The Twenty-First Annual Nebraska Conference for Undergraduate Women in Mathematics

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POSTER ABSTRACTS

Posters by Undergraduate Students

Eva Anderson, Saint Mary's College
Mathematical Modeling and Computer Simulation of Effective Diffusivity of Nicotine

Mathematical concepts and formulations of skin and its permeability play a vital role in a variety of biomedical fields such as the forecasting of transdermal drug distribution and contact with various toxins. Mathematical modeling can be used to build off existing theoretical models of skin's structure to better illustrate and describe diffusion behavior in the skin. Through our analysis, we attempted to find the most important parameters of the effective diffusion process in human skin and apply these to the calculation of a diffusion process using partial differential equations. This process was solved using the necessary initial and Dirichlet boundary conditions to investigate the effective diffusivity and concentration profiles across the skin. The computer programs MATLAB and COMSOL were used to provide further visual illustration of the process.

Mayra Banuelos, San Francisco State University
Analyzing CODIS Loci STRs and Their Relationship to Gene Expression in Two Datasets

The CODIS Loci STRs are short tandem repeats (STRs) adopted by the FBI around 1996 to be used as forensic identification markers. Since the primary use of these markers is individual identification, the CODIS STRs are thought not to reveal any other genetic information (particularly medical information) outside their use in forensics. We know, however, that the change in length of STRs can alter phenotypes and expression levels in certain genes. In this study, we isolate the CODIS STRs and analyze the correlations between their lengths and gene expression levels. Our initial analysis showed no standout patterns of correlation at the genome-wide level. Therefore, we looked at genes within 100kb of distance of each STR. In the next phase of the study, we expanded the analysis to a larger set of data utilizing the 1000 Genomes Project dataset. While we expect to find similar results as with the HGDP dataset, I will be presenting an updated summary of findings at the time of the conference.

Danielle Barna, Colorado School of Mines
Detecting Backcountry Avalanches in the Teton Range with Synthetic Aperture Radar

Backcountry avalanche activity represents a significant gap in many avalanche centers' databases. The location and timing of events in the backcountry are difficult to determine using current field-based methods; while data gathered from field expeditions is reliable, it tends to be skewed toward easily observable events in good weather. This gap makes carrying out statistically meaningful analyses for the broader region quite difficult. Applying remote sensing techniques–specifically Synthetic Aperture Radar (SAR) imaging–to the Teton backcountry has the potential to bolster avalanche event data and provide a more comprehensive picture of the region. Using data from the Sentinel 1A and 1B satellites we manually detected a large avalanche in the Tetons that occurred February 2017 and applied clustering techniques to the data to explore automated avalanche detection.

Sydney Benson, University of St. Thomas
Getting More from Generalized Linear Mixed Models in R

In the case of non-normal response variables or where correlated data are present, generalized linear mixed models are often preferable and can be created using the R package glmm. Most recently, the abilities of this R package were expanded to decrease the computational expense of model-fitting through parallel computing, executing calculations simultaneously instead of sequentially. This package uses Monte Carlo likelihood approximation, an iterative importance sampling procedure that estimates the true parameters of a model. Therefore, decreasing the computational expense of the command allows the user to increase their Monte Carlo sample size, giving more accurate estimates without increasing the model-fitting time.

Julie Bittner, Concordia College
Rebecca Twait, Concordia College
The Traveling Salesman: Optimizing Concert Tours

The Traveling Salesman Problem (TSP) requires that each city in a given list is visited once and only once before returning back to the starting location. Parameters such as time windows and distances placed on this problem quickly increase the complexity of a TSP. In this research, we explored algorithms used to find optimal tours and studied existing code that found tours given availability, travel, and time constraints. We then adjusted the code to make it more applicable to problems with differing constraints, including those with and without availability requirements. Specifically, we modified the code to find possible tours for two different scenarios involving cities across the United States and one scenario involving European cities.

Julia Bohman, Brigham Young University
Using Network Similarity with Machine Learning to Predict Group Formation and Movement

A useful problem to consider in network theory is network (graph) similarity. We explore how network similarity can be used in machine learning algorithms to predict group formation and movement, focusing on the movement of baseball players between teams.

Laney Bowden, Colorado State University
Ellie Lochner, University of Wisconsin-Eau Claire
The Numerical Range of a Composition Operator on the Hardy Space

For a bounded operator T on a Hilbert Space $\mathbb{H}$, the numerical range of T is the subset $W(T)$ of $\mathbb{C}$ given by $W(T) = \{ : ||x|| = 1\}$. We study the numerical range of the composition operator, C_A, on the Hardy space $H^2(\mathbb{B}_n)$ where A is an $n \times n$ matrix that is a self-map of the unit ball. We show the set of homogeneous holomorphic polynomials of degree k is a reducing subspace for C_A; it follows that $W(A) \subseteq W(C_A)$. In the special case where A is a weighted shift, $W(C_A) = \text{convex hull}(W(A) \cup \{1\})$. We completely characterize the numerical range of the operator when A is unitarily similar to a Jordan-normal form that maps the ball to the ball by decomposing our operator into the direct sum of shifts and normal operators.

Judith Brennan, Georgia Institute of Technology
Integer Linear Programming Optimization Model for Fantasy Hockey

Fantasy hockey leagues consist of owners who draft teams of hockey players from the National Hockey League player roster. We determine the optimal team for fantasy hockey using linear integer programming. Each owner is assigned a draft position from 1 to n and the draft order rotates (1-to-n, n-to-1) for each round. Players are assigned weights based on statistics from the 2000-2001 to 2016-2017 seasons. The program returns an optimal team composed of nine forwards, six defensemen, one utility player, two goalies, and five benched players. The draft is simulated using the optimal draft choice given by the program for our team and the highest-ranked player available from ESPN's rankings for the remaining owners. The 2017-2018 season statistics are used to compare how the optimal team competes within the league during that season.

