is that $T \times T$ is ergodic. This in particular implies that $T \times T^{-1}$ must be ergodic. It has been known for some time that many of these characterizations do not remain equivalent in the infinite measure-preserving case. In this presentation we will construct infinite measure-preserving rank one transformations such that $T \times T$ is ergodic but $T \times T^{-1}$ is not ergodic, and other related examples. This partially answers a question of Bergelson. The methods are combinatorial and probabilistic and use the notion of descendants in the constructions of the transformations. In parallel, we prove that for all rank-one transformations T, the product $T \times T^{-1}$ is always conservative. We also show that the situation is different in countable state Markov shifts.

44. A New Class of Basis Polynomials Derived from the Generalized Prouhet-Thue-Morse Sequence

Jennifer Crawford Rowan University
Advisor(s): Hieu D. Nguyen, Rowan University

The famous Prouhet-Thue-Morse (PTM) binary sequence $\{0, 1, 1, 0, 1, 0, 0, 1, \ldots\}$ has important applications in coding theory, number theory, and combinatorics. Its product-generating function is well-known and has been used to identify sets with equal sums of like powers. We consider the product-generating function of the PTM sequence generalized to base p in terms of a new class of basis polynomials. New explicit formulas are given for these polynomials in terms of eigenvectors and eigenvalues derived from their recurrence matrices.

45. An exploratory investigation using electroencephalography and machine learning techniques for fine motor classification in the EggLink brain-computer interface.

Chrono Nu Westminster College
Advisor(s): Richard Wellman, Westminster College

The EggLink is an electroencephalography-based brain-computer interface that will operate common household computers based on numerous data transformation techniques and machine learning classifications of fine motor signals generated in the brain. At this stage, the project involves exploring how subtle differences in measurable neurological signals can be revealed mathematically for the prototype system that classifies fine motor activity (the flicking of each of 10 fingers) to a high degree of accuracy. The performance of the system will be discussed in terms of overall accuracy of true positive predictions made by machine learning ensembles.

46. Risk Taking in Epidemiology

Andrew Latham Western Carolina University
Aaron Moose Western Carolina University
Solvei Stenslie Concordia College
Advisor(s): Daniel Maxin, Valparaiso University

We study several epidemic models that incorporate risk taking behavior as a response to an effective treatment or vaccine. We assume that knowledge about the number of recovered individuals has an effect in increasing the contact rate between susceptible and infectious individuals. We show that a relatively mild risk-taking behavior response changes the fate of an epidemic from disease clearance to disease persistence. Moreover, under certain conditions on the parameters, increasing the efficiency of treatment or vaccine has a counter-intuitive and unwanted effect of increasing the reproductive number suggesting a wider range of diseases may become endemic due to risk taking alone. These results indicate that the manner in which treatment/vaccine effectiveness is advertised can have a dramatic influence on how the epidemic evolves.

47. Investigating the Dependence of Transmission Rate to Water Temperature in a Host-Parasite System

Mary O'Driscoll University of Wisconsin - La Crosse
Advisor(s): James Peirce, University of Wisconsin - La Crosse

Every year, thousands of waterfowl around the upper Mississippi River are dying from parasites transmitted to them through an invasive species of snail. The parasite species exhibit temperature-dependent transmission patterns with no transmission occurring when temperatures either fall below or exceed certain thresholds. The transmission window overlaps the waterfowl's seasonal migrations. The purpose of this study was to determine how the temperature of the water affects the transmission rate of the parasite. First, we moved the range and the location of the temperature window for parasite transmission. Second, we created an algorithm that defined the transmission parameters based upon the length of time temperature spends above or below a known threshold. In both studies, the size of the infected host populations depended on the temperature window and accrued time. Results reinforce biological observations and emphasize why it is important to study transmission at various temperatures in the laboratory.

48. Computational Modeling of the Thyroid Hormones Homeostasis and its Manipulation by Chemicals

Catherine Read UNC Asheville
Kai Bartlette Providence College
Ross Donatelli Florida Institute of Technology
Advisor(s): Hisham El-Masri, Environmental Protection Agency

To describe the interaction between propylthiouracil (PTU) and thyroid hormones, a thyroid hormone production model was created and connected to a physiologically-based pharmacokinetics (PBPK) model of all organs. As a treatment for hyperthyroidism, propylthioracil inhibits hormone production in the thyroid gland. Using a basic schematic of thyroid hormone creation to model the previous phenomena, equations were derived, adapted, and parameters were optimized from Ekerot et al. dog data. A physiologically-based pharmacokinetic model was then created to provide a basis for concentration equations. After solving the differential equations for each organ, parameters were optimized

to Cooper et al. experimental rat data. A dynamic model for T4 and T3 production required linking the thyroid in the PBPK model to the original thyroid kinetics model.

49. The Effective Conditions of an Open Limestone Channel in Treating AMD

David Wolfe Saint Francis University
Advisor(s): Ying Li, Saint Francis University

Acid mine drainage (AMD) is the outflow of acidic water from metal mines or coal mines. When exposed to air and water, metal sulfides from the deposits of the mines are oxidized and produce acid, metal ions and sulfate, which lower the pH value of the water. An open limestone channel (OLC) is a passive and low cost way to neutralize AMD. A mathematical model has been created to numerically determine the change in pH of the water and the concentrations of species from the dissolution of calcium on the surface of the limestone into the acidic water. The model is used to predict the conditions in which a OLC would be an effective solution for AMD. Effective ranges will be determined for the concentrations of calcium and iron, as well as the temperature and velocity of the water.

50. Polynomial expansion method for the numerical solution of the Lenard-Balescu equation

Andrew Belt University of Tennessee, Knoxville
Nathan Ng University of Maryland
Advisor(s): Susana Serna, Universitat Autnoma de Barcelona

We explore an approach to solving the kinetic equation for plasmas by expanding the solution in orthogonal polynomials to obtain a system of coupled ordinary differential equations (ODEs) of the expansion coefficients. Here we consider a one-species plasma described by the quantum Lenard-Balescu equation. We first obtain the system of ODEs for a simplified version of the quantum Lenard-Balescu equation by excluding the dielectric function, which accounts for electrostatic screening. Taking the expansion coefficients of common distributions as initial conditions, we are able to numerically solve this system using certain computational techniques. For all tested initial conditions, the distribution function evolves to the expected equilibrium state on physical time scales, conserving both particle number and energy throughout the process. From the simplified quantum Lenard-Balescu equation, we take the classical limit to obtain the well-studied Landau equation. Finally we derive an exact expression for the dielectric function given an arbitrary distribution function and consider its various physical limits.

51. Dynamical Model of Consumer Rumor Transmission in a Twitter-like Network

Jessica Bustamante Westminster College
Advisor(s): Janine Wittwer, Westminster College

True or false, consumer rumor (i.e., rumor that targets a company and/or its products) is challenging to control and poses a real threat to company reputation, earnings, and employment. As our title suggests, our talk will discuss the construction and application of a dynamical model of consumer rumor transmission in a Twitter-like network. Twitter is different from most online social networking sites because it allows for communication that is non-symmetric. Using difference equations, rather than differential equations, we determine under what conditions a consumer rumor is likely to infect so many nodes as to make a significant impact on a company's bottom line.

52. A Mathematical Model for Setting Crime Reduction Targets

Anthony Gusman Vanguard University
Advisor(s): Yoon Sik-Cho, University of Southern California

This project investigates the potential of improving the Los Angeles Police Department's (LAPD's) ability to forecast future crime rates along time scales of months to years. The current forecasting approach does not account for changes in long-term trends or seasonality in crime data. Our study develops models that extract long-term and seasonal factors, offering a data-informed method to support crime reduction target setting. The patterns detected can be used to predict future crime rates. These predictions are compared with those of the department's current method. Accuracy is quantified using standard goodness-of-fit tests. Furthermore, a graphical user interface is developed to provide an environment for comparing forecast model predictions. This can also serve as prototype software for LAPD personnel. Our approach could be extended to other agencies as well.

53. A Simulation Model For Backup-System Capacity Planning

Caleb Miller California Polytechnic State University San Luis Obispo
Advisor(s): Erim Kardes, UCLA RIPS Program

Due to the growing amount of data that clients need to store, effective procedures to predict the future size of *backup storage systems* are becoming increasingly important. This report introduces a simulation approach to forecast the growth of a backup-system. *Time series models* and *machine learning techniques* such as *autoregressive integrated moving-average* and *clustering algorithms*, respectively, are used to characterize the behavior of clients' workloads and then forecast future development. We developed *forecasting* software for predicting the storage size given parameters such as backup sizes and deduplication rates. The model gives a distribution of time for when capacity will be reached. Using synthetic datasets, we compared our results with those of Mark Chamness of the EMC Corporation, who published an alternative method to predict backup-system storage.

54. Calculating the Channel Capacity of Satellite Communication Systems

Peter Morfe Cooper Union
Kathreen Yanit University of Guam
Elizabeth Spencer University of Maryland - College Park
Advisor(s): Stephen DeSalvo, University of California - Los Angeles

The Aerospace Corporation sponsored this Research in Industrial Projects for Students (RIPS) project in order to compute the channel capacity of satellite communication systems, particularly the Mobile User Objective System. The research can be divided into two categories: mathematical modeling of the channel and development of numerical methods for computing the channel capacity. First, the channel models incorporated two and three sources of fading, as well as frequency selectivity. The two-source fading channel models a cascade of ionospheric scintillation and terrestrial multipath. The three-source fading channel models ionospheric scintillation, terrestrial multipath and shadowing, based on the Lutz 2-state model. Three methods were developed for computation of channel. The first method computes the capacity using the pdf of the combined fading process. The other method computes the capacity by integrating against the pdfs of the individual sources of fading. Lastly, the capacity is approximated using a time average.

55. The Black-Litterman Model: Exploring the Sensitivity of Inputs

Timothy Dombrowski Saint Leo University
Jessie Byrnes Morningside College
Jahlani Clarke The University of the District of Columbia
Dorian Kandi Morehouse College
Advisor(s): Tao Pang, North Carolina State University

In modern portfolio optimization theory, the goal is to identify the optimal portfolio. Optimal portfolio weights are obtained by either maximizing mean portfolio return or minimizing portfolio risk. The classical mean-variance optimization (MVO) model uses historical mean returns and a historical covariance matrix as inputs, but the optimal portfolio tends to be infeasible in practice and lacks diversification. The Black-Litterman (BL) model integrates investors' views and their confidence in these views into the MVO model through Bayesian estimation. In this project, we investigate the sensitivity of investors' views in the BL model by using real market data. We also determine the parameters' effects on the optimal portfolio. Our results are validated by back testing with actual market returns and by simulating returns with multivariate normal distributions. Through our research, we discover that the sensitivity of the parameters in the BL model is based on many factors, which falls inline with the intuition behind the model. We also prove the convergences of several parameters from a theoretical standpoint. Using our research, investors are able to better understand the impact of their views, as well as other parameters, on the optimal portfolio in the BL model.

56. Self-organized criticality for optimal random search

Michelle Randolph UNC Asheville
Kathleen Donahue Harvard University
Advisor(s): Aliki Mavromoustaki, UC Los Angeles

Self-organized criticality (SOC) is a phenomenon found in dynamic systems ranging from rice piles to solar flares. HRL Laboratories discovered that shapes generated by these systems produce search patterns that are well suited for

approximating solutions to certain hard optimization problems. Improving the efficiency of random search could have widespread application (supply chains, allocation of resources, transportation networks). We investigated the properties and performance of shapes generated by an SOC model, the Bak-Tang-Wiesenfeld sandpile model and compared them to other search patterns for optimizing the Ising spin glass. Specifically, we examined: fractal dimension of the boundary, size-to-boundary ratio, variation in shape, size distribution and boundary structure.

57. Evolutionary games on cycles

Christopher Paoletti Emmanuel College
James Withers Emmanuel College
Advisor(s): Christine Sample, Benjamin Allen, Yulia Dementieva, Emmanuel College

Evolutionary game theory is a mathematical approach to studying the evolution of social behavior. Interactions that affect reproductive fitness are conceptualized as games and spatial population structures are represented as graphs. Using this framework, we investigate the effects of self-interaction on the evolution of cooperative strategies. In our model, the population is represented as a cycle with self-loops and individuals can employ one of two competing strategies in a matrix game. Interaction and replacement can be governed by the same graph or by two different graphs, which can be weighted or un-weighted. We calculate fixation probabilities for these strategies and derive exact conditions for natural selection to favor one strategy over the other. We determine the behavior of these conditions in the limits of weak selection and large population size, and show that the limiting conditions do not depend on the order in which limits are taken. We also consider evolutionary success when mutation is present. All calculations are performed for two different update rules (birth-death and death-birth). We conclude that self-interaction can promote the evolution of cooperative strategies in spatially structured populations.

58. A Geometric Approach to Voting

Lee Fisher Appalchian State University
Advisor(s): Vicky Klima, Appalachian State

Arrow's theorem informs us that while some voting methods may be more fair than others, a certain set of reasonable fairness conditions cannot simultaneously be satisfied by any one voting system. Well-known voting systems include the plurality method, where voters are told to pick just one candidate and the candidate who receives the largest number of votes wins; and the Borda count, where candidates are ranked and given points in equally-spaced descending order. This presentation proposes a new voting system which functions as a generalization of the Borda count. In our new system, we assign a value of one to first place, zero to last place, and intermediate rankings are assigned values in arbitrary intervals of non-increasing order. We then use geometric methods to consider the winning results space associated with each candidate. We will compare this voting system against the fairness criteria stated in Arrow's theorem. We will show this voting procedure is monotone, equivalent to the Borda count only in the three-candidate case, and like both the plurality and Borda count methods does not necessarily satisfy the Condorcet winner criterion; which selects the candidate who wins each pairwise comparison to win the election.

59. Determining Sufficiency for Comparison in the Friction Ridge Impression Examination Process

Jason Zellmer University of Wisconsin-Milwaukee
Advisor(s): Gemechis Djira, South Dakota State University

Friction ridge impressions, better known as "fingerprints" , have gained recognition for their use in identification purposes due to their uniqueness among individuals and their persistence throughout an individuals' lifetime. Two characteristics that are used in the identification process are: the quality of the print and the quantity of unique characteristics of the print. Previous research has focused on the lack of examiner consistency in the determination of sufficiency for comparison based on the quality and the number of minutiae (unique characteristics) of the fingerprint. Sufficiency of determination is a subjective calculation of the examiner that states whether the print in question has enough unique characteristics and is of good enough quality that it will likely yield a match when comparing prints. This research developed an ordinal logistic regression model and examined the predicted usefulness of fingerprints (measured by their ordered categorical rank when searching a database for a potential match) in an effort to determine a sufficiency standard for a fingerprint to be considered useful in casework. The results of this project determined that the minimum standards for the quality and quantity of minutiae of a print may be higher than those currently recommended.

60. Matching video segments with relevant documents

Ilan Morgenstern Instituto Tecnológico Autónomo de México
Lingxin Zhou Rutgers University
Advisor(s): Bin Bi, UCLA

The USC Shoah Foundation has collected over 52,000 video testimonies from survivors and other witnesses of the Holocaust. The goal of this research project is to improve the learning experience for the people who watch the testimonies by integrating external knowledge to the archive. Since the videos are indexed by keywords for each minute of video, we use these data to extend various information retrieval methods to match each segment to a Wikipedia article; these methods include the vector space model approach, latent semantic indexing, and statistical approaches. Based on the existing techniques, we propose a new method that exploits the metadata of the document corpus to match the video segments with relevant documents.

61. Parameter Selection Techniques for Nonlinearly Parameterized Models

Jared Cook Asbury University
Nicholas Myers University of Wisconsin-Milwaukee
Nina Ning George Washington University
Advisor(s): Ralph Smith, North Carolina State University

In this research, we apply parameter selection techniques to nonlinearly parameterized models for disease dynamics. The objective is to develop techniques to determine the sets of identifiable or influential parameters in these models. We first illustrate the use of randomized singular value decomposition (SVD) and QR techniques to quantify these sets for linearly parameterized problems. We then demonstrate the use of the global Morris screening, Sobol analysis, and active subspace techniques for nonlinear problems. For the considered example, we also show that non-identifiable parameters can also be determined by considering pairwise correlation plots obtained through Bayesian model calibration. Parameter selection in this manner is a necessary full step before employing Bayesian and uncertainty propagation techniques to quantify the uncertainties associated with model outputs.

62. Computational Modeling for Optical Coherence Tomography of the Human Eye

Camille Sanchez Mount St. Mary's University
Asha Cyrs California State University Fullerton
John Maxwell III North Carolina A&T State University
Leah Frederick Pennsylvania State University
Advisor(s): Mansoor Haider, North Carolina State University

Optical coherence tomography (OCT) is a medical imaging technique that uses light waves to produce high-resolution images of internal tissue microstructures. Using data obtained from OCT images, it should be possible to compute local curvature maps of the human cornea that exceed the accuracy of existing keratometric technology. However, accurate three-dimensional reconstruction of the cornea is insufficient to ensure comparable accuracy in curvature maps because curvature computation is extremely sensitive to small errors in the surface measurements. This project goal was to develop theoretical cornea models to validate the curvature mapping algorithms and analyze the propagation of certain types of error. Models were sampled on a hexapolar grid to simulate data from an OCT scanner. Interpolation of the simulated data was done using Zernike polynomials, which represent a complete orthogonal basis on a unit disc. The main sources of error considered were perturbations in the surface representation and noise in the OCT image data. The perturbations that were considered were a result of polynomial over-fitting, and the noise in the data was simulated using Gaussian white noise. Adjusted models accounting for different corneal disorders were also taken into account and implemented.

63. Estimating Liquidity Risk Using Exchange Traded Funds

Claire Kelling Virginia Tech
Hannah Li Pomona College
Evan W Witz Wisconsin Lutheran College
Rachel Crowell University of Missouri- Kansas City
Advisor(s): Marcel Blais, Worcester Polytechnic Institute

The financial crisis of 2008 starkly illustrated the perils of ignoring liquidity risk. This risk is particularly crucial to index and ETF providers that explicitly guarantee the provision of underlying shares through time and implicitly agree

to absorb the associated liquidity risks and costs. In this paper we propose an ETF specific liquidity measure. The proposed model isolates liquidity risk from other factors by forming a portfolio of buying the ETF and shorting the underlying basket of securities using the weighting system employed by the ETF issuer. This work is closely related to a similar measure proposed by Chako et al which we find while useful provides counterintuitive results during times of fast changing liquidity environments. Since liquidity crises typically evolve rapidly, the time sensitive nature of our measure is a particularly important feature. Our analysis is performed on JNK and its underlying securities. We also compare the proposed liquidity metric to those existing in the literature and industry standard measures. We find that our measure captures the shifts in liquidity in a conservative and timely fashion making it particularly applicable to risk management purposes for ETF investors and providers.

64. Applying Queuing Theory to a Queuing System

Su Ji Hong California Lutheran University
Advisor(s): Villalpando, California Lutheran University

Queuing theory uses flow balance equations derived from steady states to determine the probability of each state; in queuing theory a state represents the number of customers present at the system. I modeled the queuing system at the Centrum café on California Lutheran University campus assuming that the arrival and service rates follow exponential distribution. The queue system at the register followed $M/M/1/\text{FCFS}/\infty/\infty$: the arrival and service times are independent, there is one server, it has a first come first serve queue discipline, infinitely many people can be in the queue, and there are infinite many people from which customers are drawn. I figured out the arrival rate, λ, and service rate, μ. I computed the waiting time and compared it to the data. I simplified the model at the kitchen to $M/M/1/\text{FCFS}/\infty/\infty$. Then I connected them using the fact that λ depends on μ of the register. After calculating the probability of each steady state, I calculated the queue time at the register and the kitchen.

65. Model Refinement Through Verification and Validation Methods and Anomaly Detection

Jordan Menter Smith College
Hannah Schwarze Saint Mary's University of Minnesota
Advisor(s): Hien T. Tran, North Carolina State University

Mathematical models can be assessed and refined using two separate procedures: verification and validation (V&V), and anomaly detection. Together they determine a model's reliability. Verification assures a model implements the developer's concepts correctly, and validation assures the model is an accurate representation of a real world system. The purpose of anomaly detection is to identify features of the model or data set that throw off the model's reliability. We looked at a mechanistic model that takes a system of differential equations describing the dynamics of Hepatitis C and its treatment system. The system includes the triple drug combination of Ribavirin, Pegylated Interferon-alpha, and Telaprevir (a new Hepatitis C drug). In addition, we validated and verified a data-based model created by NCSU REU students in the summer of 2013. By using PITCH f/x data from Major League Baseball and machine learning methods, they created a pitch prediction system that decides whether or not the next pitch will be a fastball. Through V&V and anomaly detection, we have developed a level of confidence in both models and are able to make suggestions for future refinement.

66. A Locally Adaptive RBF-FD Method

Wade Meyers University of Wisconsin-Stout
Talin Masihimirzakhanian California State Polytechnic University-Pomona
Advisor(s): Keith Wojciechowski, University of Wisconsin-Stout

Conventional Radial Basis Function (RBF) methods for numerically solving partial differential equations use global approximations resulting in dense matrices that grow in size if data refinement occurs. The Radial Basis Function – Finite Difference (RBF-FD) approach is a local approximation method that utilizes nearest neighbor data and yields a sparse implementation. Unfortunately RBF-FD differentiation matrices have fixed stencils and the approximations can lose accuracy under refinement. In this paper we propose using local approximations with locally adaptive stencils that take advantage of the features of both global and local approximations. In this approach the stencil sizes stay fixed where the solution is smooth but grow in size only where refinement is needed. The advantage of this method is that it is computationally efficient and stable much like the RBF-FD method but offers comparable accuracy to global approximations with significantly lower computational cost.

67. Recognition of Textural Differences in Infrared and Ultraviolet Imagery Using Fractal Characteristics

Jack Ryan North Central College
Advisor(s): Charles Tolle, South Dakota School of Mines and Technology

Due to the complexity of the world, there are many aspects of nature that cannot be completely or correctly analyzed using Euclidean geometry. For that reason, the study of fractals is of great interest when attempting to study the natural world. This project utilized an algorithm written by Troy Thielen which is used to estimate the fractal dimension and lacunarity of gray-scale images. New ultraviolet and infrared images were taken throughout the project. An extensive portion of the project was devoted to the process of aligning the multi-spectral images so that they line up correctly. This was necessary due to the way that light bends in the different spectrums; the images do not line up correctly without intervention. The fractal characteristics of these images were then to be analyzed to recognize textural differences, a useful method when attempting to recognize objects or locate targets, however the algorithm was found to be insufficient in dealing with the complexities of the multi-spectral imagery. Instead, this research project provides a foundational background that suggests a method for image registration that can be used for future research projects that include revising the algorithm in order to handle the higher-dimensional nature of the multi-spectral images.

68. The Impact of the Effectiveness of Needle Exchange Programs on Addiction-Treatment Dynamics

Natalia de la Torre Mary Baldwin College
Mayra Coronado Regis University
Advisor(s): Muntaser Safan, Aprillya Lanz, Arizona State University, Norfolk State University

The aim of this research is to determine the impact of needle exchange programs as motivation for intravenous drug users to seek treatment for addiction. A mathematical model of the dynamics of a population of drug users that incorporates a needle exchange program is formulated. We define the basic addiction reproduction number for the proposed model and explore its role in the prevalence and control of needle-sharing drug addiction. Specifically, the local stability of the injection-addiction free and endemic equilibria are determined.

69. Artificial Intelligence of Modern Board Games: Battle Line

Daniel Bladow Gonzaga University
Advisor(s): Sean McCulloch, Ohio Wesleyan University

Many turn based board games played by computers use game state trees to determine what moves to make. Traversing through game state trees is time consuming, especially with random factors such as a deck of cards. Battle Line is a game where two players are competing over nine different three card poker hands using a 60 card deck with six suits and number values one through ten. Each hand is called a flag and the type of hand (such as a straight flush) is called a formation. Together, the deck and flags create an exponentially large number of game states. We created an artificial intelligence using a probabilistic approach to approximate future game states. We estimate future game states by determining the top formations we could make by playing a card from our hand on each flag. Then we calculate the odds of completing each formation, of each formation winning, and finally of any of the top formations resulting in a win on that flag. There are two main advantages to this approach. First of all, it is less time consuming and can be played on weaker computers, possibly cell phones. Secondly, the computer's thinking avoids ad-hoc strategic knowledge. Therefore, the computer is both more time efficient and capable of devising unique strategies based on mathematical principles.

70. Dynamics of Co-orbital Moons Near Collision

Kimberly Stubbs UNC Asheville
Advisor(s): Samuel R. Kaplan, UNC Asheville

This project is about celestial mechanics and dynamical systems. Specifically, the goal is to explore the techniques used in modern celestial mechanics to analyze near-collision dynamics and chaos. The model we're working with is a 3-body co-orbital system. Josep Cors and Glen Hall wrote a paper on 3-body co-orbital systems and determined when the moons will pass each other and/or change orbits. They were only interested in these two occurrences, and so they left out the dynamics of near-collision. We're interested in finding out what happens near collision of the two

moons and have done the necessary change of variables to allow analysis of the dynamics and chaos. We'll look into the dynamics and what they mean for the entire system.