Shannon Bride, Colorado School of Mines
Lindsey Nield, Colorado School of Mines
SIR Epidemic Models for H1N1: Modeling the 2009 Outbreak in Denver, Colorado

The present study was conducted to investigate the impact vaccinations and hygiene had on the 2009 H1N1 epidemic in the Denver metropolitan area. Two variations of the standard SIR model were created to explore the effects that vaccinations and hygiene had on the spread of the H1N1 virus. The standard SIR model was manipulated to create an SVIR model, which includes a vaccination state. Parameter values were chosen based on past research. By comparing the solutions between the SVIR model and the standard model, it was discovered that vaccinations contributed to less total infected individuals during the 2009-2010 flu season. Using sensitivity analysis, it was found that the infection rate and the recovery rate are the parameters that affect the total number of infected individuals the greatest. The SVIR model was manipulated further to produce the Hygiene-Vaccination model, which includes classes of people that either wash or do not wash their hands. It was concluded that, proportionally, a greater number of people who do not wash their hands became infected versus those who do wash their hands. The QOI, or total number of infected individuals, was most sensitive to the infection rate and the recovery rate. The findings for these models indicate that the H1N1 vaccination for the population of Denver prevented infections. The data from the Hygiene-Vaccination model shows that a person who washed their hands during the 2009 H1N1 epidemic decreased their likelihood of infection.

Kate Bubar, Colorado School of Mines
Modeling glycerol dynamics during an oral glucose tolerance test

In a fasted state when glucose is not readily available, the body undergoes lipolysis, a process in which adipose tissue is broken down to be used as source of energy. Lipolysis results in the release of glycerol and free fatty acids into the bloodstream. Insulin resistance in adipose tissue affects the suppression of lipolysis. Our objectives were to model the glycerol dynamics during an oral glucose tolerance test with a stable glycerol tracer to explore methodologies to quantify adipose insulin resistance. We used a one-compartment model in which the rate of glycerol enrichment is given by a glycerol concentration-dependent clearance and an implicit insulin-dependent rate of appearance. Our model reliably describes our dataset and estimates the glycerol rate of appearance in insulin resistant patients and the control group.

Julie Campos, University of New Mexico
Zero Distribution of 2-Filtrations of Recurrently Generated Polynomials

The n-filtration of a polynomial is the new polynomial obtained by keeping only those terms with exponent divisible by n. We apply 2-filtration to a recursively generated sequence of complex polynomials $P_m(z)$ satisfying a generating function $\sum_{m=0}^{\infty} P_m(z)t^m = \left(1 + A(z)t + B(z)t^2\right)^{-1}$, where $A(z)$ and $B(z)$ are linear polynomials. We identify sufficient conditions on the coefficients of $A(z)$ and $B(z)$ so that the 2-filtration of each $P_m(z)$ has only real and purely imaginary zeros. We also conjecture natural generalizations for n-filtrations.

Emilee Cardin, College of William & Mary
Spectra of Kohn Laplacians on Spheres

A CR-manifold is a submanifold in $\mathbb{C}^M$ with extra structure stipulating that the dimension of the complex part of its tangent space is pointwise invariant under some complex structure map. The Kohn Laplacian $\Box_b$ is a second order differential operator intrinsically defined on any CR-manifold, and the spectrum of $\Box_b$ reveals information about the embeddability of abstract CR-manifolds.

In this project, we study the spectrum of $\Box_b$ on unit spheres in $\mathbb{C}^N$ and revisit Folland's eigenvalue computation. Folland computes the eigenvalues of $\Box_b$ on $L^2(\mathbb{S}^{2N-1})$ using unitary representations; we use spherical harmonics. When restricted to the finite dimensional subspaces of spherical harmonics, $\Box_b$ can be expressed as a matrix, and one can either explicitly compute or obtain bounds on the eigenvalues. This approach enables us to write `SymPy` code to compute the eigenvalues of $\Box_b$. We also look at the growth rate of the eigenvalue counting function of $\Box_b$ on $\mathbb{S}^{2N-1}$ and expand on previous work, studying the asymptotics of the spectrum on the Rossi sphere with the perturbed Kohn Laplacian. We provide sharp upper and lower bounds on the maximum eigenvalues on the invariant subspaces by invoking the Gershgorin Circle Theorem.

Elise Catania, University of Rochester
Codes for Storage with Queues for Access

With the rise of big data and machine learning, distributed computing systems are used to process data. A distributed system is analyzed that has m identical servers with exponentially distributed service times. The stream of incoming jobs is assumed to have exponentially distributed inter-arrival times. To circumvent the issue of stragglers, i.e. slower workers, an erasure coding technique is utilized. Specifically, each arriving job is split into k pieces and coded into n tasks with $k \leq n$, such that the output from any k tasks is enough to construct the output of the entire job. This property could be effectively achieved by implementing Maximum Distance Separable (MDS) Codes. Due to the coding, the $n - k$ slowest servers will be circumvented, and the straggler problem averted. The question to answer is: How does the way in which the n tasks are sent to the m servers affect average job completion time of a system? The known hierarchy of job scheduling policies from most to least efficient is JSQ (join shortest queue), power-of-d, round robin, and random. This poster explores balanced and incomplete block design and how its efficiency compares to that of the designs in the existing hierarchy, and explores other models where the hierarchy is unknown. As a result, in certain scenarios, balanced and incomplete block design outperforms the other schemes in the hierarchy.

Weiru Chen, University of Illinois at Urbana-Champaign
Qianqian Li, University of Illinois at Urbana-Champaign
Comparing University Rankings: Statistical Analysis of Four Global University Ranking Systems

University rankings are provided by companies and organizations such as US News and World Report, Shanghai Ranking, Quacquarelli Symmonds (QS), and Times Higher Education. These rankings play a major role in a university's ability to recruit top students and faculty and to attract government funding and resources. In our research we seek to answer questions such as the following: How similar are the rankings produced by the different ranking systems? How similar are subject-specific rankings to overall rankings? Are there significant regional differences in rankings produced by different providers? To investigate these questions, we analyzed data from the four ranking systems mentioned above using well-known ranking metrics such as Kendall tau and the Spearman Footrule measure, as well as statistical tests such as the paired comparison test and the Wilcoxon rank-sum test. We found, for example, that Shanghai Ranking and US News and World Report produced the most similar results overall, and that the discrepancies in rankings produced by the different ranking systems are significantly greater for universities in Asia and Europe than for North American universities.

Alice Chudnovsky, University of Illinois at Urbana-Champaign
A Graph-Theoretic Approach to Stern's Diatomic Series

This poster will build upon research presented at the Young Mathematicians Conference this past summer. Stern's Diatomic Series exist in a close relationship to widespread mathematical concepts such as the Calkin-Wilf tree, Farey sequence, Fibonacci numbers, et cetera. However, most of the analyses of the Stern series have occurred via classic combinatorial or number theoretic techniques. Innovatively, we take a graph-theoretic approach: by representing the series as a graph and using the new representation to draw conclusions. This allows for visual confirmation of properties of the series as well as gives rise to new conjectures, previously not obviously visible due to cumbersome notation. A potential connection to integral friezes is explored.

Molly Creagar, University of San Francisco
An Iterative Markov Ranking Method

Much work has been done on problems of ranking and rating teams in paired comparisons. Examples of well-known ranking methods include the Markov method (closely related to PageRank), Colley's method, and Massey's method. All of these methods can be understood in the context of a network diffusion paradigm that brings insight to how they work and how they differ. These three methods are also examples of the global (or accumulative) method family, which compile season results into a matrix and solve a linear system retrospectively. By contrast, methods like Elo's ratings in chess use an iterative (or adjustive) approach that gives real-time updates to ratings after each competition. Using the diffusion paradigm, we show how to reinterpret the global Markov method into an iterative form that reveals a close relationship to Elo's method and converges, in a natural sense, to its global counterpart. We illustrate concepts with empirical examples from real and simulated data sets.

Nan Ding, Bowdoin College
Daisyworld Dynamics and Resilience

Daisyworld is a simplified model of planetary climate that captures the dynamics of homeostasis between a system of biotic components and their environment. The original form was introduced by James Lovelock and characterizes a simple planetary system with black and white daisies regulating the global temperature through planetary albedo. The model sets up a rein-control system that maintains global temperature homeostasis across an enormous range of solar luminosities. Computer simulations revealed a rich structure behind this simple model and provided a clear picture of how the dynamics evolve as luminosity increases. While the original model was deliberately oversimplified, recent extensions of the Daisyworld can be brought to bear on phenomena from evolution to microbial communities.

Debra Dunham, College of Saint Benedict
Pythagorean Triples à la Mod

It is already known that there is a mapping from the integers $\mathbb{Z}$ to $\mathbb{Z}$ mod n for any n that preserves Pythagorean triples. However, there are also triples in some mods that cannot be traced back to the integers. The triples in the mods that have no counterpart in the integers are what we call neopythagorean triples. We seek to find which mods have neopythagorean triples and why.

Maria Escobedo, Saint Mary's College
Mathematical Models of Chemical Reactions in Equilibrium

One of the rising challenges in an increasingly digital world is that future scientists and researchers may not be equipped to respond to the rapidly changing industrial and research landscape. Few individual experts within their respective fields create computer programs that can potentially aid their peers with analyzing and collecting data. When scientists and researchers rely on existing software, they often find these programs difficult to learn, out of service, or costly. My research demonstrates the value of interdisciplinary education in the sciences, mathematics, and computer programming. In collaboration with the Haas Lab in the Chemistry Department at Saint Mary's College, I developed a mathematical model for chemical reactions in equilibrium of copper with the human copper transport protein (Ctr1) that will improve equilibria data analysis. I also developed resources to assist chemistry students and researchers in fitting the model to data.

Ilana Freeman, Pacific University
Mathematical Applications to Gerrymandering

Gerrymandering is the practice of manipulating district lines to change an election outcome. Mathematicians, such as Dr. Jonathan Mattingly, have used different models and metrics like outlier analysis to determine if gerrymandering has occurred, as well as work to find ways to generate fair, non-partisan maps through Markov chain Monte Carlo sampling. Currently, these methods have proven that both Wisconsin and North Carolina have been gerrymandered to favor one party over another. Our elected officials need to be representative of the true population; thus, gerrymandering is detrimental to the foundations of our democracy. In my research, I examine the strengths and weaknesses of multiple metrics, such as the efficiency gap, outlier analysis, and consider other possible models to determine if gerrymandering has occurred.

Katie Gallagher, University of Notre Dame
Generating functions for power moments of elliptic curves over $\mathbb{F}_p$

Seminal works by Birch and Ihara gave formulas for the mth power moments of the traces of Frobenius endomorphisms of elliptic curves over $\mathbb{F}_p$ for primes $p \geq 5$. Recent works by Kaplan and Petrow generalized these results to the setting of elliptic curves that contain a subgroup isomorphic to a fixed finite abelian group A. We revisit these formulas and determine a simple expression for the zeta function $Z_p(A;t)$, the generating function for these mth power moments. In particular, we find that

$$Z_p(A;t) = \frac{\widehat{Z}_p(A;t)}{\prod\limits_{a \in \mathrm{Frob}_p(A)} (1-at)},$$

where $\mathrm{Frob}_p(A) \coloneqq \{a : -2\sqrt{p} \leq a \leq 2\sqrt{p} \text{ and } a \equiv p+1 \pmod{|A|}\}$, and $\widehat{Z}_p(A;t)$ is an easily computed polynomial that is determined by the first $\left\lceil \frac{2\lfloor 2\sqrt{p} \rfloor}{|A|} \right\rceil$ power moments.