71. Mathematical Modeling and Optimal Control of Alternative Pest Management for Alfalfa Agroecosystems

Cara Sulyok Ursinus College
Julia Senkevich Ursinus College
Advisor(s): Mohammed Yahdi, Ursinus College

Alfalfa is the most cultivated forage legume in the world and is used primarily to feed cattle. The pest, potato leafhopper (PLH), damage to the host-plant alfalfa is costly and chemical pesticides are unsafe. The goal is to investigate alternative farming techniques for pest management to minimize the alfalfa damage. More precisely, based on data and results from field experiments that integrate enemies hypothesis (predators) and polyculture farming (plant diversity) approaches, this project developed a mathematical model for designing cost-effective and environmentally-safe control strategies to minimize the plant damage. A mathematical model of a system of non-linear differential equations was created and shown to accurately fit results from open-field experiments and to predict outcomes for scenarios not covered by experiments. Optimal control theory was used to determine optimal and practical pest management strategies to minimize the plant damage and the impact on the revenues from milk production for farmers. Tools used include non-linear systems of differential equations, Bang-Bang controls, Pontryagin's Maximum Principle, and computer simulations.

72. Improving the Error-Correcting Code Used in 3-G Communication

Tahseen Rabbani University of Virginia
Sung-Min Park University of Virginia
Advisor(s): James Davis, University of Richmond

Consider a digital message sent through a noisy channel with an undesirable amount of interference. Error-correcting codes encode messages in such a way that the recipient is able to correct bit errors up to a certain threshold. In 2011, Samsung Electronics Co. filed a complaint against Apple Inc. for alleged infringement of patents concerning error-correcting codes. One of the primary patents in question was a [30, 10, 10] non-cyclic code which was implemented in all devices communicating on the 3-G network, including many Apple products. However, in the patent, Samsung leaves the derivation of the basis for their code rather ambiguous. We first present an explicit construction of a similar [30, 10, 10] idempotent code. Using elementary manipulations of our code, we then develop a novel and improved [30, 10, 11] non-cyclic code with stronger error-correcting capabilities.

73. 3-D Data Fitting and Inverse Kinematics Algorithms for Robot Mimicking of Human Action

Jared Brown St. Olaf College
Christie Mauretour Florida Gulf Coast University
Julian Sass University of Maryland Baltimore County
Ziyue Shuai Bryn Mawr College
Advisor(s): Thomas Höft, University of St. Thomas

The development of techniques allowing artificial intelligences to learn and adapt in real time remains an open question in Machine Learning, Robotics, and related fields. In this vein, we approach the problem of instructing a general robotic frame to mimic actions as demonstrated by humans. The solution to this problem requires the solving of two separate systems. The first, dubbed the Forward Kinematics Problem, involves describing the motion of the human. To this end, we develop a robust linear interpretation of a geometric model of the human frame as well as the transformations on that model allowing motion through time. We additionally apply regression techniques to fit this model to 3-dimensional point-cloud data about the current orientation of a particular human subject. The second problem to be solved, the Inverse Kinematics Problem, entails mapping end-effector position (usually the tip of a hands on the human subject) to the robot. This being a problem without a unique solution, we apply constraints to find the single optimal path which the robotic frame should follow.

74. Relationship among FKBP5 genotype, serum cortisol, and cognitive function in aging humans: a Project FRONTIER study

Cody Tucker Texas Tech University
Advisor(s): Breanna Harris, Texas Tech University

Stress induces physical responses in organisms, one being activation of the hypothalamic-pituitary-adrenal axis, resulting in release of glucocorticoids (cortisol). Prolonged elevated levels of cortisol have been shown to negatively affect cognitive function in humans. Cortisol exerts its effects by binding to intracellular receptors, therefor factors associated with receptor sensitivity may affect cortisol actions. One of these factors is FKBP5, a cortisol receptor co-chaperone, a single nucleotide polymorphism of this gene, rs1360780 (T allele), has been associated with impaired negative feedback and prolong cortisol exposure. We predict that high levels of cortisol in addition to the T allele of FKBP5 will lead to an enhanced decline in cognitive function over time. Using human data from Project FRONTIER ($n = 193$, 140 females, 53 males, age 40–87), funded and maintained by the F. Marie Hall Institute for Rural and Community Health, we will measure serum cortisol via radioimmunoassays at two time points (baseline and 3 years). We will determine FKBP5 genotype by PCR. We will assess how these two variables relate to cognitive function at baseline and 3 years as measured by the Mini-Mental Status Examination (MMSE), which assesses five areas of cognitive function.

75. Exploring Phase Space Localization Using a Coherent State Basis in Bargmann Space

Jacob Goudreau Westfield State University
Advisor(s): Brian Jennings, Westfield State University

In 1961 Valentin Bargmann published a paper in which he outlined the structure of a new kind of Hilbert space. "Bargmann Space," as it came to be known, contained complex-valued analytic functions. A decade later Bargmann, et. al, published a new paper wherein they established a basis for Bargmann Space. Building upon the work of the great John Von Neuman, they asserted it was possible to form a minimal spanning set using a subset of coherent states. They considered a lattice superimposed over the complex plane and showed that by constructing this lattice such that each cell bounded an area equal to $2\pi\hbar$, a set of coherent states centered at each lattice point formed the minimal spanning set they were looking for. While it is known that the coherent states about the lattice points do form a basis in Bargmann Space, a rigorous study regarding its utility had not yet been undertaken. I began by examining the approximating capability of the coherent state basis with respect to well-known wave functions, like the harmonic oscillator basis states. After working with the harmonic oscillator states, I shifted my focus to the coherent states basis' ability to approximate the more general class of semiclassically-localized wave functions.

76. Sediment Transport at Wallops Island, Virginia

Joshua Updike Shippensburg University
Advisor(s): Ben Galluzzo, Shippensburg University

Wallops Island, Virginia is home to NASA's principal suborbital research facility and the United States Navy's Surface Combat Systems Center; it is also extremely prone to shoreline erosion. Due to over $1 billion in facilities and resources on the island, shoreline maintenance and restoration is of utmost importance. The poster presentation will cover the motivation for the research, data collection techniques and the mathematical processes used to create a model for sediment transport on Wallops Island and the region. In particular, we will highlight the interaction between geology, physics and mathematics as well as the engineering of a new single-wave sediment collection device.

77. Correcting Holographic Images Distorted by Atmosphere

Thomas Welle University of St Thomas
Anne Fink University of St Thomas
Advisor(s): Thomas Hoft, University of St Thomas

When a holographic image of a distant object is recorded it is often blurred due to atmospheric turbulence. Phase screens constructed from radial disk harmonics can be used to correct for these aberrations. Since in digital holography systems the atmospheric turbulence phase distortion is not know, the correcting phase screen must be found computationally. We use optimization methods and an image sharpness metric to compute approximate corrections

which substantially improve the blurred imagery. This paper discusses the implementation and effectiveness of ten optimization methods, including gradient descent, simultaneous perturbation stochastic approximation, ALOPEX, and simulated annealing. Simulated data and results are presented.

78. Linear long wave propagation over discontinuous submerged shallow water topography

Mark Brandao Virginia Polytechnic Institute and State University
Megan Golbek California State University Monterey Bay
Tucker Hartland California State University Chico
Ravi Shankar California State University Chico
Yan Sheng Emory University
Advisor(s): Sergei Fomin, California State University Chico

The dynamics of an isolated long wave passing over underwater obstacles are discussed in this paper within the framework of linear shallow water theory. Areas of practical application include coastal defense against tsunami inundation, and harbor protection. Three sea-floor configurations are considered: an underwater shelf, a flat sea-floor with a single obstacle, and a series of obstacles. A piecewise continuous coefficient is used to model the various sea-floor topographies. A simple and easily implementable numerical scheme using explicit finite difference methods is developed to solve the discontinuous partial differential equations. The numerical solutions are verified with the exact analytical solutions of linear wave propagation over an underwater shelf. The scope of this simplified approach is determined by comparison of its results to another numerical solution and experimental data available in the literature for wave transmission and reflection coefficients. The efficacy of approximating more complicated continuous underwater topographies by piecewise constant distributions is determined. As an application, a series of underwater obstacles are modeled and reflection/transmission coefficients determined.

79. Modeling Microscopic and Macroscopic Traffic Flow Utilizing the Particle Filter and Ensemble Kalman Filter

Melissa McGuirl College of the Holy Cross
Advisor(s): Bjorn Sandstede, Brown University

Mathematicians and engineers have been studying traffic flow for decades. In this project we combined new methods of researching traffic flow in hope of creating a more effective way to model traffic and predict when traffic jams will occur. We have studied both macroscopic and microscopic traffic flow. In the microscopic traffic flow model we track the velocity, headway, and position of individuals cars, whereas in the macroscopic traffic flow model we study the density and flux of cars over a segment of the road. We use the Lighthill-Whitham equations to model traffic flow, but we have expanded this existing model to include various road conditions for more realistic settings. We also use data assimilation for our microscopic and macroscopic traffic flow models. Implementing both the particle filter and the ensemble Kalman filter has allowed us to compare data assimilation techniques in diverse road conditions. Our research shows that data assimilation works in dynamic traffic settings for both the microscopic and macroscopic traffic models. To test the efficacy of our methods we applied our models and data assimilation techniques to real data from a traffic study in Minnesota.

80. Smoothing a Simulated Three-Dimensional Brain Image using an Edge Map

Emmanuel Estrada California State University Stanislaus
Tiffany Chu California State University Stanislaus
Advisor(s): Jung-Ha An, California State University Stanislaus

Three-dimensional images can be represented as a three-dimensional matrix of byte values, with each cell representing the intensity of a single ‘pixel.’ During data transmission, values can become corrupted with noise. The goal of this project is to correct for these errors, maximizing image fidelity while eliminating noise. To accomplish this, we apply our image smoothing algorithm combined with an edge map to simulated brain images. Numerical results show the effectiveness of the presented algorithm.

81. Performance Sensitivity in Vertical Geothermal Energy Harvesting Systems

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Mahalia Sapp
Samuel Naden Macalester College
Keenan Hawekotte Nebraska Wesleyan University
Advisor(s): Burt Tilley, Suzanne Weekes, Worcester Polytechnic Institute

Residential geothermal energy systems have the potential to provide a cost-effective, low carbon footprint technology for heating and cooling. The systems use the soil beneath a residence to store thermal energy in the summer and harness energy in the winter. The soil exchanges heat with the coolant that flows through a pipe inserted into a vertical bore. The energy transfer in the soil changes the coolant temperature, setting the efficiency of the residential heating/cooling system. We are interested in finding how the cross-sectional arrangement of pipes in the bore affects the temperature of the coolant as a function of depth. For a given cross-section, we describe the temperature functions of the coolant and the surrounding soil through a system of time-dependent partial differential equations. From these equations, we find a Sturm-Liouville eigenvalue problem in each cross-sectional variable, whose eigenvalue determines the decay rate of the eigenfunction over depth. We find a numerical solution via the finite element method for the eigenpair corresponding the lowest decay rate. Our results can be used to determine the borehole depth necessary to meet the energy needs of a residence given a desired geometry of the system.

82. Quantum Audio Embedding Using M-Band Wavelets

Cameron Sakurai Western Connecticut State University
Alex Potocki Western Connecticut Statue University
Advisor(s): Xiaodi Wang, Western Connecticut State University

Information hiding is a modern method of privately transmitting information from sender to recipient. In recent there have been developments in the field of quantum computing. It is therefore important to develop means of encoding information that will resist attacks from both standard and quantum computers. We will utilize wavelet transforms and pseudo-quantum encoding to transmit audio data hidden inside of images. Wavelet transforms offer energy conservation and the separation of energy levels, allowing our audio to be embedded with the portion containing the highest energy. We are exploring the use of M-band wavelets, however for demonstration purposes, we will utilize 4-band wavelets.

83. Symmetries of the Gross-Pitaevskii Equation

William Barker University of Central Arkansas
Advisor(s): Danny Arrigo, University of Central Arkansas

We consider the classical and nonclassical symmetries of the Gross-Pitaevskii equation (GPE). We will show that the nonclassical symmetries are more general than the classical symmetries. We further consider first order compatibility and the GPE and show a class of compatible equations exists that are not obtainable by the symmetry method.

84. Fractal and Wavelet Image Compression

Brian O'Connor Western Connecticut State University
Advisor(s): Xiaodi Wang, Western Connecticut State Univerity

In the application of mathematics, image compression has seen advancements both from fractals and wavelets. Fractal methods use self-similarity accross different scales to reduce stored information. Segmentation probably plays the most significant part in fractal image compression. The success of acheiving a large compression ratio effectively rests on an efficient segmentation algorithm. Wavelet methods exploit redundancies in scale to reduce information stored in the wavelet transform domain. Hybrid methods apply fractal techniques to information in the wavelet transform domain to provide even greater compression performance. In our research, we will investigate compression of fractal images using the Daubechies 4 wavelet.

85. On Globally Defined Solutions of the Generalized CLM Equation

Gopal Yalla College of the Holy Cross
Samantha Davies Carnegie Mellon University
Advisor(s): Johnny Guzman, Brown University

We consider a generalized one dimensional model of the three dimensional vorticity equation, proposed by Constantin, Lax, and Majda. Results for the one dimensional model may provide insight to the behavior of solutions of Euler's equation. Specifically, we studied the effect the parameter that controls the amplification of the convection term has on solutions to this equation. Cordoba and Okamoto showed that nonpositive parameter values lead to singularities in finite time. While the behavior of solutions for positive values of the parameter are unknown, it is conjectured by Okamoto et al. that the solutions undergo a bifurcation from blow up to global existence for some parameter value between 0 and 1 (around 0.6). Several different numerical and analytic methods are utilized to analyze whether or not solutions form singularities in finite time, and results reveal evidence contrasting the conjectured value.

86. An Agent-Based Approach to Modeling Police Patrol Strategies and Their Effects on Crime

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Hye Rin Lin Lee California State University, Fullerton
Advisor(s): Laura Smith, California State University, Fullerton

In many urban communities crime is an unfortunate reality for its inhabitants. High levels of crime require law enforcement agencies to optimize their resources to address criminal behaviors. The goal of this project is to extend an agent-based model for crime pattern formation to incorporate police. This approach allows us to simulate criminal and police behaviors. Through these simulations, we can provide a means to test hypothetical policing strategies without costly or unethical experiments. The theories we test incorporate realistic patrolling scenarios and the effect it has on both criminal behavior and the total crime in a region. We compare our results with existing agent-based approaches, such as random patrols and "hot spot" policing. Using more realistic models, we can test theories to help law enforcement mitigate crime.

87. Dealing with Damage: A New Approach to Image Segmentation with Dynamic Artifact Detection

Nicholas Takaki Carnegie Mellon University
Jing An University of California, Los Angeles
Advisor(s): Dominique Zosso, UCLA

In this research, we introduce a new model for segmenting damaged images. A segmentation of an image $I : \Omega \to \mathbb{R}$ is a two-color piecewise constant approximation representing "object" and "background." Traditionally, segmentation involves evolving a level set function ϕ and colors c_1, c_2 to minimize the Chan-Vese functional

$$E_{CV}(c_1, c_2, \phi) = \int_\Omega (I - c_1)^2 H(\phi) + (I - c_2)^2 (1 - H(\phi)) + \mu \int_\Omega |\nabla H(\phi)|,$$

where H is the Heaviside function and μ is a weight term. This approach works well on undamaged images, but fails when artifacts are introduced.Our research has two parts. First, we introduce a dynamic artifact class $X : \Omega \to \{0, 1\}$ with weight γ, which prevents outliers from skewing the segmentation. Our new functional is

$$E_{new}(c_1, c_2, \phi, X) = \int_\Omega (1 - X)((I - c_1)^2 H(\phi) + (I - c_2)^2 (1 - H(\phi))) + \mu \int_\Omega |\nabla H(\phi)| + \gamma \int_\Omega X,$$

which has been very effective at segmenting both damaged and undamaged images. Second, we develop a minimization scheme based on diffusion and thresholding, which runs significantly faster than traditional gradient descent techniques. We also include results and comparisons with existing methods.

88. Quantum-Inspired Robust Audio information embedding algorithms in M-band wavelet Domain

Zhang Mingyang Affiliated High School to Jilin University Changchun China
Yuting Liu
Xuanhe Liu
Advisor(s): Ren Yulian, Affiliated High School to Jilin University

The research is in the area of information embedding has recently gained substantial attention. This is mainly due to the increased interest in digital watermarking technology that potentially can solve copyright infringements and

data integrity disputes. As digital music has become increasingly popular, there is a great need to further develop a method that could be used to enhance copyright protection in the music industry. This paper addresses this problem by providing a way to protect against unauthorized copying of digital music by the use of M-band discrete wavelets to transform the audio signal into the wavelet domain, then create corresponding "pseudo quantum signal," and finally insert watermark into such "pseudo quantum signal."

89. Nonparametric Regression Algorithm Based on M-band Wavelet Transform

Matt Nejame Western Connecticut State University
Brian Bucknam Western Connecticut State University
Advisor(s): Xiaodi Wang, Western Connecticut State University

Accurately predicting the future changes in the stock market is highly sought after by many businesses and people. Many corporations need and pay lots of money for accurate analysis of stock market behavior. In this research we will be applying wavelet based-nonparametric regression models to predict changes in the stock market. Wavelets can analyze stock market cycles over a short period of time in order to predict future behavior. A nonparametric regression model can, by putting a line of best fit, also give you a representation of stock market behavior in order to predict changes. This paper will use these mathematical tools, to predict stock market prices, and compare them to actual stock market prices.

90. Spatial Knowledge and Relatedness

Rebecca Harper Willamette University
Advisor(s): Shilad Sen, Macalester College

Semantic relatedness (SR) is a burgeoning field in computer science that attempts to replicate the human process of determining the relationship between two concepts. The current SR algorithms, however, do not attempt to incorporate the effect of differences in human knowledge on the perceived relatedness. Furthermore, the assessments of the accuracy of SR algorithms depend on a universal, human-based "gold standard" data set collected from people with unknown levels of knowledge. This study predicted a positive correlation between spatial or geographical knowledge and evaluated SR of spatial concepts. After analyzing survey data from 1000 participants, this study found that the greater the respondent's spatial knowledge of two spatial concepts, the more related the respondent perceived the concepts to be. The data set contains 34,422 SR judgments of spatial concepts that include respondents' spatial knowledge and valence toward the concepts. This is an important find for the field of semantic relatedness in computer science because it uncovers a need to reassess the "state-of-the-art" techniques used to emulate human perception of semantic relatedness.

91. Determining Optimal Level of Unemployment to Maximize Growth of Real GDP

Angela Hanson Rose-Hulman Institute of Technology
Andrew Kipp Rose-Hulman Institute of Technology
Advisor(s): Wayne Tarrant, Rose-Hulman Institute of Technology

There is much debate over the effects of unemployment on the economy. Some people believe that 0% unemployment is the best level because everyone should be able to find a job. The Federal Reserve believes that it should be about 5%, or the natural unemployment rate. However, a definitive percent of unemployment has not been mathematically calculated to maximize the output of the economy. The purpose of this research is to determine if there is a level of unemployment which maximizes percent growth in real gross domestic product (GDP). This will be determined by creating an optimization model which considers the effects of employee compensation, consumer price index, labor force participation rate, and unemployment on real GDP. Also, each contributor to change in real GDP listed above must be given a value to proportionally weight its effects. This model will use real GDP growth as a reference for an improved economy because it applies a measure to economic change even if the annual value is imprecise. The data gathered will be from the various time spans across different countries including the United States. Ultimately, the goal is to create a model which can be tailored for multiple countries around the world in order to determine a more precise goal for the unemployment rate.

92. Musical Exploratory Data Analysis

Rachael Fountain Westfield State University
Advisor(s): John Judge, Westfield State University

Founded by John Tukey, the most influential statistician of the second half of the twentieth century, exploratory data analysis (EDA) is the process of creating new and original methods of analyzing data through visual graphics. The power of EDA is that it allows the brain to approach and view data in an entirely different way; it lets the data speak for itself. It is common knowledge that music is so much more than just the notes, pitches, and beats we hear and in fact there are surprising connections between music and mathematics that can be uncovered through exploratory data analysis. In this project we will discuss how we used EDA to create two visual graphics which we call will variability graphs and contour graphs. These graphs allow for pitches, scales, and distances between notes to be examined quickly and they also allow for the standardization of music in all genres, keys, and tempos. Each of these graphics will then be used along with techniques from statistics and real analysis to investigate the relationship between musical melodies and mathematics.

93. Cellular Automata and Shrinking Cities: A Mathematical Model of Youngstown, Ohio

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

Youngstown, Ohio, a city found in the affectionately labeled "rust belt," is a shrinking city plagued by thousands of vacant homes. Since the crash of its steel economy in the 1970s, Youngstown has lost over half of its population. This has led to mass abandonment and blight, which severely inhibits the health of several of Youngstown's neighborhoods. The city has taken measures to battle blight by developing a demolition program for blighted properties and investing resources in a community development corporation. This, however, has sparked a debate as to where the extremely limited demolition and revitalization funds should be spent within a city. Individual based models, specifically cellular automata models, are employed to model the dynamic systems that are found in a shrinking city. The goal of the model is to offer insight as to what demolition and revitalization strategy is a better use of city funds — a suggested prioritized approach or the current "scattershot" approach. The model also investigates the spatial spread and concentration of blight. The model results compare the effectiveness of city programs, policies, and strategies.

94. Binomial Solutions to Smale's 17th Problem and their Application to Chemical Reaction Networks

Caleb Bugg Bugg Morehouse College
Advisor(s): J. Maurice Rojas, Texas A&M University

In 1998, Stephen Smale proposed a list of eighteen questions for the mathematical community. Smale's 17th problem is concerned with the development of a deterministic algorithm that can approximate a root of a random polynomial system in polynomial-time. This project in its current form provides a positive answer to Smale's 17th problem for binomial systems, and explores a concrete application of the algorithm in chemistry. The main result of this project is an algorithm that approximates a root of an entire binomial system (n variables, n equations) in polynomial-time. The algorithm utilizes matrix exponentiation and the Smith Normal Form of an integer matrix in order convert the system to a simpler system. Binomial systems are used in a variety of mathematical modeling situations. In particular, there are sufficient, easily verifiable conditions for the expression of a chemical reaction network (CRN) as a binomial system. We utilize our algorithm to solve these systems to determine the steady-state concentrations of the species in chemical reaction networks.

95. Algorithmic and Theoretical Exploration of Tiling Harmonic Functions

Yilun Du PRIMES-USA
Advisor(s): Sergiy Merenkov, City College

Consider a square tiling of a region D in the complex plane as a square tiling (finite or infinite) with edges parallel to the coordinate axes and mutually disjoint interiors whose union is all of D. For each tile, we define the oscillation upon the tile as the maximum value of vertex on the tile minus the minimum value squared(vertexes may not necessarily be the actual vertices of the squares). A function u on the grid is defined as tiling harmonic if interior points are assigned such that oscillation over the entire grid is minimized. We present a computationally efficient algorithm that determines the values of the interior points from the value of exterior points in square tilings. In addition, we generate an algorithm for computing graph harmonic functions(values as averages of neighboring values) defined on boundary

values. We then use 3D images comparisons of the values of graph and tiling harmonic function and explore the general behavior of tiling harmonic functions given boundary values. We find in general that graph harmonic functions are not equivalent to tiling harmonic functions. In addition, we prove that the function $f(x + iy) = cy$ as tiling harmonic, and find criteria for bounded tiling harmonic functions on infinite tilings.

96. Applying Dynamic Amino Acid Interaction Preferences to GNM with X-ray Crystallography and Solution NMR Data

Robert Marek Houghton College
Advisor(s): Kristin Camenga, Advisor/Houghton College

Modeling the folding structure in proteins may improve drug manufacturers' ability to design effective medical inhibitors for proteins involved in the treatment of diseases by allowing more precise and accurate prediction of the folded protein structure. The Gaussian Network Model (GNM) is one method to model these folding patterns. Our research modified the GNM model to take into account amino acid interaction preferences. Using X-ray crystallography and NMR data from the Protein Data Bank, we predicted B-factors, experimental values that correlate with amino acids' mean square deviation, of a set of proteins. The predicted B-factors from our modification of the GNM showed a higher correlation to the experimental B-factors than did a simple form of the GNM. In the future, incorporating additional variables such as bond torsional forces and multiple conformations of the same protein would likely increase the efficacy of the model.

97. A Model of Sedimentation and Consolidation in Colloidal Suspensions With Applications to Industrial Paint Products

Eric Johnson University of Wisconsin Milwaukee
Advisor(s): Eric Johnson, University of Wisconsin Milwaukee

Pigments settling out of paint can destroy the product when settled pigments are consolidated into a hardened cake. Our industrial collaborators have found that this process seems to be amplified during transport via cargo ship. We have chosen to model the paint as a colloid instead of a discrete particle system. We assumed the mixture to be continuous and the fluid to be Newtonian and satisfy the point Navier-Stokes equations. We then developed a two-phase PDE model. It extends work done by Kynch and others. We added diffusion effects in the flux term during hindered settling, and account for both effective stresses and pore pressure in consolidation. Taking these terms into account gave us a degenerate parabolic PDE. We used a finite volume scheme to run several numerical experiments and have partially verified previously obtained results. However, we were not able to obtain results for Peclet numbers of order 10^5, a realistic estimate for our mixture. We suspect we will need to implement fraction step methods into our finite volume scheme. Future work will include allowing gravity to vary to capture the effects of waves, finding physically principled parameter ranges and quantifying the added effects of high frequency vibrations from the ship's engines on consolidation.