These rational zeta functions have two natural applications. We find rational generating functions in weight aspect for traces of Hecke operators on $S_k(\Gamma)$ for various congruence subgroups Γ. We also prove congruence relations for power moments by making use of known congruences for traces of Hecke operators.

Vanessa Gomez, University of California, Los Angeles
Convergence of Simple Continued Fractions

Anselm and Weinstraub explored a generalization of simple continued fractions, in which they replace all numerators with a constant N. Our work further explores this type of continued fraction, beginning with the generalization of eventually periodic simple continued fractions. We replaced all numerators with a constant N and evaluated the limit of such a continued fraction as N approaches infinity.

Allyson Hahn, North Central College
Cops and Robbers on Toroidal Chess Graphs

In the standard game of Cops and Robbers, the cops and a single robber occupy vertices of a graph. They take turns moving between vertices of the graph with the cop's goal being to occupy the same vertex as the robber, resulting in a winning strategy for the cops. We play this game on an $n \times n$ toroidal chess graph, G. In our investigations, we focus on obtaining the minimum number of cops, $c(G)$, required to guarantee a winning strategy for the cops. We create variations of this game by defining the cops and robber to move as the knights, the queen, and the rook in a game of chess. The value of $c(G)$ is determined in these variations.

Rebecca Hicks, University of Central Oklahoma
The Interaction of Language Transfer and Language Processing in Second Language Acquisition

Project SCHOLAR (Statistical Consulting Help for Organizational Leaders and Academic Researchers) is a student statistical consulting service at the University of Central Oklahoma (UCO). SCHOLAR students work under the supervision of faculty from the Department of Mathematics and Statistics on various projects submitted from other researchers from both on and off campus. A faculty member from The English Department at UCO partnered with the students in Project SCHOLAR to study the influence of first language in learning a second language. Participants consisted of native speakers of English as the control group and native speakers of Arabic and Korean as the experimental groups. The participants were divided into three subgroups: elementary, intermediate, and advanced, based on level of English proficiency. The participants were then asked to rate a series of sentences on a 4-point scale from based on the correctness of the sentence. The reading times of the individual words will be used to develop a linear regression model predicting reading time from word length. An analysis of variance (ANOVA) will then be performed to test for differences in first language and English proficiency with respect to mean residuals from the regression model. Logistic and/or ordinal regression will also be performed to test for differences with respect to the sentence ratings.

Ashley Holcomb, Blackburn College
Common Neighbors in Graphs with an Even Number of Vertices

Graphs exhibit different properties depending on how many vertices and edges they have. In particular, graphs with an even number of vertices always have at least two vertices with an even number of common neighbors. We explore the types of graphs for which this holds in a proof by case for this presentation. The simple cases are graphs with zero edges and graphs with the maximum number of edges (complete graphs). Then disconnected graphs, partite graphs, and graphs containing at least one cycle are addressed. In this way, we assess all possible cases and find that every graph with an even number of vertices has a vertex that shares an even number of neighbors with at least one other vertex.

Ashton Irvin, The University of Montevallo
Fourier Analysis

Periodic functions are very interesting functions for mathematicians. Periodic functions were the basis for Joseph Fourier's study on heat conduction in 1807. These functions can be expressed as infinite series and integrals by using trigonometric functions. By taking the trigonometric functions, we can look at one section of the infinite graph from 0 to 2π. Since our functions are periodic, we know our results will repeat over and over again. This idea is crucial to being able to produce a Fourier Series. Using a Fourier series, we are able to see that a normal curve might not be as simple as up and down. It could have several spikes and falls within what looks like a simple bell curve. One application is by looking at the sound waves produced by instruments. We can tell what instrument produced what key just by the graph and how unique the pattern is.

Megan Kaiser, North Central College
Emma Peterson, University of Minnesota, Twin Cities
Multi-Skein Invariants For Welded and Extended Welded Knots and Links

The theory of welded and extended welded knots is a generalization of classical knot theory. Welded (resp. extended welded) knot diagrams include virtual crossings (resp. virtual crossings and wen marks) and are equivalent under an extended set of Reidemeister-type moves. We present a new class of invariants for welded and extended welded knots and links using a multi-skein relation, following Z. Yang's approach for virtual knots. Using this skein-theoretic approach, we find sufficient conditions on the coefficients to obtain invariance under the extended Reidemeister moves appropriate to welded and extended welded links.

Abbey Knowles, St. Joseph's College New York
Brittany Moore, St. Joseph's College New York
Computations of the (Weak) Global Dimension of a Ring

Groups, rings, and R-modules form the popular categories in which Modern Algebra is studied. One way that algebraists study rings is by computing their "weak global dimension" which is an invariant of the ring in question. Our talk will first walk through the familiar calculations of the projective dimension of a given R-module. Next, we will focus on computing the (weak) global dimension of certain well-known rings before moving onto some more exotic cases. At the same time, throughout the talk, we will demonstrate how to use the language of category theory to describe these definitions when possible.