98. Probing the Early Universe with Deuterium and Helium-4 utilizing Second Order Runge-Kutta Method

Jeremy Ariche Morehouse College
Advisor(s): George Fuller, University of California - San Diego

Sterile Neutrinos are a primary candidate for dark matter. Their origin is unknown, yet it is plausible that a lepton asymmetry could generate sterile neutrinos. In addition, observations of the Cosmic Microwave Background suggest the presence of extra radiation energy density. We aim to investigate how lepton asymmetry and extra radiation energy density affect the abundances of Helium-4 and Deuterium as determined in Big Bang Nucleosynthesis (BBN). We will utilize the Wagoner-Kawano code which employs a second order Runge-Kutta differential equation solver to time evolve the electron chemical potential, temperature, and baryon density as well as nuclear abundances. The first three quantities are significant because they are the thermodynamic variables that describe the early universe, hence setting the environment for the production of the light elements during BBN. We will compare the deviation of these abundances due to lepton asymmetry and extra radiation against the standard model for primordial nucleosynthesis.

99. An Aggregate Stochastic Model incorporating individual dynamics for Predation Movements of Anelosimus Studiosus

Alex John Quijano East Tennessee State University
Advisor(s): Michele L. Joyner, East Tennessee State University

In this poster, we discuss methods for developing a stochastic model, which incorporates behavior differences in the predation movements of Anelosimus Studiosus (a subsocial spider). Stochastic models for animal movement and, in particular, spider predation movement have been developed previously; however, this paper focuses on the development and implementation of the necessary mathematical and statistical methods required to expand such a model in order to capture a variety of distinct behaviors. A least squares optimization algorithm is used for parameter estimation to fit a single stochastic model to an individual spider during predation resulting in unique parameter values for each spider. Similarities and variations between parameter values across the spiders are analyzed and used to estimate probability distributions for the variable parameter values. An aggregate stochastic model is then created which incorporates the individual dynamics. The comparison between the optimal individual models to the aggregate model indicates the methodology and algorithm developed in this paper are appropriate for simulating a range of individualistic behaviors.

100. Barcode Decoding Using M-band Wavelet Transform

Jordan Marquis Western Connecticut State University
Josh Torres Western Connecticut State University
Advisor(s): Xiaodi Wang, Western Connecticut State University

A barcode is a pattern of parallel black and white lines with varying widths and distances. It is printed on products and readable by a barcode scanner or machine in order to identify them. The varying widths and distances distinguish the product so that it is a unique identifier. With new technology, there has been a demand for barcodes to be interpreted by mechanisms other than designated barcode scanners. In our research we will use wavelet transforms to show that a two-dimensional image can be taken of a one-dimensional barcode and transformed back into the unique identifier. This can be applied to taking a picture of a barcode with a cellphone camera, transforming it into a 3-level wavelet transform, and finally performing horizontal sampling in order to allow the information to be read for decoding.

101. puzzleJAR: Automated Constraint-based Generation of Puzzles of Varying Complexity

Justin Kaashoek Massachusetts Institute of Technology
Amy Chou
Advisor(s): Rishabh Singh, Microsoft Research

Engaging students in practicing a wide range of problems facilitates their learning. However, generating fresh problems that have specific characteristics, such as using a certain set of concepts or being of a given difficulty level, is a tedious task for a teacher. In this paper, we present puzzleJAR, a system that is based on an iterative constraint-based technique for automatically generating problems. The puzzleJAR system takes as parameters the problem definition, the complexity function, and domain-specific semantics-preserving transformations. We present an instantiation of our technique with automated generation of Sudoku and Fillomino puzzles, and we are currently extending our technique to generate Python programming problems. Since defining complexities of Sudoku and Fillomino puzzles is still an open research question, we developed our own mechanism to define complexity, using machine learning to generate a function for difficulty from puzzles with already known difficulties. Using this technique, puzzleJAR generated over 200,000 Sudoku puzzles of different sizes (9×9, 16×16, 25×25) and over 10,000 Fillomino puzzles of sizes ranging from 2×2 to 16×16.

102. Destabilizing a Convergent Molecular Dynamics Simulation of the Hen Egg White Lysozyme Protein

William Frazier East Tennessee State University
Advisor(s): Jeff Knisley, East Tennessee State University

Molecular Dynamics (MD) is a computational tool used to simulate the folding dynamics of a protein. Typically, one begins with Protein Data Bank coordinates file for the crystallized protein, and after a sequence of preprocessing steps, subsequent coordinates for each atom are predicted for femtosecond time steps for up to nanoseconds. If an MD simulation tails, perhaps because the crystal structure is unstable or flawed, then the failure tends to occur in the

preprocessing steps. In general, it is difficult to use MD to predict the destabilization (i.e., "unfolding") of a flawed crystal structure. In the project, we develop a working MD simulation of Lysozyme, after which we explore how the crystal structure can be modified so as to cause the failure of the protein without causing premature termination at the MD run. The goal is to suggest how MD simulations can be used to simulate the destabilization of a protein, which would be useful information in applications of MD to drug design and similar areas.

103. Analysis of the Discrete Maximum Principle

Arman Green Morehouse College
Cassidy Krause University of Wisconsin-Platteville
Advisor(s): Johnny Guzman, Brown University

The maximum principle is a fundamental property of solutions to Laplace's equation with Dirichlet boundary conditions. To numerically solve the equation we use the Finite Element Method (FEM). However, for certain triangulations of the domain, the numerical solutions will not satisfy the maximum principle. The triangulation of the mesh affects the values of the global stiffness matrix, which is directly used in calculating the numerical solution to the equation. If all the entries of the inverse of the global stiffness matrix are positive, then the maximum principle will hold, (Ciarlet, 1970). An interest that naturally arises is identifying conditions of the triangulation of the mesh to ensure a positive inverse of the global stiffness matrix. Recently Korotov et al. showed that an obtuse triangulation produces a global stiffness matrix whose inverse has negative entries. *We investigate the location and magnitude of the negative entries of the inverse of the global stiffness matrix for arbitrary obtuse triangulations.*

104. Topic Point Process Models for Twitter Data

Eric Lai University of California, Irvine
Advisor(s): Blake Hunter, Alexandre Robicquet, Eric Fox, Claremont McKenna College

The widespread use of social media as a form of communication tool has enabled automated detection of trends and extraction of useful information. Social media is attractive for such purposes because its data clusters geographically around events such as sports competitions. However, transforming raw, free-form text into meaningful information remains a challenging task. Confounding factors include the scale of posted data, recovery of event information, and the temporal behavior of messages. In the present work, we consider 500,000 timestamped and geolocalized Twitter messages from the East Los Angeles area collected over a ten-month period. After cleaning the Tweets by removing stop words and correcting misspellings, we then apply topic modeling methods such as non-negative matrix factorization to discover prevalent topics as well as frequent words associated with each topic. We can then model Tweets with topics over time as Hawkes and Poisson processes and compare their fit by computing its Akaike Information Criterion value. This allows identification of self-exciting topics and Tweets. We plan to adopt this technique to an algorithm that can automatically summarize large collections of Tweets, recover lateen relationships, and predict future events from Tweets.

105. The Schelling Model: Simulation and Analysis

Michael Roberts University of Maryland
Advisor(s): Pieter Tibboel, HKUST

We studied the Schelling model, which is a well-known model of segregation. Our primary focus was analyzing its one-dimensional variants using simulation and rigorous analysis. The variants we chose to study include those we've called the standard model and the simple model. The standard and simple models consider agents split among discrete types, with agents' happiness determined by neighbors. In the standard model, a pair of unhappy agents of different type will swap as long as both will be no worse-off. In the simple model an agent will change its type if it will become happy after the swap. We have focused on results about "tipping points", values of agents' tolerance levels (a parameter of these models), around which model behavior changes qualitatively. For the standard model, we have extended results about the "tipping point" κ, the threshold of the agents' tolerance level τ at which the segregation level qualitatively changes in the one-dimensional Schelling model, from two types of agents to m types. For the simple model, we similarly extended results from a model with two agent types to one with m types, focusing on tipping points. We furthermore combined results about two tipping points to analyze a type of scenario which can occur only for $m > 2$.

106. Population dynamics of the Tasmanian devil and modeling strategies for the containment of Devil Facial Tumor Disease (DFTD).

Ashley Sichak University of St. Francis
Advisor(s): Megan Powell, University of St. Francis

DFTD is causing a massive decline in the Tasmanian devil population in a 20-year time-span. In this poster, I will present a system of ordinary differential equations used to understand the impact of disease on the population. I will show how the model predicts future population numbers based on disease factors. The success of potential strategies to help fight the population decline such as selective culling, isolation, and vaccination are evaluated using the model.

107. A Mathematical Model for the Interaction of the Proteins MMP-1, TIMP-1, and ECM in a Wound

Hannah Pennington Western Kentucky University
Nitin Krishna University of Chicago
Advisor(s): Richard Schugart, Western Kentucky University

This study aims to formulate, quantify, and analyze a mathematical model describing interactions among matrix metalloproteinases (MMP-1), their inhibitors (TIMP-1), and extracellular matrix (ECM) in the healing of a diabetic foot ulcer. De-identified patient data for modeling were taken from Muller et al. (2008), a research outcome that collected average physiological data for two patient subgroups: "good healers" and "poor healers," where classification was based on rate of ulcer healing. Model parameters for the two patient subgroups were estimated by minimizing the least-squares residual between the data and model output using Matlab's *GlobalSearch* and *fmincon* routines. The model and parameter values were analyzed by conducting steady-state and sensitivity analyses. Both global and local sensitivity analyses were conducted and compared. The global sensitivity analysis was performed using Latin hypercube sampling, while local analysis was conducted through a classical sensitivity analysis followed by an SVD-QR subset selection. Model and clinical implications are discussed based on our results.

108. Incorporating Exposure Periods, Hospitalization, and Mosquito Control into Dengue Fever Models

Jared Bland The Richard Stockton College of New Jersey
Advisor(s): Brandy Rapatski, The Richard Stockton College of New Jersey

Dengue Fever is an epidemic in many third world nations and warrants the attention of mathematical modeling to understand its dynamics and propose solutions to combat the deadly disease. Our model incorporates hospitalization effects, which greatly reduce the deadliness of the disease, exposure periods, which more realistically model the phenomenon, and active participation by the community to reduce the ability for mosquitoes to breed. Here, I present the results of a system incorporating these effects. The exposure period and hospitalization result in a longer lasting epidemic, but with a less pronounced peak. Our model also aimed to confirm a study from Sri Lanka, which used community involvement to reduce the mosquito breeding grounds, thereby reducing the number of Dengue cases. Our model compared different results corresponding to the timing of community involvement, and, as expected, the sooner the community is involved, the less Dengue cases; this confirms the intuition that year-round maintenance is required to help prevent epidemics.

109. Glial Cell Defense Mechanisms in Response to Ischemic Hypoxia in the Brain

Tiffany Reyes Whittier College
Hasan Sumdani The University of Texas at Arlington
Matthew Buhr University of South Dakota
Advisor(s): Benjamin Morin, Anuj Mubayi, Arizona State University

Three models are introduced that explore the dual role of glial cells in the formation of scar tissue and in the neural repair following hypoxia ischemia in the brain. Scar tissue helps protect the brain during the acute phase of injury by limiting the spread of secondary damage, but limits recovery by inhibiting the repair of damaged neurons. Scar formation is not ideal, however repaired neurons are still susceptible to damage and do nothing to halt the spread of ischemic injury. A stochastic, spatially explicit Cellular Automaton (CA) model is used to capture the dynamics of neural tissue repair and the containment of damage by scar tissue. In addition, two deterministic models are developed to approximate the stochastic process namely, Mean Field (MFA) and Pair Approximation (OPA) models. We show that the MFA neglects all spatial dependence among state variables. The OPA models the dynamics of state variables

evolving as pairs, where spatial adjacency matters. Our results compare how the trade-off between scar tissue formation and neural repair impacts future brain health.

110. The Effect of Prey Dispersal on a Two-Patch Predator-Prey System

Emma Talis Marist College
Conor Wells Drake University
Victoria Kelley James Madison University
Brennan Bean Brigham Young University - Idaho
Juliana Richardson Smith College
Advisor(s): Glenn Ledder, University of Nebraska - Lincoln

We consider the effect of prey dispersal in a two-patch predator-prey model in which the two patches are qualitatively different. In particular, we assume patch two has a significantly smaller carrying capacity and a correspondingly higher predation rate. Scaling the model under these assumptions introduces a parameter of arbitrarily small order, allowing for an asymptotic analysis. We show that the predator and prey will always coexist for biologically reasonable parameter values. Furthermore, we prove the existence and uniqueness of a coexistence equilibrium and determine the stability regions in the parameter space. Using numerical simulations, we illustrate the varying effects of prey dispersal on the stability of the coexistence equilibrium and find parameter values for which a Hopf bifurcation occurs.

111. An Individual-Based Model of Chaparral Vegetation Response to Frequent Wildfires

Dayna Mann Pepperdine University
Reanna Dona Pepperdine University
Advisor(s): Timothy Lucas, Pepperdine University

In recent years, the Santa Monica Mountains (SMM) have been plagued by frequent wildfires which threaten the native chaparral species. Nonsprouting chaparral species are completely killed by a fire, but their seeds germinate in response to fire cues. Facultative sprouters both resprout after a wildfire and release seeds that germinate post-fire. This project is based on data collected since 1986 at a biological preserve adjacent to the Malibu campus of Pepperdine University with an average fire return interval of 7.25 years. We present a spatial model that simulates the growth, seed dispersal and resprouting behavior of individual shrubs that compete for space and resources in a domain similar to our study site. The model incorporates varying rainfall and fire frequency as well as the competition between plants for scarce resources. Our simulation reproduces the change in plant community structure at our study site such as the local extinction of Ceanothus megacarpus due to short fire return intervals. Our simulations also predict frequent wildfires will drastically reduce the number and size of individual shrubs. A mathematical model of this system is important because a reduction of vegetation cover can cause a decrease in slope stability that leads to rock and mudslides.

112. Combinatorics of k-Interval Cospeciation for Cophylogeny

Jane Coons State University of New York at Geneseo
Advisor(s): Joseph Rusinko, Winthrop University

The subfield of phylogenetics known as cophylogenetics is concerned with discerning evolutionary relationships between taxanomical units that are evolving concomitantly, such as hosts and parasites and genes within a species. We show that the cophylogenetic distance, k-interval cospeciation, is distinct from other metrics and accounts for global congruence between locally incongruent trees. We define the size of the neighborhood of trees which satisfy the largest possible k-interval cospeciation with a given tree. The growth of this neighborhood indicates that k-interval cospeciation is useful for analyzing simulated data.

113. A Model for Stripe Rust Growth with Two Fungicidal Effects

Josean Velazquez University of Puerto Rico at Humacao
Advisor(s): Leon Arriola, Derdei Bichara, University of Wisconsin, Arizana State University

Stripe rust, also known as yellow rust, is a disease caused by the fungus Puccinia striiformis that affects host crops, primarily barley and wheat. It is the most prevalent strain of wheat rust within North America, and can account for a significant amount of yield loss within a harvest. In order to estimate the dynamic yield loss of a wheat crop infected by stripe rust undergoing fungicide application, a single-host, single-pathogen compartmental model is introduced

using a system of nonlinear ordinary differential equations. Two fungicidal effects are considered: preventative and anti-sporulant, which reduce susceptibility and inhibit the further spread of an infection, respectively. The stability conditions associated with the disease-free and endemic equilibria are identified. Numerical simulations are then used to examine the time-dependent behavior of fungicide efficacy and approximate yield loss. Finally, sensitivity indices are calculated to study the impact of fungicide efficacy and retention relative to plant growth.

114. Modeling the Interaction Between Inflammatory and Cardiovascular Dynamics

Jessica Perez The College of New Jersey
Ailaura Donahoe Pennsylvania State University
Chelsea Ball California State University, Monterey Bay
Advisor(s): Mette Olufsen, North Carolina State University

The more quickly a patient begins to mobilize after surgery, the shorter their recovery time is. However, postoperative patients are prone to syncope, or fainting. This is due to inflammation lowering blood pressure. If a patient's heart is unable to compensate for this change in pressure, they can faint. To better understand this phenomenon, three models were developed to predict blood pressure, heart rate, and the inflammatory response. The models were formulated as systems of differential equations that were solved using MATLAB. They were then tested using blood pressure and heart rate data measured from a healthy subject who was given a dose of endotoxin to stimulate an inflammatory response. The ultimate goal of the project is to combine the models for heart rate and blood pressure in the cardiovascular system and the model of the inflammatory response, in order to achieve a better grasp of why patients faint after surgery and to shorten recovery time by expediting mobility.

115. Alcoholism-A Mathematical Model with Media Awareness Programs

Erik Ander Rollins College
Advisor(s): Zeynep Teymuroglu, Rollins College

In this paper, we address the role of media awareness on the spread and persistence of a drinking behavior in a community. Our model integrates a media awareness component (Huo et al., 2014) into a modified version of an SIR drinking model developed by Sanchez et al. (2007). Here, the number of problem drinkers that exist in the community depends on the effectiveness of media awareness programs and peer pressure without the possibility of direct relapses. Our model mimics the dynamics of media awareness programs such that the density of awareness increases as the percentage of problem drinkers increase in the population. However, as mentioned in Huo et al. (2014), maintaining continuous support for media awareness is not possible. The peer influence is modeled as a factor to encourage drinking among the susceptible population as well as to cause relapses among recovered individuals. A threshold value, R_0, is proposed for the drinking-free equilibrium. Numerical simulations are presented to study the stability conditions in the case that alcoholism culture is established in the community.

116. The Effects of Regional Vaccination Heterogeneity on Measles Outbreaks with France as a Case Study

Nicholas Roberts Arizona State University
Elaine Alexander
Savanah McMahon
Advisor(s): Sergei Suslov, Kamuela Yong, D. Burkow, M. Manning, Arizona State University

The rubeola virus, commonly known as measles, is one of the major causes of vaccine-preventable deaths among children worldwide. This is the case despite the fact that an effective vaccine is widely available. Even in developed countries elimination efforts have fallen short as seen by recent outbreaks in Europe, which had over 30,000 cases reported in 2010. The string of measles outbreaks in France from 2008-2011 is of particular interest due to the documented disparity in regional vaccination coverage. The impact of heterogeneous vaccine coverage on disease transmission is a broad interest and the focus of this study. A Susceptible-Exposed-Infectious-Recovered (SEIR) multi-patch epidemiological model capturing the regional differences in vaccination rates and mixing is introduced. The mathematical analysis of a two-patch system is carried out to help our understanding of the behavior of multi-patch systems. Numerical simulations are generated to aid the study of the systems qualitative dynamics. Data from the recent French outbreaks was used to generate parameter values and to help connect theory with application. Our findings show that

heterogeneous vaccination coverage increases controlled reproduction number compared to comparable homogeneous coverage.

117. Importance of Remineralization of Cladophora-Epiphyte Assemblages on Silicate Cycling in Lake Michigan

Kolin Konjura University of Wisconsin-Milwaukee
Advisor(s): Gabriella Pinter, University of Wisconsin-Milwaukee

Nuisance growths of benthic filamentous algae, particularly Cladophora (Cl), support dense diatom epiphytes. These algae can impact the drawdown of silica from the water column to the benthos. However, at the end of the growing season the fate of the Si in the Cl is unknown. To further examine Si dynamics in the nearshore, Si pools in Cl-diatom branches were measured during the degradation of Cl branches in triplicate 1 L tanks. Algal branches that were still attached to the wharf (attached) were compared with algae found on the beach (sloughed), which had presumably started degrading. Water samples were collected from tanks for determination of dissolved Si (dSi), particulate Si (pSi), and algal subsamples were collected to determine biogenic Si (bSi) in the Cl-diatom branches. Over 58 days, there was a large flux of Si from Cl and diatom pools into the dSi fraction; dSi within the attached increased, while mean bSi decreased. In tanks with sloughed, dSi also increased while mean algal bSi decreased. Suggesting that attached lost more Si into the dSi pool, possibly because the initial diatom populations had higher Si. A system of ordinary differential equations was used to model the predictability of the system, and analyze further constraints that needed to be considered.

118. DNA Sorting with Game Theory

Samuel Simon Carnegie Mellon University
Caroline Jansen Notre Dame
Elizabeth Tatum Rutgers University
Advisor(s): Marion Scheepers, Boise State University

Ciliates have two copies of their genomes, one an encrypted version, the "ciphertext" version, of the other. Ciliate genome maintenance involves decryption of the ciphertext genome to replace their current "plaintext" genome. According to the current biological model this decryption is accomplished through two specialized permutation-sorting operations. Not all permutations are sortable by these. For one of these sorting operations random applications to even a sortable permutation can result in a failed sorting. This suggests that either ciliates have a strategy to sort a permutation, or else there is a rescue mechanism to recover from errant sorting attempts. Strategic ciliate permutation sorting can be modeled by two-player games. Using newly developed graph theoretic tools we prove a strict bound for when a player has a winning strategy in some of these games. Using graph-based techniques we also prove that the current biological model provides a rescue mechanism for ciliate permutation sorting.

119. A Periodic Matrix Population Model for Monarch Butterflies

Emily Hunt James Madison University
Advisor(s): Anthony Tongen, James Madison University

The monarch butterfly (Danaus plexippus) exhibits a unique migration phenomenon leaving Michoacan, Mexico in the spring and traveling as far north as Southern Canada; later generations return to the same location in Mexico the following fall. However, there is concern within the scientific community about the long-term stability of this impressive annual journey. We use periodic population matrices to model the life cycle of the eastern monarch butterfly and find that this unique migration is not currently at risk. We extend the model to address the three primary obstacles for the long term survival of this unique migration: deforestation in Mexico, increased extreme weather patterns, and milkweed degradation.

120. Stochastic Delay and Signal Propagation in Gene Regulatory Networks

Sarah Stanley University of Houston
Advisor(s): William Ott, University of Houston

The overall goal of this project is to understand the flow of information through gene regulatory networks and to create a model that effectively simulates stochastic signaling during protein transcription. To accomplish this, relevant models

must be created to accurately represent the signal's path and intensity. My project sought to improve current modeling paradigms such as ODEs, which oversimplify signal complexities and exclude important dynamical features such as delay, by ignoring the time involved during transcription. As an alternative, signaling was modeled using the $M/G/\infty$ queue, where M represents a memoryless arrival process (transcription initiation); G, the service time distribution (protein formation); and infinity, the number of service channels. In this model, the queue, a virtual holding tank, incubates proteins until maturation with succeeding queues continuing synthesis, producing a cascade. My project expanded upon two models in which the effects of delay were observed in an unmodified system as well as a system with limited initiation events. In turn, I analyzed the effects of a finite number of servers on propagation speed, concluding that as the number of servers increases, signaling resembles the limited initiation system.

121. Modeling Chronic Immune Activation in HIV-1 Infection

Kenneth Goettler College of the Holy Cross
Advisor(s): David B. Damiano, College of the Holy Cross

Chronic immune activation has been implicated as a major cause of the progression to AIDS in HIV-1 infection and in the limited immune reconstitution of HIV-1 patients on antiretroviral therapy. The healthy human immune system maintains low levels of rapidly proliferating and short-lived activated CD4+ (helper) and CD8+ (killer) T lymphocytes. In HIV-1 infection, however, the presence of virus increases recruitment into this activated population and effectively burns out' the immune system over time. Here we employ a system of twelve non-autonomous ordinary differential equations, modeling CD4+ and CD8+ T lymphocyte populations, to explore the effects of chronic immune activation and how they shape the course of HIV-1 infection. Activated cells are divided into HIV-specific and non-specific compartments. Heaviside functions are used to turn on increased recruitment of non-specific cells during infection. Parameter and target values for each compartment are estimated from literature and optimized using a simplex method and Latin hypercube sampling.

122. Population Dynamics of the Green Iguana in Puerto Rico: a Pest Control Method.

Dayanara Lebron Universidad Metropolitana
Advisor(s): Luis F. De La Torre, Universidad Metropolitana

The specie Iguana iguana, commonly named as green iguana, is a reptile specie native from Central and South America, and introduced in Puerto Rico as a domestic exotic mascot in 1970. The density and abundance of the I. iguana in Puerto Rico surpass the populational ranges of their native habitat due to the lack of natural predators; thereby being identified as a pest. The consequences of their extensive population growth in the island has had a negative ecological impact; primordially, causing a depletion of mangroves. I. iguana population is believed to currently display an exponential growth, however there are no preview mathematical models to proof this observation, since a gap exist in studies that explain the population dynamics of the I. iguana in Puerto Rico. Therefore, this research aims to explain the population growth behavior of the green iguana through the development of mathematical models for the dynamic population of green iguana. These models produce the estimations of optimal parameters that could yield population equilibrium; these equilibrium must be achieved in real life by the conversion of these parameters in alternatives policies as hunting season or animal exportation, ultimately modifying the future growth of this population in the island.

123. Optimizing Anti coagulation Therapy

John Williams University of Wisconsin-Milwaukee
Advisor(s): Peter Tonelatto, University of Wisconsin-Milwaukee

Nearly 31 million people per year are prescribed anticoagulation therapy to prevent thromboembolic complications. Despite this, anticoagulation therapy lacks a standard method of treatment. This is due in part to the sensitivity of anticoagulation therapy and to the impact of patient characteristics such as age, genotype, and race on therapeutic dosing. This results in an excess of distinct dosing algorithms, all of which require regular monitoring and individualized dosing. In fact, more than 12 different dosing algorithms have been proposed and used. The aim of this project is to simulate clinical trials in order to test and identify an optimal dosing algorithm according to standard anti-clotting outcome metrics. To do this, a Bayesian network model was used to create a statistical representation of a clinical trial population, called clinical avatars. The model proposed by Hamberg was then used to Pk/Pd simulate treatment of the

clinical avatars. As a secondary objective we will use a Markov model to predict the ability of dosing algorithms to increase the cost effectiveness of anticoagulation therapy.