Anchala Krishnan, University of Washington Bothell
Conditions for Lipschitz Continuity on Post-Critically Finite Self-Similar Sets

Kigami's theory of analysis on post-critically finite self-similar (pcfss) sets applies to many well-known fractals, such as the Sierpinski Gasket. In this theory, functions with Laplacian in L^1 are Lipschitz in an intrinsic metric called the resistance metric. However, there are other useful metrics on these sets: One fundamental example is the geodesic metric on the Sierpinski gasket in harmonic coordinates. One may recognize this fractal as a one-dimensional C^1 subset of $\mathbb{R}^2$ which carries a measurable Riemannian structure. By analyzing the self-similar structure of the Green's operator which inverts the Laplacian, we give sufficient conditions for the Lipschitz and Hölder continuity of functions with L^p Laplacian on pcfss sets endowed with measures and metrics from a general class that includes the Riemannian structure on the harmonic Sierpinski gasket.

Chaimi Lee, Santa Clara University
Dual Bases for Planar Algebra Diagrams

Over the past 20 years, there has been significant interest in planar algebras, i.e. vector spaces which exhibit a natural action by planar diagrams. In my poster, I will describe what a planar algebra is, and the problem of computing dual bases for certain bases in specific planar algebras. I will address the dual basis problem problem in the Temperley Lieb planar algebra and work of Brennan and Collins on this problem. I will then present our current work on the Fuss Catalan planar algebra. This is joint work with Tyler Pham and Michael Hartglass.

Laura LeGare, Concordia College
Geodesic Interpolation on Sierpinski Simplices

In Euclidean space, two sets may be interpolated along straight lines connecting all pairs of points in the two sets. In more general spaces, interpolation happens along geodesics—shortest paths parameterized at unit speed. We study interpolation on Sierpinski simplices, which generalize the well-known Sierpinski triangle. In addition to finding an upper bound on the number of geodesics, we show some interesting self-similarity properties of interpolant measures, and prove an analogue of the classical Brunn-Minkowski inequality for interpolant sets.

Qianqian Li, University of Illinois at Urbana-Champaign
see **Weiru Chen**

Xian Li, University of San Francisco
Twists of the Rabbit Polynomial

Every polynomial gives a branched cover of the complex plane over itself. The rabbit, corabbit, and airplane are three special quadratic polynomials that each fix three points setwise. Post-composing the rabbit polynomial with a pure mapping class produces a branched cover equivalent to one of the three polynomials. Determining which mapping classes yield which polynomials is the "twisted rabbit problem". This was solved in a breakthrough by Bartholdi and Nekrashevych in 2006. We set out to find and characterize subgroups of the mapping class group where every element produces a rabbit. Few examples were previously known. We have discovered infinitely many more.

Ellie Lochner, University of Wisconsin-Eau Claire
see **Laney Bowden**

Myrianne Matundu, Delaware State University
Derivation of the Equations Defining the Scattering States and Bound States of Elements

This project utilizes the Schrodinger Equation to determine the ordinary differential equations defining the approximate wave functions of the scattering and bound electrons of atoms. Using integration and properties or orthogonality, we approximate the decoupled wave functions necessary to determine the scattering wave function and the bound wave function for Hydrogen, Helium, Lithium, Beryllium and Boron. Future work involves the exact computation of scattering and bound states using numerical method for ordinary differential equations.

Andrea McCormack, North Central College
Modeling the Dynamics of Lyme Disease in a Tick-Mouse System Subject to Vaccination

Lyme disease is one of the most prevalent and the fastest growing vector-borne bacterial illness in the United States, with over 25,000 new confirmed cases and 300,000 associated illnesses every year. The Centers for Disease Control and Prevention estimates that those numbers could be significantly underrepresented. Lyme Disease is caused by the bacteria, *Borrelia burgdorferi*, which humans contract through the bite of *Ixodes scapularis*, commonly known as the deer tick or Eastern blacklegged tick. Ticks receive the pathogen through numerous reservoirs, chiefly the white footed mouse *Peromyscus leucopus.* Our research assesses whether vaccines targeting mice are an effective method to reduce human risk for Lyme Disease. We do this using a system of non-linear difference equations to model transmission dynamics and vector demographics in both tick and mice populations.

Katelyn Meyer, Washburn University
Analyzing a Conflict Model Between Two Players with Few Outcomes and Diverse Strategies

We studied a conflict model between two players. Modifiable Randomizers (MR) gave us a simple experiment within which we could explore this type of dynamic. We designed a dynamical system with few outcomes each iteration but with an infinite number of potential steps. We then considered the circumstances as a parameter went to infinity, which involved unbounded strings of iterations of these outcomes. In this poster I will describe some computed results and some of the most successful strategy algorithms. In particular, descriptions of elements of our exploration that had to do with strategy are broken down.

Adeline Moll, Northern Arizona University
The Mathematics of the Combinatorial Game Blink

In the game Blink, we begin with a graph whose vertices are initially colored green. On each turn, the designated player selects a single vertex that is green and colors it red. Additionally, if a green vertex is connected by an edge to at least two red vertices, then it will be also be colored red. The winner of the game is the player that makes the last available move and ensures that all the vertices are colored red. One variation of Blink is a game called Switch. As before, we begin with a graph whose vertices are initially colored green. In the Switch variation, on each turn, the designated player selects a single vertex that is either green or yellow and colors it red. Additionally, if a green vertex is connected by an edge to at least two red vertices, then it will be colored yellow. Similarly to Blink, the winner of Switch is the player that makes the last available move and ensures that there are no longer any green vertices in the graph. We will discuss the winning strategy for both games for several families of graphs and present some open problems. In addition, we will present some current results concerning the misère variation of Switch.

Brittany Moore, St. Joseph's College New York
see **Abby Knowles**

Marissa Morado, California State University, Stanislaus
Harmonic Motion Equations with Related Applications

We will focus on understanding harmonic functions and their relationship with its applications, particularly investigating its relationship with differential equations. By using differential equations and numerical methods, we are able to further analyze various mathematical models. Harmonic motion is often seen in spring problems and in oscillations of objects. Our goal is to inquest the effects of harmonic motion, primarily the oscillations, and its effect on the expression of mathematical models. We will focus on the external forces that may potentially cause a system to oscillate quickly and reach resonance. The program Matlab will be used to create simulations of these systems. By analyzing various models, we will be able to focus on the sinusoidal curve when external forces are acting upon the system. We will also focus on understanding important concepts such as amplitude and frequency. This presentation is primarily aimed for undergraduate students to help further their understanding of differential equations and their applications.