124. Physiologically Based Pharmacokinetic Modeling for Acetone: How Much Do We Really Breathe In?

Vy Nguyen Baylor University
Ashley Edwards North Carolina State University
Benjamin Freedman North Carolina State University
Advisor(s): Marina Evans, EPA

We are interested in developing a PBPK model of inhaled acetone. The interest in acetone derives from two sources: its hydrophilic behavior and its ketotic structure. Since acetone is hydrophilic, it can be absorbed into the tissue of the upper respiratory tract after it is inhaled. There are other more toxic chemicals that are similarly structured to acetone, so if our PBPK model for inhaled acetone accurately represents the data, then the results can be applied to study those other more toxic chemicals. The model was developed with the respiratory tract separated into three different compartments along with a respiratory metabolizing constant. When the parameters were globally optimized, the model accurately estimated concentrations for the chamber with four varying initial conditions. Respiratory metabolism was found to be driving the elimination of acetone in the body, while the liver metabolized the chemical much more slowly. With the development of a model that is mathematically and physiologically accurate, the model can now be adapted to perform toxicological analysis on chemicals that are similarly structured to acetone, yet more toxic.

125. Modeling Latency of Thalmocortical Fast-Spiking Interneurons in Schizophrenia

Jennifer Houser East Tennessee State University
Advisor(s): Talitha Washington, Howard University

Neural thalamocortical circuits relay external sensations from the thalamus to the cortex where sensory information is then processed. Feedforward inhibition involving a subtype of fast-spiking interneurons, which are marked by the calcium-binding protein parvalbumin, reduce the chance that a postsynaptic neuron will fire an action potential. Consequences on the circuit due to the absence of parvalbumin expression in fast-spiking neurons in schizophrenia patients are caused by fast spiking latency. In this presentation, we present a conventional neuron model. We will show how to develop a mathematical model to incorporate a latency effect as well as show numerical simulations.

126. Estimating Bacterial Diversity in Defined Regions

Krista Kernodle University of California, Irvine
Advisor(s): Katherine Pollard, University of California, San Francisco

Scientists have made many predictions regarding the number of species on the planet today using varying methods, all of which produce a wide range of possibilities. In particular, the number of bacterial species (also known as OTUs) has been difficult to estimate and attempts are generally regarded as producing very low estimates. To address this problem, we present a method that uses information on the areas of bacterial ranges to estimate the number of bacteria in a defined region. The robustness of the method was tested using simulations before being applied to a dataset of OTUs observed in soil samples collected from Central Park. Further applications to real-world data may provide improved estimates of total bacterial diversity

127. A Bio-mathematical Approach to the Stability of HIV and AIDS

Talon Johnson Morehouse College
Advisor(s): Shelby Wilson, Morehouse College

HIV is a sexually transmitted disease that weakens one's immune system allowing other pathogens to affect one's body, ultimately resulting in the development of AIDS. A nonlinear mathematical model of differential equations with piecewise constants will show us the rate that HIV spread in a homogenous population. The solutions will be analyzed the systems of differential equations.The population of the model will be separated into three subclasses: the HIV negative class, the HIV positive class that don't know they are being affected, and HIV positive classes that know they are infected.

128. A meta-analysis of coastal populations' genetic diversity of species throughout their range

Fangyuan Hong Mount Holyoke College
Advisor(s): Sean Hoban, Julia Earl, Suzanne Lenhart, NIMBioS, University of Tennessee-Knoxville

High genetic diversity in the centers of many species' ranges have been thought to account for the abundant-center hypothesis (ACH), which states that populations found in the center of their natural distribution are more abundant than those found at the edges. Despite the prevalence of the ACH in population studies, relatively few studies have tested the assumption of differential genetic diversity throughout ranges by accounting for variation in sample sizes. To better assess the validity of the ACH in coastal habitats, this study is the first attempt at using a meta-analysis to investigate how genetic diversity of populations living along world's coastlines is affected by location within the species' range. An effect size of correlation coefficient (Pearson's r) for each genetic measurement of each species versus relative distance to center was calculated from the meta-analysis. Results showed positive correlations for most taxa and insignificant correlations for others. Multivariable models between taxa, range dimension, relative direction of sample sites showed significant r values, or associations. This study suggests for developing a more effective and feasible marine conservation practice that targets individual populations rather than the whole species.

129. Two Novel Non-Convex Approaches for Learning Near-Isometric Linear Embeddings

Hao-Jun Shi University of California, Los Angeles
Jerry Luo University of Arizona
Kayla Shapiro University of California, Berkeley
Qi Yang University of Southern California
Kan Zhu University of California, Los Angeles
Advisor(s): Ming Yan, Wotao Yin, University of California, Los Angeles

The large size of data acquired and processed by diverse modalities poses a challenge to current information processing systems. Thus, we propose two non-convex approaches for learning near-isometric linear embeddings of finite sets of data points. Given a set of training points $\mathcal{X}$, we consider the secant set $S(\mathcal{X})$ that consists of all pairwise difference vectors of $\mathcal{X}$, normalized to lie on the unit sphere. The problem can be formulated as finding a symmetric and positive semi-definite matrix that preserves the norms of all the vectors in $S(\mathcal{X})$ up to a distortion parameter δ. Motivated by non-negative matrix factorization, we reformulate it into a Frobenius norm minimization problem, which is solved by Alternating Direction Method of Multipliers (ADMM) and develop an algorithm, *FroMax*. Our other method seeks a projection matrix ψ such that the restricted isometry property (RIP) constraint is minimized directly. Using ADMM and a Moreau decomposition on a proximal mapping, we develop an algorithm, *NILE-Pro*, for dimensionality reduction. Both methods are then demonstrated to be more computationally efficient than previous convex approaches for a number of applications in machine learning and signal processing.

130. Properties of Self-Organized Criticality for Optimal Random Search

Kathleen Donahue Harvard University
Michelle Randolph University of North Carolina - Ashville
Advisor(s): Aliki Mavromoustaki, Heiko Hoffman, David Payton, UCLA, HRL

HRL Laboratories recently discovered that self-organized critical (SOC) systems produce search patterns that are well suited for approximating solutions to certain hard optimization problems. Self-organized criticality is a phenomenon found in dynamical systems ranging from rice piles to solar flares. Our team investigated which properties of SOC patterns led to improved random search. Improving the efficiency of random search could have widespread application (supply chains, allocation of resources, transportation networks). We investigated the following properties of search patterns: fractal dimension of the boundary, size-to-boundary ratio, variation in shape, size distribution and boundary structure. We found that smoothed shapes based on SOC-produced shapes performed better than original SOC patterns, as well as tree structures and standard shapes such as squares, rectangles and disks.

131. Raising the Bound on the Circulant Hadamard Matrix Conjecture

Brooke Logan Rowan University
Advisor(s): Michael Mossinghoff, Davidson College

A circulant Hadamard matrix is an $n \times n$ matrix with a number of properties: its rows are mutually orthogonal, its entries are all ± 1, and each row after the first is a circular shift of the prior row. It is widely conjectured that no

circulant Hadamard matrices exist with order $n > 4$. Many algebraic restrictions are known on the order of such a matrix, and as a result there are less than 1400 values less than $4 \cdot 10^{26}$ which have not been eliminated as a possible order of such a matrix. We describe a project from the Summer@ICERM REU program at Brown University in 2014, in which we raised this bound by a factor of 2500 through some careful computations. In addition to describing our computational methods, which involved searching for elusive double Wieferich prime pairs, and our new list of possible orders, we also discuss the connection between this problem and the Barker Conjecture, and we pose some directions for further research.

132. K-Knuth Equivalence for Increasing Tableaux

Michelle Mastrianni Carleton College
Colleen Robichaux Louisiana State University
Christian Gaetz University of Minnesota, Twin Cities
David Schwein Brown University
Advisor(s): Rebecca Patrias, University of Minnesota, Twin Cities

A K-theoretic analogue of RSK insertion and Knuth equivalence relations was first introduced in 2006. The resulting K-Knuth equivalence relations on words and increasing tableaux on $[n]$ has prompted investigation into the equivalence classes of tableaux arising from these relations. Of particular interest are the tableaux that are unique in their class, which we refer to as *unique rectification targets* (URTs). Here we give several new families of URTs and a bound on the length of intermediate words connecting two K-Knuth equivalent words. In addition, we describe an algorithm to determine if two words are K-Knuth equivalent and to compute all K-Knuth equivalence classes of tableaux on $[n]$.

133. Touch-based Continuous Authentication

Wendy Rummerfield University of Redlands
Advisor(s): Kiran Balagani, New York Institute of Technology

Smartphone continuous authentication seeks to add a layer of defense beyond existing entry-point authentication systems. Most pre-existing research focuses on data gathered from the touch screen itself, such as the characteristics of tapping and swiping. However, the focus of this project discovering novel features from different sources, specifically, the device's motion sensors. I hypothesized that a person's heartbeat could be detected using the smartphone's built-in accelerometer, which could be utilized as a method to differentiate between users. After collecting data from an app created last year, I analyzed the data using an algorithm I wrote in Matlab to detect peaks in the acceleration signal that could correspond to heart beat. The algorithm also creates a feature vector to hold calculated statistics which will be used to create a template in order to compare different users.

134. Barcode Deconvolution via Wiener and Dictionary Analysis of Barcode Subsections

Bohyun Kim University of California, Irvine
Advisor(s): Yifei Lou, University of Texas Dallas

While current systems already provide reliable results in correctly reading barcodes at close range, we want to increase the limits of these systems so they will be able to read these codes with extreme levels of blur and noise. We discover that we can retrieve a complete blurring function from a subsection of a blurry barcode and created a system that can analyze this subsection to deliver an estimated blurring function and a clean version of the barcode subsection that when convoluted together can recreate the blurred barcode. This function uses the Wiener filter to analyze and filter out noise and blur from a binary image: in our case, a picture of a blurry barcode, using a brute force method to try every possible combination of the first two digits of a barcode and finding a function that when convoluted with a clean subsection of the barcode, would return the result that best matches the original barcode. Through testing, our method successfully analyzes a subsection of a blurry barcode and returns an estimate kernel that is very similar to the actual function that blurred the image, possibly allowing future processes to accept even more limited data and correctly reconstruct the original data.

135. Improving plotting algorithms in SAGE

Nathan Dasenbrock-Gammon Northern Kentucky University
Advisor(s): Steven Wilkinson, Northern Kentucky University

Computers plot graphs by selecting points at which to evaluate the function, and then connecting the dots. If too few points are evaluated then the resulting graph is not smooth, too many points and the computer has to run more

calculations than necessary, which can take extra computing time. This project worked to develop and test different adaptive algorithms to determine where the computer needs to plot points so that a smooth graph is produced, but while having to evaluate a minimum number of points. All of our algorithms were written and run in SAGE, which is a python based, free and open source computer mathematics software.

136. The Accessibility Polynomial of a Sandpile Monoid

Bryan Oakley University of Georgia
Elizabeth Herman Marian University
Advisor(s): Luis Garcia, Sam Houston State University

Let Γ be a directed graph with a global sink s. A sandpile c is a vector of nonnegative integers indexed by the non-sink vertices of Γ, where $c(v)$ represents the number of grains of sand at vertex v. If a sandpile has too much sand, the unstable sandpile c may be stabilized by a sequence of vertex topplings where an unstable vertex v topples sending one grain of sand through each of its outgoing edges. A stable sandpile c is accessible from a sandpile b if one can reach c from b by a series of sand additions and topplings. The accessibility number of a stable sandpile c is the number of stable sandpiles that access c. This naturally leads to the univariate *accessibility polynomial* of a sandpile graph Γ

$$\mathcal{A}(x) = \sum_{i=1}^{m} a_i x^i,$$

where m is the total number of stable sandpiles in the graph Γ and a_i is the number of stable sandpiles with accessibility number i. In this talk we will focus on the second largest nonzero term in $\mathcal{A}(x)$. It can be checked that the degree of this term is at most $m - a_m$. We present exact conditions for undirected graphs to have $a_{(m-a_m)} = 1$.

137. Parallel Implementation of Time-Decomposition Preconditioner for the Dirac Equation

Arthur Kurlej University of Massachusetts Amherst
Advisor(s): Jung-Han Kimn, South Dakota State University

We have implemented a fully implicit numerical approach based on space-time finite element methods for the one-space plus one-time dimensional Dirac equation. The purpose of this talk is to present a stable parallel implementation of the physical system. The proposed numerical method is applied to generate a successful simulation results of gauge free, massless solution of the Dirac equation. The time additive Schwarz method is vital to make successful simulations with KSP (Krylov Subspace Methods) solvers. We show that proper time parallel implementation allows for physically intuitive boundary conditions, improvement of numerical efficiency,and reduces the overall error of the computed solution. The time parallel algorithm is implemented through PETSc (Portable, Extensible,Toolkit for Scientic Computation, developed by Argonne National Laboratory).

138. Experimental and Numerical Studies of Oceanic Overflows

Frederick Hohman University of Georgia
Thomas Gibson Baylor University
Theresa Morrison San Diego State University
Advisor(s): Shanon Reckinger, Fairfield University

Oceanic overflows occur when dense water flows down a continental slope into less dense ambient water. The resulting density driven plumes occur naturally in various regions of the global ocean and affect the large-scale circulation. The work presented here involves a direct qualitative and quantitative comparison between physical laboratory experiments and lab-scale numerical simulations. Laboratory experiments are conducted using a rotating square tank customized for idealized overflow and a high-resolution camera mounted on the table in the rotating reference frame for data collection. Numerical simulations are performed using the MIT general circulation model (MITgcm). The governing equations are a set of coupled nonlinear partial differential equations called the non-hydrostatic primitive equations, which are numerically solved using the finite-volume method. Resolution and numerical parameter studies are presented to ensure accuracy of the simulation. The results are analyzed using various calculated metrics including plume direction, plume velocity, and plume area. Laboratory and computational experiments are compared across a wide range of physical parameters, including Coriolis parameter, inflow density anomaly, and dense inflow volumetric flow rate.

139. North Carolina and Pennsylvania for Boardwalk? Trade Values for Monopoly Real Estate

Crisel Suarez St. Edward's University
Advisor(s): Michael Kart, St. Edward's University

The objective of the game Monopoly is to become the wealthiest player through buying, renting and trading properties. To improve a player's chance of winning, a player can optimize it's trading strategy. In this research a computer program written in Python 3.2 is able to model, simulate 10 million Monopoly games and collect data on the expected values of properties. For example, when two players are trading who would have a better deal? The data collected is able to determine the expected value for each property, where a player can compare other player's properties and decide if they want to make the trade. Future works for this research include optimization of the model, trading properties for money and applications to analytics.

140. Usage of FPGAs to implement complex algorithms used in linear systems and differential equations solvers

Mai Dao Texas Tech University
Advisor(s): Brock Williams, Texas Tech University

FPGAs are very flexible computer chips, and they are used to enhance the performance of complex mathematical solvers. The Verilog language in Xilinx program is used to write parallel hardware Conjugate Gradient implementation that executes numerical methods like the Finite Difference Methods and Finite Element Methods. Such methods can be used to solve various partial differential equations like fluid dynamics, heat transfer, and Laplace transformation equations and to locate the areas of possible solutions for various linear systems. Not only is the cost of such technologies greatly reduced, but this method is also super fast and can present novel approaches to complex mathematical challenges.

141. Motif-based clustering of directed networks

Thomas Reith Davidson College
Advisor(s): Laurie J. Heyer, Davidson College

The study of networks has become increasingly relevant in a variety of scientific fields, including biology, sociology, and computing. It has been shown that many real networks divide naturally into clusters, or communities, of related vertices. A large amount of research has focused on the detection of such clusters in undirected networks; their detection in directed networks, however, is a less well-studied problem. Here we introduce a novel clustering algorithm for directed graphs based on the concept of network motifs—recurrent, statistically significant subgraphs found at higher frequencies in real networks than ones that are randomly generated.

142. A Split-Explicit High Order Numerical Scheme for Atmospheric Applications

Juan Mora Arizona State University
Advisor(s): Mohamed Moustaoui, Arizona State University

A new numerical method is developed and applied to solve time-dependent partial differential equations involving advection problems. This method is based on a recently published numerical scheme which uses leapfrog and a 4th-order implicit time filter. This scheme is *split-explicit* and uses *small* and *large* time steps applied to terms responsible for *fast* and *slow* propagating waves respectively. Formal analysis of the stability and accuracy of this scheme will be presented. This scheme uses only one function evaluation per time step, is of 3rd-order accuracy for amplitude error, and damps the spurious waves due to computational modes inherent in the leapfrog scheme. The proposed scheme is compared to the 3rd- Order Runge-Kutta method which also has 3rd order accuracy for amplitude errors but requires three times as many function evaluations per time step. Examples demonstrating the performance of the proposed scheme will be presented.These includes application of the proposed scheme to the *Global Shallow Waters Spectral Model on the Sphere*, and nonlinear mathematical models used in regional Numerical Weather Prediction (NWP).

143. Coarse-Grain Model for Knotted Glueball Creation

Joseph Spitzer University of St. Thomas
Advisor(s): Eric J. Rawdon, University of St. Thomas

In the Standard Model, a quark and anti-quark can be bound together by the strong force to form a meson. In quantum chromodynamics (QCD), a meson can be modeled as a flux tube connecting a quark and anti-quark. We can think of the meson as a long cord with velcro at the two ends. If a fuzzy end touches a rough end, then they join together. If

the fuzzy and rough ends come from different mesons, then a new meson is formed with a longer cord. If the fuzzy and rough ends come from the same meson, then this connection forms a closed tube that can be knotted and/or linked with other closed tubes. Our ultimate goal is to simulate the creation of these glueballs to compare to experimental data. Currently, we employ a coarse-grain model where the mesons initially are represented by directed line segments randomly placed in a cube. Polygonal arcs are then formed by connecting heads and tails that are "close" to each other. The net result is a sort of bowl of polygonal spaghetti. The density of the initial set of directed line segments within the cube affects how many of these noodles are closed vs open and the knotting/linking of the noodles. We present initial results on this density effect. Future work will include adding velocities or Brownian motion to the polygonal noodles.

144. Encrypting Data For Web Applications

Jassiem Ifill Morehouse College
Advisor(s): Elaine Shi, University of Maryland, College Park

The primary goal of the research presented in this paper is to enhance the capabilities of the ShadowCrypt web extension in order to provide more privacy and authentication when sharing information within web applications. Throughout this summer, the section of the research in the Laboratory that was focused on enhancing ShadowCrypt attempted to improve the previously established asymmetric implementation, instead of the symmetric implementation which was not ideal. As such, this project builds upon the previous version of the ShadowCrypt extension, in order to make the asymmetric implementation more practical and easier to use in addition to increasing the extension's richness of features. The final result of this project was an improved version of the asymmetric implementation of the ShadowCrypt web extension, which allowed users to input their personal private keys, and manually input public keys. Also, this version of ShadowCrypt also possesses the feature to search, authenticate, and grab an individual's public key from Keybase.io, which is a public directory of public keys. Currently, this version of ShadowCrypt has been tested to work with gmail.com, Facebook, and Twitter among a few other web applications/domains.

145. Large Scale Computer Visualization

Omar Monarrez Texas Tech University
Advisor(s): G. Brock Williams, John Calhoun, Texas Tech University

High performance computers are designed to deal with big data sets, but oftentimes visualization tools need to be combined with high performance computing in order to render the data intelligible. Our new GPU cluster provides the raw computing power to run large scale simulations and analyze the resulting large data sets. We will describe our design for a large scale visualization system to complement the computer cluster. For example, when the disease simulation written for the cluster is running, each compute node will produce a graphical representation of the current extent of the outbreak for the area under that node's control. Combining these into a coherent whole will allow the large scale behavior of the disease to be visualized.

146. Implementing Multi-Agent Simulations

Catherine Nicosia Texas Tech University
Advisor(s): G. Brock Williams, John Calhoun, Texas Tech University

We will describe our work on the design and implementation of a large scale GPU cluster for multi-agent simulation. The new Schoenberg GPU cluster in our LAZARUS lab is designed for conducting large scale simulations and analyzing the resulting big data sets. For example, the multi-agent disease simulation software models the spread of a disease by simulating the movement of healthy, infected, and immune individuals throughout a city or continent. However, constructing and operating the cluster created numerous hardware and software challenges. For example, we will discuss our work creating a model for understanding the temperature and humidity around the computer and developing software and circuitry for the needed sensors and environmental controls.

147. Averages in Tree Space

Amber Holmes LaGrange College
Mercedes Coleman Lamar University
Emily Smith Kenyon University
Cody FitzGerald University of New Hampshire
Advisor(s): Seth Sullivant, North Carolina State University

As part of the North Carolina State University Research Experience for Undergraduates program in the Department of Mathematics, we explored a variety of means in tree space. Tree space is a subset of Euclidean space in which every

point represents a tree. In this space, there exist numerous metrics, each of which lead to a different notion of a mean tree. We have implemented the algorithm for the $(1, 1)$, $(2, 2)$ and $(1, \infty)$-mean in MATLAB.

The $(1, 1)$-mean is a weighted majority rule consensus tree, the $(2, 2)$ mean is generated using Sturm's algorithm. Unlike the $(1, 1)$ and $(2, 2)$-mean, the $(1, \infty)$ mean is not as well studied. The $(1, \infty)$-mean algorithm we propose incorporates traversing the L_2 geodesic using the L_1 midpoint as a mechanism for obtaining the mean tree's orthant. Once the orthant has been found, the mean tree can be optimized using linear programming.

148. Do Polygons Become Asymptotically Regular under Flow by Curvature?

Ryan Gallagher University of Connecticut
Jessie De La Cruz Santos College of the Holy Cross
Sarah Hadaidi University of Kentucky
Advisor(s): Andrew Cooper, North Carolina State University

The process of deforming a curve by the curvature vector at each point is known as the curve-shortening flow (CSF). Grayson showed that CSF averages the shape of a curve, causing simple, closed curves to become asymptotically circular. Our research applies the idea of curvature flow to polygons. We give a novel definition for the 'curvature vector' at a vertex of a polygon. Deforming in the direction of this curvature vector yields a flow of polygons, the polygon curvature flow (PCF). We numerically investigate the behavior of this flow and show that it exhibits several of the qualitative properties of CSF. We conjecture that PCF makes polygons asymptotically regular.

149. Centers of Triangles: Parameterization of the Distribution

Andrew Arnold University of Alabama at Birmingham
Advisor(s): John Mayer, University of Alabama at Birmingham

In response to Mueller's investigation of the loci of centers of triangles for a fixed center, we introduce a reparameterization in rectangular coordinates of the original problem in search of rigorous results. To study the distribution of triangle centers, we consider two families of triangles: those with fixed circumcircle, and those with fixed incircle, which represent all triangles up to rotation and dilation. Our goal is to find both synthetic and analytic arguments for the distribution of centroids, circumcenters, incenters, and orthocenters, when applicable, for the two families and discuss unexpected behavior of various distributions. In addition, we discuss the use of the dynamic geometry software package GeoGebra in the process of investigating the distribution, making conjectures, and arriving at both synthetic and analytic proofs of results.

150. Constant Vector Curvature in Three Dimensions

Albany Thompson Central Washington University
Advisor(s): Corey Dunn, California State University San Bernardino

Differential geometry is the use of the techniques and tools of calculus to study the geometric properties of manifolds. One of the most commonly studied properties of manifolds is its curvature. After a metric is defined on the manifold, an algebraic curvature tensor is a pointwise measurement of this curvature, and a model space is this collective information at one point. At any given point of the manifold, there are several curvature conditions that it can satisfy. This research is concerned with the necessary and sufficient conditions for a model space in three dimensions with positive definite inner product to have the specific curvature condition known as constant vector curvature. This poster outlines these conditions and provides examples of model spaces that fall into several different curvature classifications.

151. On the Levi graph of point-line configurations

Jessica Hauschild Kansas Wesleyan University
Jazmin Ortiz Harvey Mudd College
Advisor(s): Oscar Vega, California State University, Fresno

Given a certain point-line configuration C one may construct its Levi graph (AKA incidence graph), Levi(C), by connecting point-vertices with line-vertices if and only if they are incident in C. In this work we assume C to be a (v_r, b_k) configuration, and we investigate the vector space of vertex weightings of Levi(C) that are constant on all maximal independent sets of the graph, and prove that its dimension, known as the well-covered dimension of Levi(C), is always equal to 0, as long as $r > 2$.

152. Geometric Analysis of Chimu Ceramics

Joseph Hopkins Georgia College and State University
Matthew Kennedy Georgia College and State University
Advisor(s): Ryan Brown, Georgia College and State University

The Chimu Empire, an ancient pre-Columbian culture in Peru, had significant collections of ceramics and textiles. The ceramics were used for communication, to display societal status, and for religious ceremonies. Most research into these ceramics has focused on artistic and historical meaning. In this research we examine the ceramic works of the Chimu culture using mathematical analysis of their symmetries. We compare the geometry and symmetries in a sample of Chimu ceramics. We characterize structural symmetry, iconographic symmetry, and symmetry with respect to color. One goal of this project is to understand the relationship between the geometry of the Chimu in relation to other pre-Columbian cultures.