Terran Mott, Grinnell College
Building Intuition in Higher Dimensions

Visual intuition is limited to three dimensions. Despite this intuitive blindfold, plenty of reasonable geometry lives comfortably in higher dimensions. In this investigation, we will build intuition about higher dimensional material in a non-visual way. We will develop combinatorial tools to explore patterns in any dimension without the need for visualization. This exercise offers great practice at strengthening one's imagination and at building intuition about a non-intuitive concept.

This exploration is restricted to the study of N-cubes. Subdividing, categorizing, and labeling the material in an N-cube reveals intuitive clues about its structure and about how cubes change as their dimension grows. Many common fractals require an N-cube originator—either a line segment, square, or cube. The intuitive framework developed in this presentation will examine the higher dimensional analogs of such fractals. In the process, it will reveal clever patterns about the boundaries and innards of hypercubes themselves.

Zoe Nelson, Oglethorpe University
Twisted Hermitian Codes and Applications to Cryptography

In this poster presentation, we define a new family of codes called multi-twisted Hermitian codes, which are based on one-point Hermitian codes and inspired by the twisted Reed-Solomon codes described by Beelen, Puchinger, and Nielsen. We show that these codes are applicable to the McEliece cryptosystem. Our codes have high Schur square dimensions approaching those of random linear codes. Unlike one-point Hermitian codes, they are resistant to Schur square distinguishing. This is joint work with Austin Allen, Keller Blackwell, Olivia Fiol, Rutuja Kshirsagar, and Bethany Matsick, supervised by Gretchen Matthews.

Mia Nguyen, University of Nebraska-Lincoln
The Hexagonal Lattice Number of the Figure Eight is 11

Knot theory is a branch of topology that studies three-dimensional manifolds. A mathematical knot is a closed curve that is embedded in 3-dimensional Euclidean space. According to Mann et al. 2012 the simple hexagonal lattice is defined as the point lattice where $x = \langle 1, 0, 0\rangle, y = \langle 1/2, \sqrt{3}/2, 0\rangle, w = \langle 0, 0, 1\rangle$, and $z = y - x$. The x-stick, y-, z-, and w-sticks are straight line segments that are parallel to directions of x, y, z, and w. We know that the lower bound for stick numbers of any knot in the simple hexagonal lattice is equal or greater than $5b[K]$ where $b[K]$ is the bridge number of the knot K. Since the bridge number of trefoil is 2 with 2 local minima and 2 local maxima, its stick number is 11. Special attention is devoted to proving that the hexagonal lattice number of the figure eight is also 11. Based on bridge number, we are able to make some estimates about the stick number of some simple knots. From the cubic model of the knot, we project it onto the xyw-plane and transform it to hexagonal lattice. For the conversion, the angle of 30° at each corner and the minimal number of sticks are prominent.

Lindsey Nield, Colorado School of Mines
see **Shannon Bride**

Gabriella Oliver, University of Central Oklahoma
Effectiveness of Patient Education on Safe Sleep Methods

Project SCHOLAR (Student Consulting Help for Organizational Leaders and Academic Researchers) is an undergraduate student statistical consulting program in the Department of Mathematics and Statistics at the University of Central Oklahoma, where students are split into teams to work on projects along with an advisor. One such team was approached by a researcher from the Nursing department named Katherine Brashears to help with her research on safe infant sleeping methods. Over the summer of 2018, Brashears conducted a quality improvement project to improve screening for unsafe sleep practices and support the caregivers at a pediatric primary care practice. Data had also been mined from the same medical practice to give reference as to whether the screening was effective. To help Brashears with her research, the Project SCHOLAR team is using t-tests and repeated measures ANOVA to determine if there are any relationships between several variables including but not limited to socioeconomics, parental age, and first child vs. multiple children. The SCHOLAR team is also interested in assessing the effectiveness of the quality improvement project.

Andrea Padilla, Saint Mary's College of California
Fighting Gerrymandering with Math: Evaluating the Declination and a New Metric

The declination is a metric created by Greg Warrington that measures asymmetry in vote share. It has advantages, disadvantages, and implications that will be presented. A new metric will be shortly proposed that attempts to compensate for the shortcomings of other metrics.

Jordan Pellett, University of Wisconsin-La Crosse
Efficacy of Control in a Spatially Dynamic Model of White-Nose Syndrome

White-nose syndrome (WNS), caused by the invasive fungal pathogen *Pseudogymnoascus destructans*, is a virulent disease that has plagued North American bat populations since 2006. Over the past decade, WNS has rapidly spread throughout much of the eastern United States, leading to mass mortality and threatening range-wide extinction in a number of bat species. Thus, the need for development and implementation of effective control strategies has become increasingly exigent. Previous studies have explored disease dynamics and control in a single hibernaculum model. Here, using a continuous-time two-hibernacula model, we incorporate spatial dynamics to investigate the effects of seasonal bat dispersal on the efficacy of five developing control strategies. We demonstrate that informed management decisions must take inter-population movement into account, and find the effects of dispersal on control efficacy to be dependent on both the control combination and the primary mode of disease transmission.

Emma Peterson, University of Minnesota, Twin Cities
see **Megan Kaiser**

Rilee Potter, University of Nebraska-Lincoln
Exploring Derivatives of Square Knots

The study of knots in mathematics is known as knot theory. Knot theory has applications in chemistry, physics, quantum computers, and biology. The difference between just any knot and a mathematical knot involves the fact that the mathematical knot has ends that combine to create a loop that is continuous, this loop can never be cut, and it can be stretched infinitely. I am exploring curves on Seifert surfaces for square knots, using a construction developed by Jeffrey Meier and Alex Zupan. Seifert surfaces can be defined as a surface whose boundary is a certain knot or link. These curves correspond to a certain ratio. The diagrams that come of this will give instructions for constructing four-dimensional spaces that look like the four-sphere. The computer program, SnapPy, is a knot theory program that will help in data collection and analysis. The overall goal of my research is to determine what kind of knots we get from each corresponding ratio.

Hannah Price, Georgia Institute of Technology
Monte Carlo Simulations of Quantum Materials

In magnetic materials, atomic-scale magnetic moments (called spins) interact with many of their neighbors on a crystal lattice. In conventional magnets, such as ferromagnets and antiferromagnets, spins organize in well-ordered and uniquely defined patterns at low temperature. By contrast, in frustrated magnets, spins do not order at any temperature. The ground state of a frustrated magnet is not unique; instead such have degenerate ground states. To simulate these complex systems, we use Monte Carlo to simulate the spins relaxing to a minimum energy state. From this we can estimate many physical properties of the material, which can than be compared to experimental data. In particular, we compare the modeled critical temperature and structure factor from previous models and experiments, for the diamond and pyrochlore lattice at a range of interaction energies.

Leah Reeder, Colorado School of Mines
Exploring Applications of Random Walks on Spiking Neural Algorithms

Neuromorphic computing has many promises in the future of computing due to its energy efficient and scalable implementation. Here we extend a neural algorithm that is able to solve the diffusion PDE by implementing random walks on neuromorphic hardware. Additionally, we introduce four random walk applications that use this spiking neural algorithm. The four applications currently implemented are: generating a random walk to replicate an image, finding a path between two nodes, finding triangles in a graph, and partitioning a graph into two sections. We then made these four applications available to be implemented on software using a graphical user interface (GUI).

Lois Ruffle, Furman University
Predicting College Football Bowl Outcomes

For the past several years, professors at Furman have worked with ESPN on its annual "Giant Killers" project — a project designed to predict upsets in the March Madness basketball tournament. In this project, we investigate how methods used in that project might translate into another area — college football bowl games. Using a combination of standard football statistics (e.g., starting field position) and novel ones (e.g., Bill Connelly's Efficiency and Explosiveness), we apply a variety of statistical and analytical methods to study upset probabilities in bowl games of recent years.

Patricia Salas, University of Central Oklahoma
Grape Berry Ripening Signature Gene Expression Analysis

Frontenac and Marquette are cold climate hybrids derived from Vitis vinifera and North American grape species. To produce good wines from these cultivars, it is critical to characterize their ripening profile and identify optimal biomarkers. Since the varieties are relatively new, their ripening processes have not been well studied. Titratable acidity, pH, and soluble solids are commonly used to indicate grape maturity but correlate weakly with flavor maturity. Gene expression was analyzed at different fruit maturity stages to identify key genes and pathways linked with flavor development. Using results from data exploration, the cultivars showed distinct signature gene expression during the ripening process. In future research, combined genetic, sensory, and chemical analyses will aid in identifying improved harvest biomarkers. For grape growers, better markers will result in high quality wines and benchmarking cultural practice improvements.

Jessica Sandcork, Creighton University
Data Reduction on High-Dimensional Data Sets Using Principal Component Analysis

Given a data set with a considerably large amount of variables, traditional statistical testing procedures will lead to inflated Type I error rates without proper adjustment. Multiple testing procedures must be introduced to accommodate such a large quantity of variables. However, such a large data set may also exhibit exceptionally high levels of correlation between the variables, which weakens the statistical power of multiple testing procedures. In this presentation, we will explore the usage of methods of data reduction on a highly correlated, large variable data set with the ultimate goal of breaking high rates of correlation between variables to determine true significance. We propose using principal component analysis (PCA) to reduce the number of variables by searching for linear combinations of highly correlated variables that explain a large proportion of variability in the overall data set. By reducing the dimensionality of the data set, we hope to be able to apply multiple testing procedures without the additional challenge of highly correlated variables.

Sydney Schmidt, Gonzaga University
Applications of Fourier Transforms

There are many connections between mathematics and music. In this presentation, we examine how the wave equation can be used to model the vibration of a guitar string when it is plucked. We begin by developing the solution to the boundary value wave equation problem employing standard techniques, including finding eigenvalues and eigenfunctions and identifying an appropriate Fourier series expansion. We will then look at how this solution models vibration and in particular use the model to explain how harmonics (or frequencies) of a note are made. Finally, we conclude with some new directions and open questions relating to chord construction and traditional note intervals, we plan to pursue in this application.

Shraddha Shankar, Denison University
Exploring Methods of Recovering Ranked Choice Voting Data Given Partial Information

Imagine an election in which voters rank candidates in an order of preference. For example, when there are three candidates, A, B, and C, a voter might prefer A to B to C. Given n candidates, there are always $n!$ rankings for a voter to choose from. This kind of voting method is called a ranked choice voting method. Information from these elections can be encoded in the form of a matrix. When doing so, the information from the election is stored in a slightly different way: the (ij)th entry tells us how many voters ranked candidate j in the (i)th position. The question considered is the recovery of the information of how many voters chose each of the possible rankings, given only the matrix encoding of the election. By studying the properties of this matrix and phrasing these ideas algebraically, we show that under certain conditions, one can recover the original election data.