153. Investigating Square Hyperbolas and Dirichlet Domains under a non-Riemannian Metric of the Bidisk.

Hassan Nasif Wake Forest University
Advisor(s): Melissa Macasieb, William Goldman, University of Maryland, College Park

The Dirichlet Domain admitted by cyclic Fuchsian Groups on hyperbolic 2-space has been shown to only have two faces. In hyperbolic 3-space, the Dirichlet Domain admitted by the same isometries can have an infinite amount of faces. The bidisk, a cross of hyperbolic 2-space with itself, exhibits properties of both hyperbolic 2-space and 3-space, While it has been proven that a two-faced Dirichlet Domain can be admitted, computational evidence suggests that Dirichlet Domains in the bidisk can have more than two faces, but a constructive proof is not yet known. In further understanding the Dirichlet Domains and bidisk as a geometric space, we investigated the bidisk under a non-Riemannian metric and determined which properties and theorems remained true under the new metric.

154. Geometric Analysis of Chimu Textiles and Metalwork

Sidney Kennedy Georgia College and State University
Advisor(s): Ryan Brown, Georgia College

In this poster we examine geometric patterns and symmetries found in ancient textiles and planar metalwork of the Chimu, a pre-Columbian civilization of northern Peru. There are few extant Chimu textiles, but we study several pieces and compare patterns with several examples of planar Chimu metalwork still in existence. We observe reflection, rotation, and translation symmetries, and show how the Chimu incorporate subtle disruptions of symmetry.

155. Geometric Properties of Conformal Transformations on $\mathbb{R}^{p,q}$

Surya Raghavendran University of Texas at Austin
Advisor(s): Matvei Libine, Indiana University

We show that conformal transformations on the semi-Euclidean space $\mathbb{R}^{p,q}$ map hyperboloids and affine hyperplanes into hyperboloids and affine hyperplanes. We also show that this action is transitive when p or q is 0, and that this action has exactly three orbits otherwise. We then extend these results to hyperboloids and affine planes of arbitrary dimension. These properties generalize the well-known properties of fractional linear transformations on the complex plane $\mathbb{C}$.

156. Sphere Packings in Non-Euclidean Spaces

Sarah Stoops Butler University
Advisor(s): Prem, Sharma

Imagine emptying a sack containing small equal-sized ping pong balls to fill a large container. Experiment shows that the balls will occupy nearly 65% of the space in the box. However, a much higher packing density is achieved by filling the box layer by layer: Arrange the balls in the bottom layer as closely together as possible in a hexagonal lattice. Then in each succeeding layer, place the balls in the indentations created by the layer directly below it. If the container is the whole 3-dimensional space, the problem of finding a densest packing is the celebrated Sphere Packing Problem of Johannes Kepler (1611). Now suppose that instead of perfectly round spheres (ping pong balls), one were to fill the

box with identical prolate spheres (like apples) or oblate spheres (like American footballs). In this study, we introduce non-Euclidean geometries in the plane and 3-space to provide some good estimates for such packings.

157. Mean Curvature Zero Surfaces in Three-dimensional Lie Groups

Joseph Gills Longwood University
Advisor(s): Thomas Wears, Longwood University

A translation surface in a three-dimensional Lie group G is a surface that is generated from two curves $\alpha : \mathbb{R} \to G$ and $\beta : \mathbb{R} \to G$ by using the group operation of G to "multiply" $alpha$ and β together. Namely, one has the parametric surface S parametrized by $r : \mathbb{R}^2 \to G$, where $r(u, v) = \alpha(u) \star \beta(v)$ and $\star$ is the group operation of G. We investigate translation surfaces in the three-dimensional Heisenberg group and the three-dimensional group Sol_3, where the groups are equipped with a left invariant (Riemannian or Lorentzian) metric. Building off of the work of P. Piu and A. Sanini we focus on the case where our generating curves are integral curves of left invariant vector fields and/or geodesics and we present partial classification results on mean curvature zero surfaces of the indicated form.

158. Number Sequences for Rectified Cross Polytopes and 4-D regular Polytopes

Ryan Brown Grove City College
Advisor(s): Michael Jackson, Grove City College

Polytope numbers are a non-negative number sequence constructed from the geometry of a polytope. Rectification is the process of cutting of a vertex to the center of each edge connected to the vertex. We extend previous results to show a formula for the polytope numbers of an rectified Cross Polytope in any dimension. We use a stepping up inclusion exclusion and a geometric argument called Kim's process to cut the rectified cross polytope into smaller, same dimensional, cross polytopes. Our proof takes advantage of a number of identities relating cross polytopes and simplexes to each other and smaller or lower dimensional of themselves.

159. Graphs with minimal well-covered dimension

Gabriella Clemente The City College of New York
Advisor(s): Oscar Vega, California State University, Fresno

A graph is well-covered if all of its maximal independent sets have the same cardinality. The well-covered space of any graph, G, is the vector space of all functions on $V(G)$ that 'make' G well-covered, and the dimension of this space is the well-covered dimension of G, denoted by $wcdim(G)$. In 2005, Brown and Nowakowski proved that (1) $wcdim(G) \geq sc(G)$, where $sc(G)$ is the number of simplicial cliques of G, and that (2) $wcdim(G) = sc(G)$ if G is a chordal graph. In this poster, we present our main theorem, a generalization of (2) that yields a family of graphs with minimal well-covered dimension that contains chordal graphs. We also present our principal theorem on the well-covered dimension of Sierpinski gasket graphs, S_n with $n \geq 2$, which states that $wcdim(S_n) = 3$, where $sc(S_n) = 3$.

160. Radio Number for Seventh Powered Paths

Ilia Gonzales California State University
Gilbert Felix California State University San Beranardino
Antonio Saucedo California State University San Bernardino
Osvaldo Gonzalez California State University San Bernardino
Advisor(s): Min Lin-Lo, California State University San Bernardino

Let G be a connected graph. For any two vertices u and v, let $d(u, v)$ denote the distance between u and v, which is the smallest length of any $u - v$ path in G. The diameter of G, denoted by diam(G), is the greatest distance between any pair of vertices in G. A $radio - labeling$ (or multi-level distance labeling) of G is a function f that assigns to each vertex with a label from the set {0,1,2,3,...} such that the following holds for any two vertices u and v:

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

The span of f is defined as $\max_{u,v \in V(G)}\{ | f(u) - f(v) | \}$. The radio number of G, denoted by $rn(G)$, is defined as the minimum span of all radio-labelings for G. The goal of this presentation is to discuss the progress we made towards finding the radio number for the seventh power of any path during a 2014 research program which is an MAA activity funded by NSF (grants DMS-1156582 and DMS-1359016).

161. Visualizing Dessins D'Enfants

Susan Maslak Ave Maria University
Mary Kemp Occidental College
Advisor(s): Naiomi Cameron, Lewis and Clark College

Our poster summarizes the results of a summer research project motivated by the theory of dessins. Dessin is short for dessin d'enfant which means child's drawing. Mathematically speaking, a dessin is a connected bicolored graph where the edges around every vertex are cyclically ordered. Dessins can be realized by Belyi maps which are meromorphic functions $f : X \to \mathbb{P}^1(\mathbb{C})$ such that X is a Riemann surface and f is unramified outside $\{0, 1, \infty\}$. One of the goals of this project is to determine Belyi maps that realize a given loopless, connected bipartite graph on a compact Riemann surface X. We report on our considerations of certain classes of such graphs, explorations of computational methods for finding associated Belyi maps and related applications.

162. Graphs with Characteristic-dependent Well-covered dimension

Joseph Burdick Humboldt State University
Advisor(s): Oscar Vega, California State University Fresno

Given a graph G and a field F, the F-vector space of all vertex-weights that are constant on the maximal independent sets of is called the well-covered space of G. The dimension of this space is the well-covered dimension of G (relative to F). For some graphs, their well-covered dimension can depend upon the characteristic of the field used for scalars. We investigate graphs that have this property and show how more graphs with this property can be constructed.

163. Reliability of Recursively Constructed Graphs

Hanah Goetz The University of Texas at Tyler
Jon Erickson Rice University
Cecile Cornelus Adelphi University
Advisor(s): Christina Graves, The University of Texas at Tyler

The probability that a given graph G remains connected if each edge is included with probability p is the all-terminal reliability polynomial of G. A graph whose reliability polynomial is greater than all other graphs on the same number of vertices and edges is call a uniformly most reliable graph (UMR). We first investigate the UMR for some specific number of vertices and edges. We then apply a recursive process to the Petersen graph and compare the reliability polynomials of the resulting graph families.

164. Counting Symmetric Fullerene Patches with 4 Pentagons

Armando Grez Florida Gulf Coast University
William Linz Texas A&M University
Heather Chiros Massachusetts College of Liberal Arts
Advisor(s): Stephen Graves, University of Texas at Tyler

This study examines a method for constructing fullerene patches in the hexagonal tessellation of the plane. We extend a result of Graves and Graves (2013) by producing an exact process for drawing fullerene patches with 4 pentagonal faces embedded in them. Attempts to formulate a closed equation for the number of symmetric patches, up to isomorphism, are shown. These include direct counting by predetermining the placement of two pentagonal faces and noting graphical symmetries that cause overcounting, using the Principle of Inclusion-Exclusion approach and by recoordinatizing our depiction from Coxeter coordinates to Euclidean in order to analytically count the patches within the largest convex polygon interior to all the boundary lines we construct.

165. The Number of Seymour Vertices in Random Tournaments and Digraphs

Yiguang Zhang Johns Hopkins University
Advisor(s): Anant Godbole, East Tennessee State University

Seymour's distance two conjecture states that in any simple digraph with no anti-parallel arcs, there exists a vertex (a "Seymour vertex") that has at least as many neighbors at distance two as it does at distance one. We explore the validity of probabilistic statements along lines suggested by Seymour's conjecture, proving that almost surely there are a "large" number of Seymour vertices in random tournaments and "even more" in general random digraphs.

166. Knight's Tours on Boards with Odd Dimensions

Stephanie DeGraaf Iowa State University
Advisor(s): Steve Butler, Iowa State University

A popular form of recreational mathematics deals with chess problems, such as a knight's moves on a chess board. In particular, a closed knight's tour is a sequence of knight moves where each square is visited exactly once and the sequence begins and ends with the same square. The problem of determining when a board has a closed knight's tour was solved by Schwenk, with the condition that the size of the board must be of even dimension. This leads to the question of how to construct a closed knight's tour on boards of odd dimension. To do so, we must delete a square in order to have an equal number of black and white squares, so for boards of size $m \times n$ where m and n are odd, we determine which square to remove to allow for a closed knight's tour.

167. Saturation Number of Trees in the Hypercube

Kavish Gandhi Newton North High School
Advisor(s): Chiheon Kim, Massachusetts Institute of Technology

A graph H' is (H, G)-saturated if it is G-free and the addition of any edge of H not in H' creates a copy of G. The saturation number $sat(H, G)$ is the minimum number of edges in an (H, G)-saturated graph. We investigate bounds on the saturation number of trees T in the n-dimensional hypercube Q_n. We first present a general lower bound on the saturation number based on the minimum degree of non-leaves. From there, we suggest two general methods for constructing T-saturated subgraphs of Q_n, and prove nontrivial upper bounds for specific types of trees including paths, generalized stars, and certain caterpillars under a restriction on minimum degree with respect to diameter.

168. The Abelian Sandpile Model on Fractal Graphs

Rafael Setra University of Maryland
Advisor(s): Robert Strichartz, Cornell University

The Abelian Sandpile Model is a process where chips are placed on a graph's vertices. When the number of chips on a vertex exceeds its degree, chips are distributed to each neighboring vertex by a process called toppling. On the integer lattice the resulting stable configurations form interesting fractal patterns. Using these fractal patterns as motivation, we examine resulting configurations on graph approximations of post critically finite fractals. In particular, we look for connections between the boundary growth of the stable configurations and the initial number of chips. We also prove that the resulting configurations are periodic with respect to the number of chips. We may further generalize this periodic behavior on arbitrary graphs.

169. Characterizing Veto Interval Graphs and Related Graph Classes

Jessica Kawana Willamette University
Advisor(s): Joshua D. Laison, Willamette University

Given a set S of intervals on the real line, we can construct a graph with a vertex for each interval in S, and an edge between two vertices if and only if their corresponding intervals intersect. Conversely, given a graph G, G is an interval graph if it has such a representation. We define a variation of interval graphs called veto interval graphs, where each interval contains a veto mark, and two intervals do not count as intersecting if either contains the veto mark of the other. We explore properties of veto interval graphs and their relation to other classes of geometric intersection graphs.

170. A study of competition graphs induced by permutations

Elizabeth Yang Princeton University
Advisor(s): Brian Nakamura, Rutgers University

This project introduces a means to unite two active areas of research namely, the study of competition graphs and the study of patterns in permutations. We extend the work of Cho and Kim on the competition graphs of doubly partial orders of sets of points in R^2. Here, we study the competition graphs arising from permutations (using the doubly partial order on the permutation's graphical representation). We find many interesting connections especially between the graphs of permutations that avoid the pattern 1 3 2 and permutations that avoid the pattern 1 2 3. These connections involve both the structure of the graphs involved, and the enumerative aspects of these graphs (i.e. how many permutations form a certain type of graph). This was joint work with Brian Nakamura.

171. Construction and Optimality of Undirected de Bruijn Sequences

Christie Burris Colorado State University
Advisor(s): Patrick Shipman, Colorado State University

For positive integers k and n, what is the minimal length of a word over an alphabet of size k which contains every length-n word as a subword? Clearly the minimum possible length of such a word is $k^n + n1$, as this length is required to see all k^n subwords without repetition. Words that achieve this bound are commonly referred to as de Bruijn sequences. Applications of de Bruijn sequences arise as optimally random sequences in coding theory as well as in the design of DNA microarrays. De Bruijn sequences on the alphabet corresponding to the set of amino acids, $\{A, D, C, G\}$, which comprise DNA can be used to see a great variety of binding patterns relative to the length of the sequence. We introduce a variation on the idea of a de Bruijn sequence, as exemplified by the sequence 00010111. This sequence sees each of the binary words of length 3 as subwords with the minimal number or repetitions when read both left-to-right and right-to-left. We call such a sequence an undirected de Bruijn sequence. The purpose of this research is to determine the lengths of undirected de Bruijn sequences and develop methods for their construction.

172. Studying Brain Connectivity using Weighted Graph Comparison

Alexander Berger New York City College of Technology
Thierno Diallo CUNY City Tech
Advisor(s): Urmi Ghosh-Dastidar, New York City College of Technology

Studying brain components and its connectivity is an important field in neuroscience. While concepts of weighted graphs are widely used in many areas including computer, social, biological pathways, and air traffic networks, application of weighted graphs to study brain connectivity pattern is relatively new in the field of graph theory. In this project we focus on anatomical connectivity that connects nodes representing regions of interest (ROIs) and the weighted edges associated with structural connectivity, i.e., the density fibers connecting ROIs. An adjacency matrix using connectivity weights between ROIs is created and Laplacian spectrum analysis and spectral clustering method are used to study the connectivity strength between and within two cerebral hemispheres.

173. A Generalization of Higher Dimension Fibonacci Matrices and Their Graphs

Zachery Lancto Westfield State University
Advisor(s): Karin Vorwerk, Westfield State University

The 2×2 Fibonacci matrix is well studied in mathematics. One can interpret this Fibonacci matrix as a transition matrix and thus define the associated directed graph. The concept of the Fibonacci matrix and its associated graph can easily be extended to higher dimensions using concepts and techniques from linear algebra, graph theory, and discrete mathematics. We define nxn Virahanka matrices as the generalization of the Fibonacci matrix. A Virahanka matrix has the property that, when raised to integer powers, all its entries are Fibonacci numbers. We examine $n \times n$ Virahanka matrices where $n > 2$ and discuss their underlying graphs and recurrence relationships. We also provide an existence argument for certain higher dimensions and show that Virahanka matrices in higher dimensions are neither unique nor necessarily possess isomorphic associated graphs. By studying these matrices and graphs, we discover recurring subgraphs and patterns in the graphs. We propose an upper limit to the minimum number of edges needed for a graph to define an nxn Virahanka matrix and establish and prove many of its general properties. We built on work first presented by Brian Bowen in 2008.

174. Properties of the Generalized Type A and Full Flag Johnson Graphs

Linhan Chen Boston University, Program in Mathematics for Young Scientists (PROMYS)
Jongwon Kim Boston University, PROMYS
Advisor(s): Dylan Yott, University of California, Berkeley

We present a study of a family of graphs called the Johnson graphs, as well as one of its generalizations, the full flag Johnson graphs. Briefly mentioned in algebraic graph theory texts, Johnson graphs contain structural and algebraic properties that are analogous to those of the Grassmann graphs, the Hamming graphs, and the Kneser graphs. While the Johnson graphs have been well-studied with regards to their applications in coding theory, the full flag Johnson graphs have been relatively unexplored. Apart from the fact that they are regular, are connected, form permutohedra in some cases, and are Cayley graphs over S_n, not many of their properties are known. In our research, we focus on previously unexplored properties of both the Johnson and full flag Johnson graphs through novel approaches. Specifically, with

the aid of the Sage program to generate examples, we derive a recursion for the regularity of the full flag Johnson graphs through combinatorial considerations. We also exploit a structural property within the full flag Johnson graphs to determine the planarities of all cases. We then proceed to derive the clique size of the Johnson graphs, before proving the existence of a graph isomorphism between different classes within the Johnson graph family.

175. Combinatorial Analysis of the Game Grim

Richard Adams California State University, Fresno
Janae Keys Fresno State University
Advisor(s): Oscar Vega, California State University, Fresno

The game *Grim* is a subtraction game played on a graph. A move consists of deleting an available vertex (one that has not already been deleted), which also deletes vertices that become isolated as a result of this move. As usual, the last player who can make a move wins. Some was already known about Grim played on certain families of graphs (certain paths, cycles and wheels, and complete bipartite graphs and grids). Not surprisingly, the analysis of the game gets really complex when the number of vertices grows, even for very simple graphs, such as even paths. We focused on two problems:
textbf(1) Large graphs: What are winning strategies when Grim is played on graphs with many vertices.
textbf(2) Randomized playing: What happens when Grim is played randomly (no strategy, or just using a 'local' strategy) on a given graph.

176. k-dependence on Hexagonal Boards

Robert Doughty Miami University
Berkeley Bishop Anderson University
Jessica Gonda University of Akron
Adriana Morales University of Puerto Rico at Rio Piedras
Josiah Reiswig Minnesota State University Moorhead
Katherine Slyman University of Delaware
Advisor(s): Reza Akhtar, Miami University

Combinatorial chessboard problems have been studied extensively in the literature. A particular question of interest concerns determining the maximum number of kings that can be placed on an $m \times n$ chessboard such that no king attacks more than k others; similar questions have also been studied on triangular boards. We investigate this question when the chessboard is in the shape of a rhombus tiled by regular hexagons of the same sidelength. We provide upper and lower bounds for this quantity, using vertex discharging methods to improve the upper bound in certain cases.

177. On $2-2$ Graph Achievement Games

Curtis Clark Jr. Morehouse College
Advisor(s): Curtis Clark, Morehouse College

Let F be a graph with no isolated vertices. The $2-2$ F-achievement game on the complete graph K_n is described as follows. Player A first colors two edges of K_n green. Then Player B colors two different edges of K_n red. They continue alternately coloring the edges with Player A coloring at most two edges green and Player B coloring at most two different edges red. The graph F is achievable on K_n if Player A can make a copy of F in his color. The minimum n such that F is achievable on K_n is the $2-2$ achievement number of F, $a(F)$. The $2-2$ move number of F, $m(F)$, is the least number of edges that must be colored by Player A to make F on the complete graph with $a(F)$ vertices. The numbers $a(F)$ and $m(F)$ are determined for some small graphs and paths.

178. Colored strongly regular, and Colored quasi-random graphs

Mark Rychnovsky University of California, Santa Barbara
Advisor(s): Padraic Bartlett, University of California, Santa Barbara

Strongly regular graphs are often used for their powerful symmetries. Here we generalize the notion of a strongly regular graph to k colors giving what is often an even stronger symmetry group. We will see that several natural examples of strongly regular graphs extend cleanly to k colors, particularly those arising from affine spaces, and finite fields. We will also examine the similarities between these graphs and the random graph on k vertices.

179. An Excursion into the Collatz Conjecture and Related p-adic Topologies

Joseph Hoover Butler University
Advisor(s): Prem Sharma, Butler University

Let G be the graph with the set of odd positive integers $\mathbb{D}^+$ as its vertex set and with a directed edge from each vertex n to $g(n)$, where $g(n)$ is the largest element of $\mathbb{D}^+$ that divides $3n + 1$. Furthermore, let P be the component of G containing 1. We elegantly embed G in the Euclidean plane as such: place the vertex 1 at the origin and each vertex $v \in P$ on the circle of radius equal to the graph distance of v from 1. This partition of P into points on concentric circles reveals many interesting relationships among the odd integers by inducing a topology on $\mathbb{D}^+$ which we extend to p-adic topologies (for $p = 2$ and $p = 3$) on the set of rational numbers. These relationships certainly possess intrinsic value regardless of whether the Collatz Conjecture is true or not.

180. Accelerating Stochastic Local Search Algorithms with Markov Clustering

Timothy Goodrich Valparaiso University
Advisor(s): Erik Ferragut, Oak Ridge National Laboratory

The Travelling Salesperson Problem (TSP) occurs frequently in modern applications such as traffic routing, power grid design and circuit layout, and yet the NP-completeness of the problem suggests that a quick algorithm does not exist for finding an optimal solution to any given problem instance. Our purpose is to develop quick approximation algorithms for TSP instances with Euclidean distance between vertices (Euclidean TSP). Specifically, our work concentrates on implementing clustering techniques such as Markov Clustering (MCL) to provide the algorithms with valuable meta-data. Repeating this process by clustering the clusters themselves, we gain access to an innate ontology on the data set. We analyze the use of this ontology on both a theoretical and an experimental level. Theoretically, we analyze run time and solution quality when given certain properties of a clustering. Experimentally, we verify that our algorithms work well in practice when compared to current state-of-the-art algorithms. By examining the existing, natural clusters in the data, we define structures that reflect and utilize the nuances of each data set. We find that this algorithm design choice drastically reduces run time while maintaining solution quality.

181. Monomization of Power Ideals and Generalized Parking Functions

Brice Huang MIT
Advisor(s): Wuttisak Trongsiriwat, MIT

A power ideal is an ideal in a polynomial ring generated by powers of homogeneous linear forms. For a graph G and an abstract simplicial complex Δ, we define a power ideal $\mathcal{J}_{G,\Delta}$ and a monomial ideal $\mathcal{I}_{G,\Delta}$. We prove that $\mathcal{I}_{G,\Delta}$ has the same Hilbert series as $\mathcal{J}_{G,\Delta}$, and that their quotient algebras $\mathcal{A}_{G,\Delta}$ and $\mathcal{B}_{G,\Delta}$ share a monomial basis. This result generalizes and interpolates between the known monomization theory of the central and external zonotopal algebras by Postnikov-Shapiro and Desjardins, respectively. We also interpret the common Hilbert series of the algebras $\mathcal{A}_{G,\Delta}$ and $\mathcal{B}_{G,\Delta}$ in terms of generalized parking functions. We construct a bijection between a generalization of the G-parking functions and a class of forests of G, extending the known bijection between G-parking functions and spanning trees of G.

182. Forbidden Subgraphs of Competition Graphs

Aquia Richburg Morehouse College
Advisor(s): Gene Fiorini, Rutgers University

Since the introduction of competition graphs much work has been done to study their properties. In this paper we look at classifying forbidden subgraphs of competition graphs of doubly partial order. These results also extend to n-tuply partial order. This paper also looks at the correlation of Dyck paths, Catalan numbers and partially ordered sets.

183. On the Minimal Reset Words of Synchronizing Automata

David Stoner South Aiken High School (RSI MIT research)
Advisor(s): Chiheon Kim, Massachusetts Institute of Technology

Cerny's Conjecture is a 50-year old question which concerns the combinatorial field of synchronizing automata. In particular, it postulates that the maximal length of the minimal reset word among all n-state automata is $(n-1)^2$. A proof is presented for Pin's Theorem, which applies Cerny's conjecture to p-state automata consisting of a cycle and a

non-permutation, where p is an odd prime. Also, families of automata of the form $F(p,k)$ are introduced; they consist of a cycle and a group of k disjoint merging arcs. $C(p,k)$ is defined to be the maximal length of minimal reset words within these families. A lower bound of $C(p,k)$ for general k is demonstrated, and the exact value of $C(p,2)$ is found.

184. A Game of Cops and Robbers on Generalized Petersen Graphs

Jonathan Guzman California State University, Long Beach
Nikolas Schonsheck Vassar College
Advisor(s): Robert Bell, Michigan State University

The game of Cops and Robbers is a perfect information, vertex-pursuit game in which a set of "cops" and a "robber" occupy vertices in a graph G. The cops place on vertices of the graph, followed by the robber and then both alternate turns, either moving to adjacent vertices or passing. The copnumber of a graph, $c(G)$ is the least number of cops required to catch the robber. We study the game on Generalized Petersen graphs. Let n and k be positive integers such that $n \geq 5$ and $1 \leq k \leq \lfloor \frac{n-1}{2} \rfloor$. The Generalized Petersen graph $GP(n,k)$ is the undirected graph with vertex set $\{a_1, \ldots, a_n, b_1, \ldots, b_n\}$ and the edges (a_i, a_{i+1}), (a_i, b_i), and (b_i, b_{i+k}) for each $i = 1, \ldots, n$ with indices read modulo n. We lift the game to an infinite cyclic cover, $GP(\infty,k)$, which has the vertex set $\{a_i \mid i \in \mathbb{Z}\} \cup \{b_i \mid i \in \mathbb{Z}\}$ and edges defined analogously. There is a graph homomorphism $\pi : GP(\infty,k) \to GP(n,k)$ defined by reducing indices modulo n. The copnumber of every Generalized Petersen graph is less than or equal to 4.

185. Connected Matchings in Graphs of Independence number 2

Jung Yoon Kim Thomas Jefferson High School for Science and Technology
Advisor(s): Peter Csikvari, Massachusetts Institute of Technology

In this project, we study connected matching in graphs of independence number 2. This problem is motivated by Hadwiger's conjecture. We conjecture that if G is a graph on $4n-1$ vertices with independence number 2, then it contains a connected matching of size n. We confirm our conjecture for n less than or equal to 13.

186. Cyclic Jacobians of Nearly Complete Graphs

Jeffrey Davis University of South Carolina
Joshua Klarmann Kansas State University
Advisor(s): Luis Garcia, Sam Houston State University

The Jacobian group of a graph is defined as the cokernel of the reduced Laplacian of the graph. The order of this finite Abelian group equals the number of spanning trees in the graph. Its structure is an isomorphism invariant that has received much attention recently in diverse areas of mathematics including algebraic and tropical geometry, combinatorics, and theoretical computer science. A nearly complete graph is obtained by removing $n-3$ edges from a complete graph K_n on n vertices. In this paper, focus is given to removing families of graphs on $n-3$ edges from K_n that yield cyclic Jacobian groups. Among these families of graphs are forests of vertex disjoint paths, and almost-paths, i.e., the vertex-join of a path and a single edge. Necessary and sufficient conditions for the cyclicity of the groups associated with the complements of vertex-disjoint paths on K_n are presented. We also determine the cardinality of these groups as well as for those associated with almost-paths based on tree counting methods for graphs. These cardinality results are given in terms of Chebyshev polynomials of the second kind. Finally, an alternate proof is given for a previously held result about an ordering on almost-paths.

187. Laplacians Associated with Regular Bipartite Graphs and Application to Finite Projective Planes

Jesse Zhang Fairview High School
Advisor(s): David B Rush, Massachusetts Institute of Techonology

Internet search technology is a pervasively used utility that relies on techniques from the field of spectral graph theory. We present a novel spectral approach to investigate an existing problem: the critical group of the line graph has been characterized for regular nonbipartite graphs, but the general regular bipartite case remains open. Because of the ineffectiveness of previous techniques in regular bipartite graphs, our approach provides a new perspective and aims to obtain the relationship between the spectra of the Laplacians of the graph G and its line graph $\widehat{G}$. We obtain a theorem for the spectra of all regular bipartite graphs and demonstrate its effectiveness by completely characterizing the previously unknown critical group for a particular class of regular bipartite graphs, the incidence graphs of finite

projective planes with square order. This critical group is found to be $\mathbb{Z}_2 \oplus (\mathbb{Z}_{2q+2})^{q^3-1} \oplus (\mathbb{Z}_{q^2+q+1})^{q^2+q-1}$, where q is the order of the finite projective plane.

188. Diameters of polytope graphs and an improved upper bound on subset partition graphs

John Gallagher University of Wisconsin-La Crosse
Advisor(s): Edward D. Kim, University of Wisconsin-La Crosse

We study polytopes, which are generalizations of three-dimensional polyhedra. The graphs of polytopes are studied in mathematical optimization because of their relation to the simplex method for linear programming. Due to the relationship between the diameters of polytopes and the efficiency of the simplex method, we analyze diameters of abstract polytope graphs. Abstract polytope graphs are graphs which encode combinatorial data about polytopes. We present an analogue of Todd's recent bound for polytopes in the setting of subset partition graphs, a generalization of abstract polytopes.

189. Teaching Approximation Using Technology: A Survey of Calculus Instructors' Perceptions

Samantha MacMillan Nichols College
Advisor(s): Nicholas Gorgievski, Nichols College

This paper will discuss the ways and extents to which U.S. higher education calculus instructors use technology to teach approximation in first-year calculus courses. The research is a part of a larger study designed to investigate calculus instructors' perceptions of approximation as a central concept and possible unifying thread of the first-year calculus. A survey was administered to 279 calculus instructors who were asked to share information about their use of technology to promote student understanding of approximation in the first-year calculus. Qualitative and categorical measures were employed to extract themes and patterns from the data. Four major themes emerged which focused on: (a) the types of technology currently being used by college and university calculus instructors to teach approximation concepts, (b) coverage of specific topics using the same devices, (c) the frequency with which calculus instructors report using technology, and (d) calculus instructors' perceptions of the role of technology in teaching and learning approximation ideas. The findings of this research are of significance to all instructors of first-year calculus courses and have the potential to impact their instructional practices.

190. Online Professional Learning Networks

Justin Gomez Montana Tech of the University of Montana
Kaitlin Rudy Montana Tech of the University of Montana
Advisor(s): Hilary Risser, Montana Tech of the University of Montana

As technological advancements are made in the social media world, more people are connecting for professional development this way. This study served as an update to a 2011 study conducted by Dr. Hilary Risser. The previous study established a base network of teachers that used blogs to communicate educational practices. The purpose of this investigation is to analyze the differences, similarities, and benefits of online versus face-to-face communication. Interviews with multiple math and science teachers were conducted first with an online survey, and followed up via Skype. Their blogs were examined to identify connections between these teachers so that a new network of communication could be established. Preliminary results show that since 2011, networks have grown. Moving forward, the contents of each blog will be assessed. One future goal is that the conclusion of this study could lead to better equipped online social media for education professionals to grow.

191. Calculus: Conceptual or Procedural?

Brandon Finney Texas Tech University
Advisor(s): Gary Harris, Texas Tech University

The literature is rich with articles addressing and assessing the effects of conceptual versus procedural approaches to teaching and learning in Calculus. We are interested in just what these terms mean in practice and how to gauge the extent to which the teaching and expected student outcomes in our calculus classes can be viewed as conceptual, procedural, or some combination of both. To this end, using definitions motivated by the early work of Hiebert and Lefevre (1986), we have created a Conceptual/Procedural rubric (CP rubric) designed to assess the extent to which our Calculus exams are entirely conceptual (C), primarily conceptual with procedural knowledge needed (CP), primarily procedural with conceptual knowledge needed (PC), or entirely procedural (P). In this poster we present the data from our use of the CP rubric applied to the final exams given in our Calculus I and II classes over multiple semesters.

192. Coffee Wars: Bringing Data About Real World Competition into the Math Classroom

Mary Long Shippensburg University
Advisor(s): Ben Galluzzo, Shippensburg University

The recent addition of a Dunkin' Donuts café to the Shippensburg University campus was welcomed by many students, faculty, and staff. However, behind the scenes personnel wonder what the effect of this added competition will have on the Starbucks café, which has been operating on the campus for seven years. For example, questions such as: "are more individuals purchasing coffee and/or food from the university?" , and "will Starbucks on campus lose business?" are being asked. With recent implementation of Common Core Standards in many states, mathematics teachers are under pressure to incorporate real world connections into course curriculum. This study, a data driven exploration on the effect of competition between two coffee "giants" on campus, provides background for numerous applications of mathematics appropriate for students in algebra and introductory statistics courses and addresses questions that matter. This poster presentation will cover the data collection process, some preliminary results, and sample lesson plans developed from this study.

193. Mobile Devices as a Component of a Student's Response System for STEM Majors

Shontrice Garrett Jackson State University
Todderrick Robinson Jackson State University
Advisor(s): Jana Talley, Jackson State University

Mobile devices have become increasingly more accessible to students and instructors at the post-secondary level. With the implementation of Jackson State University's iPad Initiative, all first time freshmen now have access to iPads. This study is designed to investigate how iPads and other mobile devices can be used in undergraduate mathematics courses to engage students in mathematical dialogue, which has been shown to facilitate conceptual understanding. Specifically, the mobile devices will serve as components of a student response system to engage students in meaningful classroom discussions. The investigation will be conducted at Jackson State University, an urban minority-serving university and the participants will be the instructors of and the students enrolled in a freshman level mathematics course.

194. The Impact of Leading Supplemental Instruction Sessions on the SI Leader

Christina Tran California State University, Fullerton
Kelly Hartmann CSU-Fullerton
Advisor(s): Todd CadwalladerOlsker, California State University, Fullerton

The impact of Supplemental Instruction (SI) has been shown to be positive for students taking gateway STEM courses; we focus instead on the impact of leading SI workshops on the SI leaders. While the impact of SI on the leaders themselves has long been thought to be positive, evidence for this has been largely anecdotal. This study conducted at California State University, Fullerton attempted to examine this impact with more quantifiable evidence and on a larger scale than past studies may have reported. Variables included gender, first generation college status, and underrepresented minority status (URM). While the subgroups were not significantly different on variables linked to academic background and achievement such as grade point average, several significant differences emerged. For example, results showed that a higher proportion of men than women reported increased confidence and effectiveness in communicating with professors, peers, and students. Additionally, URM leaders reported increases dealing effectively with student conflict and communicating with peers than did their non-URM counterparts. This information may help inform how to improve the structure of supplemental instruction programs and training to better benefit both SI students as well as the SI leaders.

195. Primality in Numerical Monoids Generated by an Arithmetic Sequence

Jonathon Spaw Millikin University
Ashley Mailloux Transylvania University
Meghan Malachi Providence College
Advisor(s): Roberto Pelayo, University of Hawaii: Hilo

In cancellative, commutative, atomic monoids, the ω-primality function measures how far an element is from being prime. Since irreducible elements which are not prime give rise to non-unique factorizations, understanding the primality of individual elements gives us a deeper understanding of the factorization theory of these monoids. In the

context of numerical monoids generated by an arithmetic sequence with three generators, we present a thorough analysis of the ω-primality function. In particular, we provide a conjectured closed form for the ω-value of the generators, a description of the dissonance points, and closed forms for the quasi-linear portion of the function.

196. Lattice Embeddings of Planar Point Sets

Dara Zirlin Mount Holyoke College
Michael Knopf University of California, Berkeley
Jesse Milzman Georgetown University
Dantong Zhu Lafayette College
Advisor(s): Derek Smith, Lafayette College

In the Euclidean plane, let S be a set of points whose pairwise distances are integers. If the area of each triangle with vertices in S is also an integer, it is not hard to find a congruent copy of S that embeds in $\mathbb{Q}^2$. It is more surprising that S also embeds in $\mathbb{Z}^2$. What can be said if the area of some triangle is not an integer? Then S certainly will not embed in $\mathbb{Z}^2$, but there are other natural lattices of points to consider, namely those corresponding to the maximal orders of quadratic extensions of $\mathbb{Q}$. We provide a number-theoretical condition sufficient for S to embed in one of these lattices, and we conjecture that the condition is sufficient as well. It is then natural to ask whether S embeds in $\mathbb{Z}[\sqrt{-d}]$. The equilateral triangle with side length 1 provides a counterexample for $d = 3$; but the triangle does embed in the maximal order $\mathbb{Z}[\omega]$ of Eisenstein integers, where $\omega = (1 + \sqrt{-3})/2$. Our main result determines the values of d for which all S with characteristic d embed in the maximal order of the quadratic field $\mathbb{Q}(\sqrt{-d})$. We also provide similar results for point sets whose pairwise distances need only be square roots of integers.

197. Traces of singular values of Hauptmoduln

Lea Beneish Indiana University
Advisor(s): Ken Ono, Emory University

In an important paper, Zagier proved that certain half-integral weight modular forms are generating functions for traces of polynomials in the j-function. It turns out that Zagier's work makes it possible to algorithmically compute Hilbert class polynomials using a canonical family of modular forms of weight $\frac{3}{2}$. We generalize these results and consider Haupmoduln for levels $1, 2, 3, 5, 7$, and 13. We show that traces of singular values of polynomials in Haupmoduln are again described by coefficients of half-integral weight modular forms. This realization makes it possible to algorithmically compute class polynomials.

198. Design of Knapsack Cryptosystems Using Certain t-Superincreasing Sequences

Rob Rexler Baello Montclair State University
Donald Coleman New Jersey Institute of Technology
Advisor(s): Aihua Li, Montclair State University

Superincreasing sequences have been used widely in designing Knapsack cryptosystems. Generalizing the concept, we define a new type of sequence, t-superincreasing sequence. In this presentation, we report our result on designing knapsack cryptosystems using certain t-superincreasing sequences. Methods of creating t-superincreasing sequences and how to use them to construct knapsack cryptosystems are provided. This research is funded by MAA NREUP through NSF grants DMS-1156582 and DMS-1359016.

199. Metacommutation of the Hurwitz Quaternions and the Projective Line over $\mathbb{F}_p$

Shakthi Shrima Boston University - PROMYS
Adam Forsyth Boston University - PROMYS
Jack Gurev Boston University - PROMYS
Advisor(s): Raffael Singer, Oxford University

In 2013, Cohn and Kumar investigated the metacommutation mapping for pairs of primes in the ring of Hurwitz integers. Specifically, Cohn and Kumar showed that the sign of the permutation of Hurwitz primes of norm p induced by the Hurwitz primes of norm q under metacommutation is given by the quadratic character of q modulo p, where p and q are rational primes. Here, we show that this permutation is equivalent to the permutation induced by the right standard action of $\mathrm{PGL}_2(\mathbb{F}_p)$ on $\mathbb{P}^1(\mathbb{F}_p)$. Using our equivalence, we give simple proofs of the results of Cohn and Kumar and characterize the cycle structure of the aforementioned permutation.

200. The Diophantine Frobenius problem over fields.

Yan Sheng Emory University
Advisor(s): Ricardo Conceicao, Oxford College of Emory University

It is a well-known result in number theory that given a collection of positive co-prime integers $\{a_1, \ldots, a_n\}$, we can express any integer k as

$$x_1 a_1 + \cdots + x_n a_n = k,$$

with $x_1, \ldots, x_n$ integers. The Diophantine Frobenius problem asks for the largest positive integer not expressible in the above form, where $x_1, \ldots x_n$ are non-negative. Recently, this problem has been extended to polynomials over an arbitrary field by R. Conceicao, R. Gondim and M. Rodriguez. In our poster, we provide different proofs of certain results in the aforementioned work. In addition, we reformulate some theorems related to the classical problem in this new context for polynomials.

201. Density of Primes Dividing Terms in the Somos-5 Sequence

Bryant Davis Wake Forest University
Rebecca Kotsonis Wake Forest University
Advisor(s): Jeremy Rouse, Wake Forest University

The Somos-5 sequence is a recursive sequence defined by $a_n = \frac{a_{n-1}a_{n-4}+a_{n-2}a_{n-3}}{a_{n-5}}$ with $a_0 = a_1 = a_2 = a_3 = a_4 = 1$, with the interesting quality that all values of the sequence are integers. We wish to determine $\lim_{x\to+\infty} \frac{\pi_1(x)}{\pi(x)}$ where $\pi(x)$ is the number of primes less than or equal to x and $\pi_1(x)$ is the number of primes less than or equal to x that divide a term in the Somos-5 sequence. To do this, we study the relationship between the Somos-5 sequence and the elliptic curve $E : y^2 + xy = x^3 + x^2 - 2x$. There is an isogeny between the elliptic curve $E' : y^2 + xy = x^3 + x^2 + 8x + 10$ and E, and the basis for calculating $\pi_1(x)$ comes from determining the relationship between the point of order 2 on E and the point of order 2 on E' in $\mathbb{F}_p$. To determine this relationship, we make extensive use of Galois Theory, Algebraic Number Theory, and the Chebotarev Density Theorem.

202. Shopping For Nu Hats: A Lower Bound for $\hat{\nu}\{\mathbb{Z}_n, m, 2\}$

Alice Mitnick Gettysburg College
Advisor(s): Bela Bajnok, Gettysburg College

In our research, we explored the maximum value of restricted sumsets with a fixed number of terms added. In particular, given a subset $A \subseteq \mathbb{Z}_n$ consisting of m elements, one can ask how many distinct elements can be written as the sum of two elements of A. As A ranges over all subsets of $\mathbb{Z}_n$ with m elements, we define $\hat{\nu}\{\mathbb{Z}_n, m, 2\}$ to be the largest number of distinct elements that can be generated in this manner. Here, we find an explicit formula for a lower bound of $\hat{\nu}\{\mathbb{Z}_n, m, 2\}$.

203. Representations by Ternary Quadratic Forms

Edna Jones Rose-Hulman Institute of Technology
Advisor(s): Matthew Young, Texas A&M University

How can you represent integers by ternary quadratic forms? For example, can the integer 2015 be represented as a sum of a square plus three times a square plus five times a square? A few kinds of representations over the integers (such as global representation and local representation) will be discussed. To better understand these representations, we count how many solutions there are to equivalences involving ternary quadratic forms using quadratic Gauss sums and Hensel's Lemma.

204. On the Distribution of Discriminants over a Finite Field

Soonho Kwon Princeton University
Jonathan Chan Bergen County Academies
Advisor(s): Keith Conrad, University of Connecticut

For an odd prime power q, we prove a sufficient condition for the equal distribution of discriminants of monic polynomials in $\mathbb{F}_q[x]$ with a given degree. We also prove an analogous result for even q. In addition, we show for each degree

m greater than or equal to the characteristic of $\mathbb{F}_q$ that every number in $\mathbb{F}_q$ is the discriminant of a monic polynomial in $\mathbb{F}_q[x]$ of degree m.

205. Exploring the Calkin-Wilf Tree: Subtrees and the Births of Numbers

Kayla Javier Bridgewater State University
Advisor(s): Shannon Lockard, Bridgewater State University

Over a hundred years ago Georg Cantor proved that the set of rational numbers is countably infinite. In 1999, Neil Calkin and Herbert Wilf gave an alternate proof of this fact using a fraction tree which became known as the Calkin-Wilf tree. The tree presents a way to list the rational numbers so that every fraction is listed exactly once in the tree, creating a bijection from the set of rational numbers to the set of natural numbers. Since then, mathematicians have been examining this tree closely, looking for interesting patterns and properties. For this project, we investigated subtrees and the birth, or the first occurrence, of numbers within the tree. We used Maple to generate the first 1,000 births and looked for similarities within these first occurences. While investigating the births, we found a number of patterns that give us insight as to where births occur within the tree. We also studied subtrees, which are smaller fraction trees within the Calkin-Wilf tree. While examining subtrees, we determined which numbers do and do not occur in a subtree. In the future, we would like to use this information about subtrees to help us determine whether the birth of a number can be found in a given subtree.

206. Combinatorial Properties of Rogers-Ramanujan-Type Identities Arising from Hall-Littlewood Polynomials

Claire Frechette Brown University
Madeline Locus University of Georgia
Advisor(s): Ken Ono, Emory University

Here we consider the q-series coming from the Hall-Littlewood polynomials,

$$R_\nu(a,b;q) = \sum_{\substack{\lambda \\ \lambda_1 \le a}} q^{c|\lambda|} P_{2\lambda}\left(1, q, q^2, \ldots; q^{2b+d}\right).$$

These series were defined by Griffin, Ono, and Warnaar in their work on the framework of the Rogers-Ramanujan identities. We devise a recursive method for computing the coefficients of these series when they arise within the Rogers-Ramanujan framework. Furthermore, we study the congruence properties of certain quotients and products of these series, generalizing the famous Ramanujan congruence

$$p(5n+4) \equiv 0 \pmod 5.$$

207. Exact p-divisibility of exponential sums of polynomials over finite fields

Daniel Ramirez University of Puerto Rico, Rio Piedras Campus
Ramón Collazo University of Puerto Rico, Rio Piedras Campus
Julio De la Cruz University of Puerto Rico, Rio Piedras Campus
Advisor(s): Ivelisse Rubio, University of Puerto Rico, Rio Piedras Campus

The p-divisibility of the exponential sum of a polynomial F over a finite field with p elements, p a prime, has several applications in coding theory and cryptography. The covering method of [1] is an elementary method to compute the exact p-divisibility of this sum. The results presented in [2] give the exact p-divisibility (or improves its bound) of the exponential sum of F when the polynomial might have several minimal coverings. We simplify the conditions of [2] and apply the results to the estimation of the p-divisibility of exponential sums of deformations of F.

1. Francis N. Castro and Ivelisse Rubio. "Exact p-divisibility of exponential sums via the covering method" to appear in *Proc. Amer. Math. Soc.*
2. ———. "Construction of systems of polynomial equations with exact p-divisibility via the covering method," *Journal of Algebra and Its Applications,* 13(06):1450013, 2014.

208. Special Values in Leamer Monoids

Nicholas Rojina University of North Carolina, Chapel Hill
Jackson Rebrovich Angelo State University
Crystal Mackey Youngstown State University
Advisor(s): Brian Loft, Sam Houston State University

Much is known about the factorization theory for arithmetical Leamer monoids which are generated by an arithmetic sequence where the step size and the distance between the generators are equivalent. However, much is still unknown about Leamer monoids when the step size does not equal the distance between the generators. In this paper, we focus on the values of x_0 and x_f in relation to the step size of the Leamer Monoid for embedding dimension 2 numerical monoids. In particular, we present a bound on the step size for which $x_0 = x_f$ and present a method to compute x_0 in this case. We also present a closed form for the value x_0 with any step size. We apply our results to prove the Huneke-Wiegand conjecture in the case of an arithmetically generated Leamer monoid with embedding dimension 2.

209. Catalan Numbers Modulo 2^α

Gianluca Pane Brown University
Advisor(s): Victor Moll, Tulane University

Catalan numbers, defined by the explicit formula $C_n = 1/1 + n\binom{2n}{n}$, have been studied since the eighteenth century due to their frequent appearance in various fields from set theory to combinatorics. For example, C_n counts the number of permutations of $\{1, 2, \ldots, n\}$ that avoid a three-term increasing subsequence. However, there are few results about the properties of Catalan numbers modulo prime powers. In particular, we examine the number of residues obtained by viewing Catalan numbers modulo powers of 2.

210. Improving the Speed and Accuracy of the Miller-Rabin Primality Test

Shyam Narayanan MIT PRIMES-USA, Blue Valley West High School
Advisor(s): David Corwin, MIT

Currently, even the fastest deterministic primality tests run slowly, with the Agrawal-Kayal-Saxena (AKS) Primality Test runtime $\tilde{O}(\log^6(n))$, and probabilistic primality tests are still highly inaccurate. In this paper, we discuss the accuracy of the Miller-Rabin Primality Test and the number of nonwitnesses for a composite odd integer n. We also extend the Miller-Rabin Theorem by determining when the number of nonwitnesses $N(n)$ equals $\frac{\varphi(n)}{4}$ and by proving that for all n, if $N(n) \geq \frac{5}{32} \cdot \varphi(n)$ then n must be of one of these 3 forms: $n = (2x+1)(4x+1)$, where x is an integer, $n = (2x+1)(6x+1)$, where x is an integer, n is a Carmichael number of the form pqr, where p, q, r are distinct primes congruent to 3 (mod 4). Finally, we find witnesses to certain forms of composite numbers with high rates of nonwitnesses and find that quadratic nonresidues and 2 are both valuable bases for the Miller-Rabin test. This work is expected to result in a faster and better primality test for large integers.

211. Exact 2-Divisibility of Exponential Sums Associated to Elementary Symmetric Boolean Functions

Oscar Gonzalez University of Puerto Rico at Rio Piedras
Raul Negron University of Puerto Rico at Rio Piedras
Advisor(s): Francis N. Castro, Luis A. Medina, Ivelisse Rubio, University of Puerto Rico at R

An n-variable Boolean function F is a function defined over $\mathbb{F}_2^n$ with values in $\mathbb{F}_2$, the finite field with two elements. The Boolean function F is balanced if $\left|\left\{x \in \mathbb{F}_2^n | f(x) = 1\right\}\right| = 2^{n-1}$. This property is important for many applications in cryptography. A function F is balanced if and only if the exponential sum $S(F) = \sum_{x_1,\ldots,x_n \in \mathbb{F}} (-1)^{F(x_1,\ldots,x_n)}$ associated to F is zero. A Boolean function F is called symmetric if its value is not affected by a permutation of its input. On 2008, Cusick-Li and Stănică proposed a conjecture about the non-balancedness of elementary symmetric Boolean functions. In this work, we calculate the exact 2-divisibility of $S(F)$ for some families of elementary symmetric Boolean functions and use it to prove some cases of this conjecture. Our approach is completely elementary.

212. Covering Everything: An Exploration of h-Critical Numbers

Kevin Campbell Gettysburg Colege
Advisor(s): Bela Bajnok, Gettysburg College

We define an h-fold sumset of A as the set that is given by the sum of h not necessarily distinct values in a set A, where each value is taken modulo n where n is the size of the ambient group. Given an $h, m, n \in \mathbb{N}$ and the group

$\mathbb{Z}_n$, $(\mathbb{Z}_n, m, h)$ denotes the smallest possible size of an h-fold sumset of A, where A is a subset of $\mathbb{Z}_n$ of size m. An h-critical number is the minimum value of m such that $(\mathbb{Z}_n, m, h) = n$. That is, if a subset A of $\mathbb{Z}_n$ is at least the size of the h-critical number of $\mathbb{Z}_n$, then the h-fold sumset of A will span $\mathbb{Z}_n$. We present bounds for all h-critical numbers and an explicit equation for any h-critical number for all values of h where the ambient group has a size that is an even number or a power of a prime. We also conjecture an equation for a general value of n.