Emily Strong, Saint John Fisher College
Distinguishing Resource Selection from Heavy-Tailed Dispersal in Spatial Epidemic Models

The tail of the dispersal kernel of individuals plays a critical role in the spatial spread of infectious disease, invasive species, and other spreading phenomena. However, most studies where the dispersal kernel has been estimated from observed natural systems have assumed homogeneous dispersal in space, even though non-uniform use of space (i.e., resource selection) has long been recognized as important in many systems. In this study we explore the consequences of ignoring terrain heterogeneity when estimating parameters governing the tail of a dispersal kernel. We show that ignoring resource selection in general leads to estimates of dispersal kernels with heavier tails than the true kernels used for simulation. In addition, this often leads to predictions of the rate of spatial spread of infectious disease that are much faster than the true spread through a population that is moving across patchy terrain.

Shari Tanaka, Creighton University
Effects of Obesity on Essential Cardiac Action Potentials: Modeling and Bifurcation

Obesity is an epidemic that poses major risk factors such as Type 2 Diabetes, coronary heart disease, hypertension, stroke and forms of cancer. Previous studies investigated sub-cellular effects of obesity on various species of mammals to better understand obesity. This study applies previous clinical mammal obesity studies to DiFrancesco and Noble models of Sino Atrial Node and Purkinje Fibers in attempt to model the complications of obesity on cardiac action potentials. We find that the selected model was robust in demonstrating asystole resulting from obesity.

Katrina Teunis, Grand Valley State University
The Combinatorics of the Foldability of RNA

RNA, much like DNA, is made up of four building blocks called nucleotides: Adenine, Guanine, Cytosine, and Uracil. These nucleotides form a string that likes to fold in on itself and bond together - Adenine with Uracil and Guanine with Cytosine. The order and number of nucleotides present will determine how many ways the string of RNA can fold. Using these guidelines, we move into the theoretical and consider what happens when we have $2n$ nucleotides, where n is a natural number. For strings containing only one type of nucleotide and its bonding pair we determined how to build a string that will fold $n + 1$ different ways for all n that is not one less than a prime number. We also found transformations on words that can be used to produce other words with the same foldability as the original. This research was funded by the Modified Student Summer Scholars Program from the Office of Undergraduate Research at Grand Valley State University.

Michaela Trobough, Washburn University
Developing Rankings for Tournaments with Many Competitor Cycles

We created a statistical environment of competition that had many cyclic situations where there was no clear "best" competitor within the cycle. This environment used partition-like generated arrangements of the values on variable sided randomizers. We studied the processes by which we could implement a ranking system in a tournament of these automated competitors with lots of cycles. We compared the resulting rankings and explored hybrid strategies. We developed a variety of ways to establish comparisons, and checked the predictions of the rankings with the results of simulations.

Rebecca Twait, Concordia College
see **Julie Bittner**

Alexandra Veliche, Northeastern University
Shor's Algorithm and Its Impact on Modern-Day Cryptography

Factoring a given number may not seem like such a difficult task at first glance, but when the number is a few hundred digits long and is the product of two very large primes, the problem becomes infeasible. No classical algorithm for factoring in polynomial time is thought to exist, as this would solve the Millennium Prize problem of "P vs. NP". In the quantum world, however, this is another matter entirely: Peter Shor's quantum algorithm for factoring integers runs in polynomial time in terms of the size of the number being factored. Because several commonly used cryptosystems, such as RSA, rely on the difficulty of this problem, this result poses a threat to public-key cryptography as we know it. In this poster, I will be exploring the mathematics used in Shor's algorithm and analyzing its components from an algebraic perspective, with a particular focus on the roots of unity used. I will also address the impact this algorithm may have on modern-day cryptography.

Sophie Vilter, Denison University
Analysis on Ranked Choice Voting

We show how tournament data can be analyzed using techniques from algebraic voting theory. Algebraic voting theory focuses on the decomposition of a vector space of functions mapping ranked votes to the number of voters into invariant subspaces. These subspaces reveal data about the election such as voters per candidate in a given rank. In order to apply this decomposition to tournament data, we decide how to represent a tournament bracket as a ranked vote and decide which vector space to decompose. We use a representative object called a tabloid to represent a bracket and focus on the decomposition of the vector space of functions mapping tabloids to votes per tabloid. In order to properly decompose this vector space, we check that it is invariant under the action of the symmetric group, i.e, the relabelling of each candidate will not affect analysis. We determine the set of permutations in the symmetric group that can break down the space while maintaining invariance and show that this set is a subgroup.

Chengyuan Yang, Coe College
Minimal Edge-Disjoint Domino Packings on Rectangular Grids

We studied packings in which dominoes are arranged on a rectangular board such that there is no space for another domino and no dominos are side by side. We worked on finding the minimal packing number on $m \times n$ boards. We also wrote a program to find the minimal packing number using the concept of Genetic Algorithm.

Kat Yats, Grand Valley State University
Art and the Geometer

Art and the beauty of mathematics have been inextricably linked since the beginning. Through an exploration of the properties of the Poincaré disk model of hyperbolic geometry and the hemisphere model of projective geometry, the most elementary elements of mathematics (parabolas, circles, polygons, ellipses, etc.) become the building blocks of art. Using ideal polygons, an intricate kaleidoscope effect is created in the Poincaré disk; congruent polygons and hyperbolic circles define a new perspective when searching for equivalency; and the curves of math's most basic functions introduce to the eye what mathematicians have always known: mathematics is the art of the soul.

Danqi Yin, Coe College
Classifying Polynomial and Rational Solutions of a Functional Equation

The research aims to investigate solutions of the functional equation $U(z)f(z) + zU'(z)f(U(z)) = 0$. For particular linear fractional maps $U(z)$, we checked different types of functions for f (polynomials and rational functions) to see whether they solved the functional equation. In some scenarios, we have classified the solutions or have shown a class of functions that are not solutions.