213. On Numerical Semigroups Generated by Geometric Progressions

Claire Spychalla Taylor University
Advisor(s): Vadim Ponomarenko, San Diego State University

Let $n_1, n_2, \ldots, n_k \in \mathbb{N}$ such that $\gcd(n_1, n_2, \ldots, n_k) = 1$. Then the set $S = \{c_1 n_1 + c_2 n_2 + \cdots + c_k n_k : c_i \in \mathbb{N}\}$ is a numerical semigroup, and we say S is generated by $\langle n_1, n_2, \ldots, n_k \rangle$. Certain invariants of numerical semigroups, such as the delta set, elasticity, and catenary degree, give a distance measure between elements of the semigroup. Here we explore the invariants of numerical semigroups that are generated by finite geometric progressions. These semigroups have surprisingly elegant structure that give insight into the structure of all numerical semigroups and allow us to determine the delta set, elasticity, and catenary degree of many other semigroups.

214. P-adic Limits of Combinatorial Sequences

Alexandra Michel Mills College
Joseph Rennie Reed College
Advisor(s): Victor Moll, Tulane University

The p-adic field is an alternative to the real numbers as a completion of the rational numbers under a different metric for every prime p. The definition of a p-adically Cauchy convergent sequence can be equivalently stated in terms of congruences of the terms modulo arbitrarily large powers of p: a sequence is p-adically Cauchy convergent if and only if it is eventually constant modulo p^k for all $k \in \mathbb{N}$. Using results on factorials modulo powers of primes by Lin and Yeh (2010) and Granville (1997), we identify a class of p-adically convergent subsequences of Catalan numbers in terms of the p-ary expansion of the sequence elements. We then discuss the extension of our results to a more general class of sequences involving factorials and binomial coefficients.

215. Mirror Symmetry in Reflexive Polytopes

Christopher Magyar University of Wisconsin Eau Claire
Advisor(s): Ursula Whitcher, University of Wisconsin Eau Claire

The polar duality transformation takes a polytope with integer lattice points to its polar dual. If the polar dual is also a lattice polytope, then we refer to the polytopes as reflexive polytopes. Dual varieties defined from pairs of reflexive polytopes exhibit the phenomenon of mirror symmetry predicted by string theorists. We use concepts from algebraic geometry, number theory, and combinatorics to examine one-parameter families of elliptic curves obtained from reflexive polygons. Previously, we have counted points of dual hypersurfaces within these elliptic curves over finite fields to demonstrate an arithmetic mirror symmetric relationship holds for three pairs of elliptic curve families. We link these results to the Picard-Fuchs equations, which can be used to describe how these families change as their parameter is changed.

216. Sequences of p-adic valuations of polynomials: an analysis of aperiodic and non p-regular behavior

Amber Yuan The University of Chicago
Alyssa Brynes Tulane University
Advisor(s): Victor Moll, Tulane University

In the field of number theory, the p-adic valuation is a useful device in studying the divisibility of an integer by powers of a given prime p. This paper centers on 2-adic valuations of quadratic polynomials in $\mathbb{Z}[x]$. In particular, the existence and properties of roots of such polynomials modulo 2^l, are determined and assessed. Polynomials of particular interest are those that yield non 2-regular sequences in $\mathbb{Q}_2$. Such sequences are represented in a novel infinite tree form, and patterns in such trees are analyzed to classify the sequences by their structure and non 2-regular properties. Such classification is further refined through an algebraic analysis of the polynomials at hand.

217. Subtraction Makes Little Difference: The Minimum Sized h-fold Span of m-sized Subsets of Abelian Groups

Ryan Matzke Gettysburg College
Advisor(s): Béla Bajnok, Gettysburg College

Let G be a finite abelian group written with additive notation. For a positive integer h and a nonempty subset A of G, we let hA and $h_{\pm}A$ denote the h-fold unrestricted sumset of A and the h-fold unrestricted span of A, respectively; that is, hA is the collection of sums of h not-necessarily-distinct elements of A, and $h_{\pm}A$ consists of all signed sums of h not-necessarily-distinct elements, meaning you can add or subtract each element rather than only add. For a positive $m \leq |G|$, we let

$$\rho(G, m, h) = \min\{|hA| : A \subseteq G, |A| = m\}$$

and

$$\rho_{\pm}(G, m, h) = \min\{|h_{\pm}A| : A \subseteq G, |A| = m\}.$$

While one might intuitively think that $\rho(G, m, h)$ is almost always smaller than $\rho_{\pm}(G, m, h)$, we find that for almost every abelian group G, and positive integers h and m, $\rho(G, m, h) = \rho_{\pm}(G, m, h)$.

218. Newman's conjecture for function field L-functions

David Mehrle Carnegie Mellon University
Advisor(s): Steven J Miller, Williams College

De Bruijn and Newman introduced a deformation of the Riemann zeta function $\zeta(s)$, and proved there is a real constant Λ which encodes the movement of the nontrivial zeros of $\zeta(s)$ under the deformation. The Riemann hypothesis is equivalent to $\Lambda \leq 0$, but Newman conjectured that $\Lambda \geq 0$. Andrade, Chang, and Miller extended the machinery developed by Newman and Polya to L-functions for function fields. Here we consider a modified Newman's conjecture: $\sup_{f \in \mathcal{F}} \Lambda_f \geq 0$, for $\mathcal{F}$ a family of L-functions. We prove this modified Newman's conjecture for several families of L-functions. In contrast with previous work, we are able to exhibit specific L-functions for which $\Lambda = 0$, and thereby prove a stronger statement: $\max_{L \in \mathcal{F}} \Lambda_L = 0$. Using analytic techniques, we show a certain deformed L-function must have a double root, which implies $\Lambda = 0$. For a different family, we construct particular elliptic curves with $p + 1$ points over $\mathbb{F}_p$. By the Weil conjectures, this has either the maximum or minimum possible number of points over $\mathbb{F}_{p^{2n}}$. This tells us that the associated L-function satisfies $\Lambda = 0$.

219. Special Elasticity of Numerical Semigroups

Andy Fry Western Oregon University
Advisor(s): Vadim Ponomarenko, San Diego State University

A numerical semigroup is an additively closed subset of the nonnegative integers. Any numerical semigroup is generated by irreducible elements (elements that can't be written as a sum of two nonzero elements). Each non-irreducible element can be factored as a sum of irreducible elements, though these factorizations are generally not unique. In factorization theory, invariants are often used to measure the non-uniqueness of factorizations within a given monoid. One such invariant is special elasticity, which compares the factorization lengths of certain elements. In this project, we investigate the extremal cases of specialized elasticity, and characterize which semigroups with exactly three irreducible elements have minimal special elasticity.

220. Moduli Space of Heron Triangles

Jason Murphy University of California, Santa Barbara
Advisor(s): Jordan Schettler, University of California, Santa Barbara

We present an invariant, called k^2, associated to elliptic curves over the complex numbers. Like the well-known j-invariant, the k^2-invariant can be regarded as a function on the complex upper half plane, and, as such, it is modular with respect to the congruence subgroup $\Gamma_0(3)$. In fact, k^2 generates the function field of the associated modular curve $X_0(3)$. Certain rational values of k^2 come from elliptic curves which parameterize Heron triangles with fixed inradius. Thus, we relate special analytic properties of k^2 and the field theoretic properties of the function field of $X_0(3)$ to the geometry of Heron triangles. We present an analogous set of results for an invariant whose rational values come from a family of elliptic curves which parametrize hyperbolic Heron triangles with fixed inradius.

221. Delta Sets of Numerical Semigroups

Zofia Stanley Stanley Brown University
Advisor(s): Vadim Ponomarenko, San Diego State University

A numerical semigroup S is a subset of the non-negative integers which is closed under addition and has a finite complement in $\mathbb{N}$. A factorization of an element in S is a linear combination of the generators with non-negative integer coefficients; the length of this factorization is the sum of the coefficients. The length set of an element is the set of lengths of all factorizations of this element, and the delta set is the set of differences between consecutive elements of the length set. We define the delta set of the semigroup to be the union of delta sets of all elements of S. It is known that semigroups which are generated by arithmetic progressions have delta sets which contain exactly one element, namely, the step size of the progression. Through the use of mathematical software and algebraic calculations, we examine semigroups which are generated by subsets of arithmetic progressions and determine when the delta set contains exactly one element. We establish a lower bound for the number of generators which must be removed from an arithmetic progression in order to alter the delta set. We also determine when a numerical semigroup with three generators has a delta set of size one.

222. An Exploration of Subsequences of the Fibonacci Sequence and their Applications to Cryptography

Yi Wang Millburn High School
Advisor(s): Aihua Li, Montclair State University

The subset-sum problem has widespread applications, including but not limited to the design of knapsack cryptosystems. In this paper, I investigate various superincreasing subsequences of the Fibonacci sequence applied to this problem and search for patterns that arise, involving what types of numbers can and cannot have solutions.

223. Counting The Number of Real Roots of Random Polynomials

Joseph Cleveland Sam Houston State University
Jeffrey Dzugan Samford University
Anthony Morse
Taylor Schlenk
Advisor(s): Dhagash Mehta, University of Notre Dame

Though solving high degree univariate random polynomials and determining the precise real roots out of all the roots are some of the most important problems in mathematics, science and engineering, it has remained a highly challenging problem in computational mathematics. By combining an efficient implementation of the Lindsey-Fox algorithm that can compute roots of high degree univariate random polynomials and Smale's alpha theorem which can certify if a given numerical root in the quadratic convergence region of a nearby exact solution, we obtain the certified real roots and certified counting of the number of real roots of the polynomials.

224. The Modified Galerkin Method for the Modified Wave Equation for the Shape of Biconcave Disk (Bloodcell)

Jill Resh Roger Williams University
Advisor(s): Yajni Warnapala, Roger Williams University

The objective of this work was to find a numerical solution for the Dirichlet problem for the Helmhloltz for a smooth biconcave disk. The biconcave disk is a shape that is controlled by one parameter. There are some numerical issues in this type of analysis; any integration method is affected by the wave number, k, because of the oscillatory behavior of the fundamental solution. I significantly reduced the number of terms in the infinite series needed to modify the original integral equation and use the Green's Theorem to solve the problem on the boundary of the surface. One practical value of this computation can be getting a shape for a part of a space shuttle that one day might go to planet Mars.

225. Applications and mathematical challenges of digital image mosaicking

Erika Ordog Pepperdine University
Hanna Kristensen Pepperdine University
Advisor(s): David Strong, Pepperdine University

We have created an automatic algorithm that creates a mosaic of user-supplied digital images to reproduce a user-supplied single larger digital image. In creating the mosaic of smaller images to reproduce the larger image, the

simplest approach in selecting which image to place in each larger image pixel location is simply to select the one image of all smaller images whose overall color or grayscale levels best matches that of the larger image at that pixel location. However, for a higher quality result, other additional considerations and issues arise, including: reshading of the smaller images to better match the color or grayscale value at each large image pixel location; how to best reproduce essentially solid (constant-valued) areas in the larger image; creating more smoothness between smaller images in the mosaic for a more visually pleasing large image; ensuring that all of the smaller user-supplied supplied images are used at least once in reproducing the larger image, or possibly using all of the smaller images essentially an equal number of times; and numerical issues such as image and integer types in working in Matlab. Our work thus far has focused primarily on grayscale images and is the foundation of our ongoing work with color image mosaicking.

226. Boundary value problems for a self-adjoint Caputo nabla fractional difference equation

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Lydia DeWolf Union University
Liam Mazurowski Carnegie Mellon University
Tim Rolling University of Nebraska-Lincoln
Dominic Veconi Hamilton College
Advisor(s): Al Peterson, University of Nebraska-Lincoln

In this paper we develop the theory of initial and boundary value problems for a self-adjoint nabla fractional difference equation containing a Caputo fractional derivative that is given by

$$\nabla[p(t+1)\nabla_{a*}^{\nu}x(t+1)] + q(t)x(t) = h(t),$$

where $0\nu \leq 1$. We begin by giving an introduction to the nabla fractional calculus and then look at a certain type of initial value problem containing the Caputo fractional derivative. We investigate properties of the specific self-adjoint nabla fractional difference equation given above, where we show existence and uniqueness for both initial and boundary value problems. We introduce the definition of a Cauchy function which allows us to solve initial value problems, as well as the definition of a Green's function that allows us to certain boundary value problems. Finally, we look at various inequalities regarding the Green's function for a particular self-adjoint boundary value problem where $p(t) = 1$, $q(t) = 0$, and $h(t) = 0$.

227. Quantifying Limits on Replication, Death, and Quiescence of Mycobacterium tuberculosis in Mice

Margaret McDaniel University of Tennessee Knoxville
Winode Handagama Maryville College
Advisor(s): Vitaly Ganusov, Shigetoshi Eda, NIMBioS

According to the World Health Organization, an estimated 2.3 billion people are infected with *Mycobacterium tuberculosis* (Mtb). Current models for Mtb hold that the total bacterial burden approaches a static equilibrium during chronic infection. A recent study of Mtb-infected mice by Gill et. al used a mathematical model to show that bacterial replication and death rates do not necessarily remain constant. In our study, we extend this model by investigating the effects of a time-dependent segregation rate and the inclusion of quiescence for growth rates and bacteria counts. We address lingering questions related to Mtb pathogenesis, by developing a mechanistic model, to understand population of macrophages, bacteria, and the host immune response.

228. Economical Extremal Hypergraphs for the Erdős-Selfridge Theorem

Emily Heath Occidental College
Advisor(s): Eric Sundberg, Occidental College

A positional game can be thought of as a generalization of Tic-Tac-Toe played on a hypergraph (V, H). We study the Maker-Breaker game in which Maker wins if she occupies all of the vertices in an edge of H; otherwise Breaker wins. The Erdős-Selfridge Theorem, a significant result in positional game theory, gives criteria for the existence of an explicit winning strategy for Breaker for the game played on H. The bound in this theorem has been shown to be tight, as there are several examples of extremal hypergraphs for this theorem. We focus on the n-uniform extremal hypergraphs on which Maker has an economical (n-turn) winning strategy. We identify two equivalent criteria to classify these economical extremal hypergraphs.

229. Visualizing Dessins D'enfants

Mary Kemp Occidental College
Susan Maslak
Advisor(s): Naiomi Cameron, Lewis and Clark College

In this presentation, we will discuss the results of a summer research project motivated by the theory of dessins. Dessin is short for dessin d'enfant which means child's drawing. Mathematically speaking, a dessin is a connected bicolored graph where the edges around every vertex are cyclically ordered. Dessins can be realized by Belyi maps which are meromorphic functions $f : X \to \mathbb{P}^1(\mathbb{C})$ such that X is a Riemann surface and f is unramified outside $\{0, 1, \infty\}$. One of the goals of this project is to determine Belyi maps that realize a given loopless, connected bipartite graph on a compact Riemann surface X. We report on our considerations of certain classes of such graphs, explorations of computational methods for finding associated Belyi maps and related applications.

230. Pattern Avoidance in Double Lists

Frehiwet Negassi Saint Joseph's College
Advisor(s): Lara Pudwell, Valparaiso University

Originally motivated by sorting algorithm discrepancies in computer science, pattern avoidance is a rapidly-growing area of combinatorics. In particular we study pattern avoidance in restricted forms of a word, i.e. a sequence of positive integers. The poster will offer an introduction to the topic of pattern avoidance in double lists. Results for enumeration of double lists of length n which avoid nontrivial patterns up to length 4 are presented.

231. Mixed Smiles: An Analysis of the Coherence Between Experiential and Behavioral Response During Ambiguous Emotional Stimuli

Marina Massaro State University of New York College at Geneseo
Advisor(s): Charles Collins, University of Tennessee, Knoxville

In 1971, Paul Ekman published that the six basic emotions (anger, happiness, surprise, disgust, sadness, and fear) have distinct, universal facial expressions. Past studies confirm that high levels of coherence exist between emotional experience and facial expression when subjects are shown poignant film clips. But what happens to the tie between emotional experience and facial response when the eliciting event isn't purely of one sentiment? In this study, data collected from video recordings of individuals watching ambivalent film clips are used to examine the relationship between emotional experience and facial response when mixed emotion is elicited. Cross-correlations between data sources measuring positive and negative emotional response indicate low to moderate amounts of coherence between response systems. Contributors to coherence are being investigated, including the degree to which emotion is "mixed" at a given time, individual personality characteristics, and attitude toward various emotions. Furthering the understanding of response coherence and mixed feelings will shed light on various psychiatric disorders, where emotional dysfunction skews the normal emotional experience and response.

232. Coloring Techniques for Pattern Avoidance over an Infinite Sequence

Paula Egging Benedictine College
Robert Laudone Boston College
Amanda Owens McDaniel College
Advisor(s): David Milan, University of Texas at Tyler

We investigate Grytzcuk's conjecture and extend the entropy compression method to prove that long-square-free sequences (length ≥ 6) can be chosen from lists of size 3. Within this proof we utilize and independently discover a bijection between plane trees and difference sequences (sequences of integers generated when running an algorithm). We also investigate Ω Sets, utilizing new strategies to surpass the results of entropy compression. We then expand known work on shuffle squares to apply to shuffle long-squares and provide a general formula for further expansion.

233. Elliptic Curve Cryptography

Samantha Sprague Marist College
Advisor(s): Joseph Kirtland, Marist College

An elliptic curve E is the set of solutions to an equation of the form $y^2 = x^3 + Ax + B$ where the constants A and B satisfy $4A^3 + 27B^2 \neq 0$. The collection of points on E, with coordinates in $\mathbb{F}_p$, along with the point at infinity $\mathcal{O}$,

form the group $E\left(\mathbb{F}_p\right)$ which is of interest in cryptography. This poster will present how $E\left(\mathbb{F}_p\right)$ can be used to create a secure public-key cryptosystem.

234. Inverses and Invariant Subspaces for a Certain Non--self-adjoint $n \times n$ Toeplitz

Zach Walter Butler University
Advisor(s): William Johnston, Rebecca Wahl, Butler University

For any size n, when $[a_{r-c}]$ is $c - r - 1$, for $c\,r$, and $c - r + 1$ for $c \geq r$, each corresponding $n \times n$ non–self-adjoint Toeplitz matrix turns out to have a remarkably simple inverse with only six distinct nonzero entries. This result is new, and it points toward fruitful investigation into a broader category of non–self-adjoint Toeplitz matrices, which this poster will also describe. The inverse also exhibits a pattern, no matter what size n. This poster explicitly describes each inverse, giving a formula for each of the inverses' entries, no matter what size n. It also explains why the calculation of this inverse is not trivial. Finally, it exhibits all of the invariant subspaces for these matrices, no matter what size n, in terms of the corresponding lattice diagram.

235. Explicit Bounds for Matrix Pseudospectra

Jeremy Meza Carnegie Mellon University
Abigail Ward The University of Chicago
Olivia Meyerson Williams College
Advisor(s): Mihai Stoiciu, Williams College

We study the ϵ-pseudospectra $\sigma_\epsilon(A)$ of square matrices $A \in \mathbb{C}^{N\times N}$. We give a complete characterization of the ϵ-pseudospectrum of any 2×2 matrix and describe the asymptotic behavior (as $\epsilon \to 0$) of $\sigma_\epsilon(A)$ for any square matrix A. We also present explicit upper and lower bounds for the ϵ-pseudospectra of bidiagonal and tridiagonal matrices, as well as for finite rank operators.

236. Pattern Avoidance in Forests

Peter Nugent University of Wisconsin Eau Claire
ML Tlachac University of Wisconsin-Eau Claire
Derek Levin University of Wisconsin-Eau Claire
Advisor(s): Manda Riehl, University of Wisconsin Eau Claire

Pattern avoidance in permutations is a growing research specialty, and we widen its application to forests. An increasing forest is a collection of t trees where each of the trees has v labels, and every path from root to leaf is an increasing sequence of labels. These forests contain associated permutations which are found by conducting a depth first search on each tree from left to right, starting at the root and moving left to right by level. We enumerate pattern avoidance classes within the permutations associated to these forests and create bijections to other combinatorial objects. We have a bijection from forests avoiding the pattern 123 to the set of paths loosely under the line $y = vx$ from $(0, 0)$ to $(t, tv - t)$ using vertical steps $(0, 1)$ and horizontal steps $(1, 0)$. Additionally, the number of forests of n increasing 2-node trees avoiding 321 is the same as the number of 321-avoiding ordered set partitions of $\{1, \ldots, 2n\}$ where all blocks are of size 2. We also found that the number of 321 avoiding binary forests with 2 trees is given by $\binom{2n}{n}$. Lastly, in unary forests where each tree has 2 nodes, there is a bijection between forests avoiding each of the patterns 132, 213, 312, and 231.

237. Diagrammatics of Coxeter and Braid Groups

Uma Roy MIT PRIMES
Niket Gowravaram MIT PRIMES
Advisor(s): Alisa Knizel, Massachusetts Institute of Technology

Elias, Khovanov and Williamson recently developed a diagrammatic language to attack many problems of current interest in representation theory. We examine using diagrammatics, a problem related to the $K(\pi, 1)$ conjecture for braid groups, which we refer to as the $K(\pi, 1)$ conjecturette, and an analogous problem for Coxeter groups. Given a Coxeter or braid group, one can form a family of colored planar graphs based on the generators and relations of the group, which we refer to as diagrams. Two diagrams are considered homotopic if one can be transformed into the other through a series of allowed transformations. For braid groups, proving that any diagram is homotopic to the

empty graph is equivalent showing that π_2 of the associated Salvetti complex is trivial, which is a part of the $K(\pi, 1)$ conjecture. For Coxeter groups, proving that any diagram is homotopic to the empty diagram is equivalent to showing that π_2 of a cell complex introduced by Elias and Williamson is trivial. We present a diagrammatic proof of the $K(\pi, 1)$ conjecturette for a family of braid groups as well as analogous results for several families of Coxeter groups.

238. SmarTrAC: Activity Detection with Smartphone Sensor Data

Bryan Martin Macalester College
Anya Phillips Macalester College
Mitchell Kinney University of Iowa
Heather Berlin Washington University in St. Louis
Lindsey Schadler Shippensberg University
Advisor(s): Vittorio Addona, Macalester College

As smartphones become more prevalent in everyday society, their technology can be harnessed for new purposes. Our research develops a model for SmarTrAC, an android application that uses smartphone GPS and accelerometer data to more fully understand how the urban population travels. Our problem is activity detection; we want the application to determine, in real time, which mode of transportation is currently being used without the smartphone user using manual inputs. In order to accomplish this, we collected training data and analyzed it for descriptive features. We then utilize machine learning modeling techniques, focusing on decision trees and random forests. Our final models achieve accuracies ranging from approximately 90% to 94%.

239. Tauer of Terror: Not as Scary as One Might Think

Elizabeth Matys Gettysburg College
Advisor(s): Béla Bajnok, Gettysburg College

Given a subset A in a finite abelian group G and a positive integer h, A is zero-h-sum-free if the signed sum of any h (not necessarily distinct) elements in A is never equal to zero. Working in $\mathbb{Z}_n$, we explore the maximum zero-h-sum-free set size over the set of all integers for odd h. That is, the quantity defined as

$$\tau_{\pm}(\mathbb{Z}_n, h) = \max\{|A| \mid A \subseteq \mathbb{Z}_n, 0 \notin h_{\pm}A\}$$

We establish the value of $\tau_{\pm}(\mathbb{Z}_n, h)$ for all even n and construct two lower bounds where n is odd. We also determine the value for some cases of prime n.

240. On the Minimum Size of Spanning Sets in Cyclic Groups

Tyler Reckner Gettysburg College
Advisor(s): Bela, Bajnok

A subset A of a finite Abelian group G is said to span G if the h-fold span, $h_{\pm}A = \{\lambda_1 a_1 + \lambda_2 a_2 + \cdots + \lambda_m a_m : |\lambda_1| + |\lambda_2| + \cdots + |\lambda_m| = h\}$, is equal to G. Here, we are interested in the minimum size of such a spanning set for cyclic groups $\mathbb{Z}_n$. This quantity is denoted $\phi_{\pm}(\mathbb{Z}_n, h)$. We discuss several conditions on positive integers h and m for which $\phi_{\pm}(\mathbb{Z}_n, h) = m$ for small values of m, offering both foundational propositions and new results.

241. Uptake, Translocation, and Stress Effects of Carbon Nanotubes in Drought Induced Corn

Sabrina Deleon Texas Tech University
Advisor(s): Jaclyn Canas-Carrell, Texas Tech University

Carbon nanotubes are one of the most used manufactured nanomaterials. However, these materials are not regulated and there are concerns regarding their behavior in the environment and human health. This study was conducted to evaluate uptake of various types of carbon nanotubes in corn under ideal watering and drought conditions. Corn was exposed to either non-functionalized carbon nanotubes (CNTs) or functionalized carbon nanotubes (COOH-CNTs). Plants were grown for 21 days in soil with 10 mg/kg of CNTs or COOH-CNTs in 1 L or 3 L of soil in a greenhouse with natural day:night conditions. Corn was also grown under conditions simulating a seven-day drought and photosynthesis measurements were taken using a LI-6400XT Portable Photosynthesis System. Following harvest after 28 days, roots, stems, and leaves were dried, grounded, and analyzed using a microwave-induced heating technique to quantify CNT and COOH-CNT concentrations in the corn. Photosynthetic rate declined throughout the duration of the drought

treatments. CNT uptake was only detected in roots of drought-treated plants exposed to CNTs and COOH-CNTs. Additional plant analyses are currently ongoing.

242. Investigating Properties of $Cay(\mathbb{Z}, \{\pm 2^k\})$ and $Cay(\mathbb{Z}, \{\pm 3^k\})$

Daniel Gulbrandsen Utah Valley University
Advisor(s): Violeta Vasilevska, Utah Valley University

Richard E. Schwartz [1] posed the following problem: Are the Cayley graphs $C_2 = Cay(\mathbb{Z}, \{\pm 2^k\})$ and $C_3 = Cay(\mathbb{Z}, \{\pm 3^k\})$, for $k = 0, 1, 2, \ldots$, quasi-isometric? Moon Duchin and Bryan White [2] have shown that C_2 and C_3, with the associated word metric, are not quasi-isometric under the identity map. In this presentation we further investigate this problem. Namely, a particular class of maps will be considered and proved that these maps are not quasi-isometries between C_2 and C_3. In addition, properties known to be quasi-isometric invariants, such as hyperbolicity and metric ends, are studied. It will be shown that these properties cannot be used to determine if C_2 and C_3 are quasi-isometric. Further work will also be discussed. Joint work with Daniel Adams and Kristen Smith.

1. Melvyn B. Nathanson, Bi-Lipschitz Equivalent Metrics on Groups, and a Problem in Additive Number Theory. 18 Feb. 2009
2. Moon Duchin, Bryan White. Two presentations of $\mathbb{Z}$ that are not Quasi-Isometric. (preprint)

243. An Algorithm for Maya Division

Nicholas Heil Millersville University of Pennsylvania
Advisor(s): Ximena Catepillan, Millersville University of Pennsylvania

The ancient Maya civilization, which began ca. 1200 BC, had a long history divided into three periods. These people were sophisticated astronomers who developed a positional number system with base twenty along with the concept of zero. They used this system to build their roads, construct monumental architecture, and carry out astronomical computations. This vigesimal system used bars and dots to represent numbers and carry out the four basic operations with whole numbers. There is research on processes for addition, subtraction, and multiplication; however, there is limited information for how division was performed. In this presentation a new model for division, using repeated subtraction and multiplication, is explained. The process was made simpler by using a Maya multiplication table. The spatial aspect of the division algorithm was expanded to include columns for current product, partial working quotient, and partial final quotient.

244. Graphs, Probability, and Separating Families

Luke Serafin Carnegie Mellon University
Daniel Condon Georgia Institute of Technology
Cody Stockdale Bucknell University
Advisor(s): Samuel Coskey, Boise State University

Suppose we have a herd of cows, one of which has an illness that can be detected by means of a blood test. We want to determine which cow is sick using as few simultaneous tests as possible; this is an example of a combinatorial search problem. We can solve our problem by using a separating family to ensure each cow goes through a unique series of tests. In addition to combinatorial search, separating families and related concepts have applications to digital fingerprinting, cryptanalysis, coding theory, and related fields. Our project focuses on generalizations of separating families. In particular, we define the concept of an n-separating family, which simultaneously separates all collections of n pairs which are in fact separable. To facilitate use of this definition, we give a graph-theoretic characterization of separability. Finally, we use the nonconstructive probabilistic method to compute bounds on the minimal size of n-separating families.

245. Can Governments Curb Bitcoin? How Regulation Affects Virtual Currency

Connor Kispert Rose-Hulman Institute of Technology
Advisor(s): Wayne Tarrant, Rose-Hulman Institute of Technology

One of the most notable qualities of Bitcoin is its decentralized nature and disconnect with banking and regulatory systems. However, recent government bans and regulations on the virtual currency are being linked to the current downward trend of Bitcoin. Most notably was the drastic falloff in December of 2013 which began immediately after

China introduced new regulations on the currency. In this paper, we look at whether or not government regulations can have a significant effect on the trend of Bitcoin in terms of both its price and volatility. By analyzing trends surrounding the event window of the introduction of new regulations on Bitcoin by a national government, we can measure if there is any significant change in trend for either measure. By answering whether or not a government's regulations can have substantial influence over Bitcoin, we can give insight as to whether a decentralized virtual currency could have sustained success or stability.

246. Solving Rubik's Revenge

Kyle Lewis Coastal Carolina University
Advisor(s): Thomas Hoffman, Coastal Carolina University

In this poster presentation, we find the average number of moves to solve a 4×4 Rubik's Cube. To solve this puzzle, a personal algorithm is used in a computer program that will keep track of the number of moves being made. The program ran ten thousand times for an accurate average. The presentation will also give a brief explanation of the algorithm and a comparison to the 3×3 algorithm.

247. 3D Printing and Its Uses in Super-Computing Clusters

Cody Stafford Texas Tech University
Advisor(s): John Carrel, Texas Tech University

In this project, the Texas Tech University Department of Mathematics is working closely with the Department of Industrial Engineering to build, modify, and test a "homemade" 3D printer. This printer will be used to prototype and assemble custom parts for the Schoenberg high performance computing cluster, these parts will allow for full customization of the cluster. Also the 3D printer will be used as a promotion tool for STEM education by showing prospective students how Mathematics and Engineering majors can work together on a project. The poster will cover the involvement of an undergraduate student in the assembly of the 3D printer and Computer Aided Drafting/Computer Aided Manufacturing (CAD/CAM) of prototyped parts. In addition, the poster will show how the parts produced will be used to customize the Schoenberg cluster.

248. Bathtub and Unimodal Hazard Flexibility Classification of Parametric Lifetime Distributions

Dana Lacey North Central College
Anh Nguyen Texas Christian University
Advisor(s): Kahadawala Cooray, Central Michigan University

There are a number of bathtub and unimodal hazard shape parametric lifetime distributions available in literature. Therefore, it is important to classify these distributions based on their hazard flexibility to facilitate their use in applications. For this purpose we use the Total Time on Test (TTT) transform plot with two different criterion: I. measure the slope at the inflection point on the scaled TTT transform curve; II. measure the slope at selected points from the constant hazard line on the scaled TTT transform curve. We confine our research to classify the flexibility of Weibull extensions and generalizations and also select one-shape parameter lifetime distributions to exemplify the two criterion process.

249. Predictive Power of a Generalized Preventive Care Segmentation Model

Sirui Wang Cornell University
Ciaran Evans Pomona College
Parker Hund The University of Texas at Austin
Erics Varley St. Olaf College
Advisor(s): Matthew Willyard, The Pennsylvania State University

As the cost of healthcare rises, health insurance providers are encouraging their customers to take preventive actions against illness. Using data from a health insurance company, we built several models that predict if a customer will take preventive healthcare actions. Since contacting every customer can be very costly, insurance companies can use our predictive models to economically target their outreach to only customers who are likely to respond. We find that Chi-Squared Automatic Interaction Detection is best at predicting whether a customer will take a preventive action, and Random Forests using Conditional Inference Trees is best at predicting the number of these preventive actions.

250. Too Many Variables too Many Conclusions? Using Mahalanobis-Taguchi Analysis on Health Risk Factors

Sarah Appelbaum NYU Polytechnic School of Engineering
Advisor(s): Lindsey Van Wagenen, NYU Polytechnic School of Engineering

The Mahalanobis-Taguchi System (MTS) is a binary classification system that incorporates multidimensional statistics with industrial engineering practices to determine key variables. The Taguchi aspect of MTS allows us to simulate many different scenarios, maximizing the variety of variable combinations while minimizing computation time. MTS is particularly useful when there are large numbers of variables (e.g. medical applications) and it works with any type of distribution, yielding an ordered sequence of variables in terms of their influence on the multidimensional system. Many medical conditions result from a combination of factors (e.g., genetic, lifestyle) but can result in widely different prognoses. The genetic variables can differ in expression and thus contribute to different progressions of the condition. Environmental and lifestyle factors are thought to contribute to the severity of the condition and have become of great interest to researchers. Infertility is a prime candidate for analysis by MTS. The research conducted applied MTS to infertility patient data. This has the ability to correlate different lifestyle factors with genetic conditions to isolate the human factors at the root cause of infertility and thus improve patient treatment.

251. Estimation of Option Prices with Heston's Stochastic Volatility Model

Robin Dunn Kenyon College
Paloma Hauser The College of New Jersey
Tom Seibold Western Kentucky University
Advisor(s): Hugh Gong, Valparaiso University

An option is a security that gives the holder the right to buy or sell an asset at a specified price at a future time. The Black-Scholes model is the most widely used option pricing model, but it makes the strong assumption of constant volatility of the asset's price. This project focused on deriving and testing option pricing formulas for the Heston model, which treats volatility as a stochastic process. With the assistance of computational software, R and Maple, the method of moments estimated parameters of the Heston model. Historical option data provided a basis for comparing the estimated option prices from the Heston and Black-Scholes models. Based on root-mean-square error values, the Heston model provided more accurate option pricing estimates than the Black-Scholes model.

252. Mixing Times of Markov Chains

Matthew Sutter University of Michigan - Flint
John Rahmani Virginia Tech
Advisor(s): Peter Otto, Willamette University

The mixing time of a convergent Markov chain measures how fast it converges to its stationary distribution. The Rook's walk can be represented by a Markov chain that describes the motion of a Rook (chess piece) moving uniformly randomly on an $N \times N$ chessboard. The Restricted Rook's Walk is a variation on the Rook's Walk, but limiting the distance the Rook can move in a single step. We apply spectral and coupling methods in order to bound the mixing times of these two Markov chains, and explore asymptotic properties of these bounds.

253. The Probabilistic Change Point Algorithm

Marcus' Antonellis College of the Holy Cross
Advisor(s): Eric Ruddieri, College of the Holy Cross

While data sets have often been approximated through the usage of linear models, it is often inappropriate to use just a single line segment, especially when the data is expected to vary over time. Often a piece-wise function of multiple line segments is the proper solution, however deciding where to break up the model poses its own set of challenges. Possible solutions grow exponentially with the size of the data set and this makes finding the "right" change point very difficult. The analysis of these "change points" in a Bayesian setting was the intention of this study. A probabilistic model was developed for accurately predicting the location of change points. Using Bayes' rule suitable model parameters could be found and from that probabilities could be assigned to the suspected change point. These methods were all tested on temperature data sets provided by the NOAA on departures from long standing temperature averages the years 1880 to 2012. Moreover the probabilistic model that has been developed can be used to search for change points in a wide variety of data sets.

254. The Stock Price Effect of Apple Keynotes

Ethan Petersen Rose-Hulman Institute of Technology
Advisor(s): Wayne Tarrant, Rose-Hulman Institute of Technology

Apple's product announcements have been colloquially termed "Mini-IPOs" for their behavioral similarities to other companies' IPOs. Exploring this claim, I analyzed the volatility of Apple's stock beginning January 3, 2005 up to October 9, 2014, then focused on a range from 30 days prior to each product announcement until 30 days after the announcement. Product announcements were filtered; only announcements whose 60 day range was devoid of other events were used. This filtration was chosen to limit the potential cross-effect of a previous or upcoming announcement on each event. Analyzing the data within these ranges, there was a clear trend prior to Day 0 and significantly different trend after the event. To explore any confounding effects, a comparison to the VIX was made to determine if the changes in trends were simply following the market or were truly deviating from a trend. Again, these results showed significant activity around Day 0. We believe the findings from this study may raise concerns with the Efficient Market Hypothesis, providing an insight on how strongly this idea relates to activity surrounding Apple keynotes.

255. Topological Data Analysis — The Use of Non-Parametric Statistical Methods to Distinguish Between the Topologies of Data Sets

Joshua Kiers Taylor University
Christopher Cericola Seattle University
Advisor(s): Inga Johnson, Jordan Purdy, Willamette University

Homology is a well-established area of algebraic topology that can be used to distinguish between topological spaces. By forcing a parameterized topological structure on discrete data sets, features of homology within the data can be detected. As shown in a paper by Robinson and Turner, non-parametric statistical methods can then be employed on groups of data in order to distinguish them topologically in a meaningful way. This method of hypothesis testing is relevant and more insightful than established clustering methods when certain limitations are considered. The extensions and limitations of the method when applied to a variety of data sets are explored.

256. Chi-Squared Versus Fisher's Exact Test

Lillian Nicholson UNG
Advisor(s): Brad Bailey, University of North Georgia

When looking at Chi-Squared Test and Fisher's Exact test one may wonder where differences lie. We used a Maple procedure to look at all possible two-way tables for a pair of dichotomous variables to compute p-values for Fisher's exact test and chi-squared test of independence. From there, we sought to find answers involving the proportion for which the two tests disagree based on samples sizes 4-1,000. Also, we investigated, which of the two test proves to be more conservative. Through our research we will reveal the secrets to the relationship of the Chi-Squared Test and Fisher's Exact Test.

257. Understanding Neuroticism and its Mediation of Optimism

Samantha Hulsey University of North Georgia
Lillian Nicholson University of North Georgia
Advisor(s): Robb Sinn, University of North Georgia

Optimism is most commonly measured using the Life Orientation Test (LOT). To measure neuroticism, we used two surveys, a Likert scale instrument and a dichotomous scale, to demonstrate the how neuroticism mediates many correlates of optimism. The goal of this study is to explore the relationship between how neuroticism instruments measure optimism.

258. Modeling Related Failures of Vehicle Components using Bayesian Copula Selection

John Kumerow University of St. Thomas
Nicole Lenz University of St. Thomas
Katie Wifvat University of St. Thomas
Kelsie Sargent University of St. Thomas
Advisor(s): Arkady Shemyakin, University of St. Thomas

In the automotive industry it is important to know whether the failure of some car parts may be related to the failure of others. This project studies warranty claims data for five engine components obtained from a major car manufacturer

with the purpose of modelling the joint distributions of failure of two parts. The one-dimensional distributions of components are combined to construct a bivariate copula model for the joint distribution that enables us to estimate the probabilities of two components failing before a given time. Ultimately, the influence of the failure of one part on the operation of another related part can be described, predicted and addressed. The performance of several families of copula models (Clayton, Gumbel-Hougaard, Student) is analyzed, and Bayesian model selection is performed.

259. On the Probability of Weak Lattice Point Visibility

Rebecca Rachan North Central College
Advisor(s): Neil Nicholson, North Central College

A specifi c rectangular array of lattice points is investigated. We say that a point in the array is weakly visible from a lattice point not in the array if no point in the array lies on the line connecting the external point to any other point in the array. A necessary and su fficient condition for determining if a point in the array is weakly viewable by the external point, as well as the number of points that are weakly visible, is determined. From this, the probability that an external point can view a randomly chosen point in the array can be calculated.

260. Tug-of-war games with spatial and temporal dependence in noisy environments

Yair Shenfeld Massachusetts Institute of Technology
Advisor(s): Scott Sheffield, Massachusetts Institute of Technology

Zero-sum games called Tug-of-War games are known to give rise to solutions of differential operators such as the 'infinity Laplacian' if the movements of the players are deterministic and the p-Laplacian if the movements of the players are effected by noise. Recent works have investigated the types of PDEs that arise in games where the movements of the players are deterministic but the sets of possible movements depend on space and time in the domain of the game. The case where the movements of the players are spatially and temporally dependent and are also effected by noise which depends on time and space has not be treated in the literature thus far. We address this problem and find the PDE that arises out of this game. We also provide intuition about the form that the PDE takes and allude to possible real-world applications that follow from our analysis.

261. Scoring Cardiac Health: A Model of the Relationship between Diet and the Risk of Cardiovascular Disease

Matthew Miller Southwestern University
Advisor(s): Therese Shelton, Southwestern University

Like many other types of disease, cardiovascular diseases can be treated with a greater success rate the earlier that they are detected. For this reason medical researchers have long been developing means of detecting cardiovascular diseases earlier and earlier. Our goal is to develop a "scorecard" to measure cardiac health in the hopes of identifying cases of serious cardiovascular disease earlier. To this end we compiled the diet and health profiles of patients who came to an emergency room complaining of chest pains and have begun to study them for relationships between diet and other factors and the patients' outcomes. Those who chose to participate were asked to complete a food frequency questionnaire, and their doctors completed surveys about the health profiles of the patients. From the results of the questionnaire, we measured the subjects' diet compositions in terms of five nutrients: protein, carbohydrates, fat, fiber, and total caloric intake. We will apply regression analysis to measure the relationships between those nutrients and certain risk factors for cardiovascular disease. We intend for the scorecard to also be used to measure general cardiac wellness.

262. Knot Depth for Positive Braids

Patricia O'Brien The University of Texas at Austin
Elliot Kaplan Ohio University
Advisor(s): Teena Gerhardt, Michigan State University

Given a projection of a knot, one can alter it at a crossing using what is called the *oriented skein relation*. This relation takes this projection, and considers instead the two new knot projections which result by (a) changing which strand in the crossing is on top, and (b) removing the crossing in a way consistent with the orientation. The depth of a knot is essentially the minimal number of levels in a resolution tree for that knot using the oriented skein relation. The depth of

a knot is related to the complexity of the knot's Alexander polynomial and, more generally, any polynomial invariant which satisfies the skein relation. Every knot can be represented by a word in a group called the braid group. We study the depth of knots representable by positive braids—a class including all torus knots and links. We have proven that the depth of a knot represented by a positive braid is $\ell - w + 1$, where ℓ is the length of the braid word and w is the number of strands in the braid.

263. Quandles of Virtual Knots

Sherilyn Tamagawa Scripps College
Advisor(s): Sam Nelson, Claremont McKenna College

Knot theory is an important branch of mathematics with applications in other branches of science. In this poster, we explore invariants on a special class of knots, known as virtual knots. We find new invariants by taking quotients of quandles, and introducing the fundamental Latin Alexander quandle and its Gröbner basis. We also demonstrate examples of computations of these invariants.

264. Bounds for self-intersection numbers of closed curves on the 2-Punctured Plane

Cameron Thieme University of Southern California
Advisor(s): David Crombecque, University of Southern California

The homotopy classes of closed curves on a topological space form a group called the fundamental group. The fundamental group of the 2-punctured plane is free on two generators, where each generator is a simple closed loop around a puncture. In this project, we address the problem of finding the minimum number of self-intersections of these loops up to homotopy equivalence. In 2010, M. Chas & A. Phillips approached this same problem and provided a bound for any element in the group. Although this bound is powerful because of its generality, often it is also very wide. By constructing some algorithms, we were able to improve these bounds for two types of elements in the fundamental group.

265. Closing Open Knots with Random Equilateral Polygons

Nicole Lopez University of St. Thomas
Madeline Shogren University of St. Thomas
Advisor(s): Eric J. Rawdon, University of St. Thomas

The recent discovery of knotting behavior in proteins has stimulated discussion about how to classify knots in open chains. Topology is trapped in closed curves, so it is possible to study the knotting mathematically. Therefore, in order to study and better understand the knotting patterns in open chains, their endpoints must first be connected to create closed knots and make it possible to identify and classify the knots embedded within them. The purpose of this project is to analyze and compare two methods used to classify knots in open chains. The first method draws from a previous project and closes knots by extending rays from the endpoints out to infinity and then connecting them. The second method closes equilateral open chains using random equilateral arcs. This process utilizes closure arcs that are 1, 2, and 3 times the length of the missing edges in the open chain. Varying closure lengths more closely resembles real-life applications. The two methods are compared by applying each to the same set of open chains and analyzing their classifications. This project develops efficient processes for all methods and compares them to determine the most precise method for classifying an open knot.

266. Distinguishing Colored Links

Grant Roth University of Wisconsin-Eau Claire
Advisor(s): Christopher Davis, University of Wisconsin-Eau Claire

A link is an array of circles with various numbers of twists in space which never cross each other. To give a better picture, one should imagine a collection of strings tangled up with their ends fused together. Classically in link theory, tools were studied which treat all of these strings the same. The recent idea of coloring the components of links has spawned a collection of new tools which do distinguish the components. Using these tools we construct examples of links whose components cannot be interchanged, but which are elementary in the sense that if a single string is removed then the link comes undone. This work represents an ongoing project.

267. Knot Invariants from Spanning Surfaces for a Two-Bridge Knot

Vincent Longo The College of New Jersey
Advisor(s): Cynthia Curtis, The College of New Jersey

The Alexander polynomial of a knot is one of the most well known and useful knot invariants in the field of Knot Theory. One way of finding the Alexander polynomial of a knot is by constructing a matrix using the unique orientable surface bounded by the knot, and taking the determinant of that matrix. We present an extension of this notion for non-orientable surfaces bounded by a knot by defining the State polynomials of a two-bridge knot. We then present some of the properties shared by the State polynomial and Alexander polynomial, along with some notable differences between the two.

268. Knot Colorings and Dimer Graphs

Maisie Newman Washington College
Advisor(s): Heather Russell, Washington College

A central question in knot theory is whether two knot diagrams represent the same knot. We can answer this question with invariants: specific quantities assigned to knots that are the same for isotopic knots. In 1956, Fox defined n-Fox coloring of knot diagrams as a way to get new invariants. We introduce a new—but related—method to color knot diagrams called face coloring. One can construct a matrix that encodes a knot's face coloring data. When a knot is alternating, there is a way to build a planar bipartite graph from this matrix. Kasteleyn theory provides a framework for obtaining matrix data from a graph. We apply Kasteleyn theory to our specific class of graphs in order to more efficiently find data about face coloring and more directly relate this data to a knot's structure.

269. Defining Virtual Rational Tangles

Ellen Lehet SUNY Potsdam
Advisor(s): Laura Person, SUNY Potsdam

The concept of virtual crossings was first introduced in Kauffman's paper, "Virtual Knot Theory." These virtual crossings differ from classical over-under crossings because the two strands involved co-exist in the same space. For this reason, virtual crossings and virtual knots do not exist in physical world. These virtual structures can be studied along with the classical structures and often have comparable properties. This project discusses the investigation of virtual crossings when they are considered in rational tangles. Previously, there has not been very much study of virtual rational tangles and so the goal of this research is to define virtual rational tangles along with identify properties of virtual tangles. The majority of this project has been inspired by Kauffman's paper about rational tangles, "On the classification of rational tangles" and involves drawing comparisons between the classical tangles Kauffman describes and the idea of virtual rational tangles. These properties include an extension of the continued fraction form, methods and properties for adding and multiplying tangles, and identifying matrix and fraction invariants.

270. Non-left-orderable surgeries on twisted torus knots

Justin Goluboff Columbia University
Katherine Christianson Columbia University
Srikar Varadaraj Columbia University
Linus Hamann Columbia University
Advisor(s): Jennifer Hom, Columbia University

Boyer, Gordon, and Watson have conjectured that an irreducible rational homology 3-sphere is an L-space if and only if its fundamental group is not left-orderable. Since large classes of L-spaces can be produced from Dehn surgery on knots in the 3-sphere, it is natural to ask what conditions on the knot group are sufficient to imply that the quotient associated to Dehn surgery is not left-orderable. Clay and Watson develop a criterion for determining the left-orderability of this quotient group in and use it to verify the conjecture for surgeries on certain L-space twisted torus knots. We generalize a recent theorem of Ichihara and Temma to provide another such criterion. We then use this new criterion to generalize the results of Clay and Watson and to verify the conjecture for a much broader class of L-space twisted torus knots.

271. A reduced presentation of the virtual singular braid monoid

Andrew De la Pena California State University, Fresno
Sarah McGahan California State University, Fresno
Advisor(s): Carmen Caprau, California State University, Fresno

A braid is a set of n strings passing between two horizontal bars. These strings may interact with one another but must always travel in the downward direction. If the two horizontal bars are brought together and each pair of string ends are glued together in order, the resulting structure will be a knot or a link, called the closure of the braid. The focus of our research has been to study the set of braids whose closure is a virtual singular knot or link. We define the set of virtual singular braids on n strands as a monoid via generators and relations. The defining set of relations mimic the isotopies of virtual singular links. Further we prove that the virtual singular braid monoid has another presentation using fewer generators and relations.

272. The Three-Variable Bracket and Tutte Polynomial

Maggie Miller University of Texas at Austin
Advisor(s): Rolland Trapp, California State University San Bernardino

Kauffman's three-variable bracket for a knot diagram and the Tutte graph polynomial are highly related. In this poster, we derive an expression for each coefficient of the three-variable bracket for an alternating diagram in terms of the Tutte polynomial of the checkerboard graph. We use this relation to recover twist number of two-bridge links and alternating three-braid links from the three-variable bracket. We also show that we may almost recover the number of crossings in each twist from the three-variable bracket.

273. Harmonic Nine Crossing Knots

Rebecca Miller Carthage College
Advisor(s): Aaron Trautwein, Carthage College

A knot is an embedding of the unit circle into real three-space. Harmonic knots are defined as trigonometric polynomial parameterizations of the unit circle. In this poster we construct harmonic nine crossing knots. To construct harmonic knots we created a program in Mathematica that uses truncated Fourier series to approximate linear functions representing the paths of polygonal knots. Harmonic representations of knots are used to define knot invariants including the harmonic index. The harmonic index of a knot is the minimum integer n such that there is an nth degree harmonic parameterization of the same knot type. Previous research found the harmonic parameterizations of knots types up through eight crossing knots. The parameterizations presented in this poster are used to determine upper bounds for the harmonic index of each nine crossing knot. These parameterizations also aid in the research of new knot invariants by providing more examples of harmonic representations.

Index