The Twelfth Annual Nebraska Conference for Undergraduate Women in Mathematics

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POSTER ABSTRACTS

Posters by Undergraduate Students

Holly Arrowood, Furman University
Distance Related Labelings of Graphs

Vertex labeling has been a widely studied concept in the field of graph theory. The type of labeling studied in this project is called L(3,2,1)-labeling, and it is related to distances between vertices in the graph. In my project, I determine optimal L(3,2,1)-labelings for several different types of graphs.

Kristen Bretney, Loyola Marymount University
Singular Value Decomposition of Los Angeles Voting in the November 2008 Presidential Election

This presentation will discuss the findings and analysis of a singular value decomposition (SVD) on Los Angeles exit poll data from the November 2008 Presidential election. The SVD revealed: the political views of both Los Angeles voters as a whole and voters in each particular precinct polled, the groups of precincts that have similar political views, and the most significant ballot issues for the precincts.

Suzanne Carter, University of Iowa
Samantha Fuller, Penn State University, University Park Campus
Classifying Molecules Using Group Theory from a Geometric and Topological Perspective

Point groups provide a mathematical way to classify molecules using their structure and their resulting symmetries. This allows us to represent them as solids, which has several surprising applications in chemistry. They also provide a visual examination of group theory. We will take both a geometric and topological look at point groups and their properties.

Nicole Casella, Ithaca College
Chebyshev Polynomials and Their Relationship to Trigonometry and the Fibonacci Numbers Part I

In this presentation we will define Chebyshev polynomials of the first kind using the difference equation and then discuss some properties such as the Binet type formula and relations to trigonometry. We will then look at properties of the Chebyshev polynomials of the second kind and see how they relate to those of the first kind. Finally, we will compare the Binet type formulas of the Chebyshev polynomials to the Binet type formula of the Fibonacci numbers.

Morgan Chatham, University of Montevallo
The Foundation Mathematics of General Relativity

In the study of General Relativity, we will study manifolds, vector spaces and tensors as they relate to Einstein's conceptualization of gravitation as spacetime curvature. These ideas work together to form the structure of spacetime. We will discuss the more general idea of tangent vectors as functions on certain types of mappings as opposed to the more familiar, purely spacial three-vectors and the motivation for this generalized viewpoint.

Lilith Ciccarelli, Bellarmine University
Poset Reconstruction

Poset reconstruction is a relatively new area of mathematics related to graph reconstruction. In recent years, very little has been published and research has been at an apparent standstill. It remains an open question whether posets (partially ordered sets) can be reconstructed from their one element deleted subgraphs. These subsets are called cards and the collection of all the cards of a poset is called the deck. This poster presents the summary of a semester-long research project surrounding this open question, including a survey of known results. I explored various structures of posets to find new approaches toward resolving this question, including series decomposable and series parallel posets, and posets with maximal and minimal elements.

Amber Clinton, Clarkson University
Can You Hear Me Now?

Many customer service departments use automated telephone systems. When people respond to automated prompts, a computer interprets the sound waves and decomposes them into digital signals. There are two methods, the Discrete Wavelet Transform, and the Discrete Fourier Transform that can be used to decompose the signals. The audio signals can then be used to figure out how computers correctly identify the verbal responses. A library of average words is created and used for comparison. The difference between a persons unknown response and all the words in the library can be seen graphically and their response is identified as the word with the least error. Using the graphs, we compare how well each method identified selected unknown words.

Jalonda Coats, Tougaloo College
Tougaloo College and Mathematical Applications Used in the Jackson Heart Study

Mathematics has importance in several areas such as statistics, prediction curves, and various applications in mechanics. One specific area that is important in research is statistics. In Jackson, MS, there is cohort study called the Jackson Heart Study. A mission of this study is to collect data from its 5,000 participants to observe cardiovascular disease in African Americans. Tougaloo College is the undergraduate training center that provides insight to students about public health, medicine, and the sciences. Undergraduates enroll in a biostatistics class that allows them to analyze data in order to condense it into a readable and understandable format. This class also provides knowledge to students about some statistics of analysis that corresponds to research. Mathematics is an essential, diverse area of scientific study. The subspecialty of statistics is used in the Jackson Heart Study to produce an end result to better the health of the African American community.

Natalie Coston, Northern Arizona University
Anita Doerfler, Northern Arizona University
Some Recent Results Involving Greek Ladders

Greek Ladders are an ancient technique in Diophantine Approximation. Our poster will show some recent results involving classic Greek Ladders, including some connections between Greek Ladder approximations and those derived from the continued fraction algorithm and Newton's Method, as well as some advances involving higher-order Greek Ladders.

Belinda Cruz, University of Texas Pan American
Melissa Martinez, University of Puerto Rico at Cayey
Analyzing Stability of Model Ecosystems

We developed ordinary differential equation models for competing, cooperating, and predatory interactions between multiple species. In the case of two species we analyzed our models globally and determined mathematical conditions for stable interactions. These mathematical conditions have an ecological interpretation in terms of carrying capacity. We also analyzed the interactions using a method called linearization, which gives an algebraic expression for local stability. While it is more straight forward and generalized, the method only works near equilibrium points. The analysis is much more complicated for models with more than two species. Because of this, we relied on the linearization technique to analyze the local stability around the equilibrium points. In the case of three species we have examples for stability and instability but not complete classification.

Anita Doerfler
see **Natalie Coston**

Clarice Dziak, Clarkson University
Mathematical Modeling at the Middle Level: The Colton-Pierrepont Project

Colton-Pierrepont Junior/Senior High School has only 192 students. This school is very small and low enrollment numbers have forced students at CPHS to choose from limited extra-curricular activities. In trying to give CPHS students more options, we created a mathematical model to determine if it is feasible to add another activity, and which activity to add. Our model considers factors such as student interest, cost, and availability of facilities, and uses a scoring system to make data categories comparable. While creating this model, optimization and weighting, reasoning behind assumptions, and scoring systems were addressed. A solution was reached via a generalized linear model. The purpose of making this model was to develop an example modeling problem and solution to educate middle school teachers about using models in the classroom. To show that it is a plausible Middle School project, the model was created using only mathematical techniques that would be known to middle level students.

Terra Fox, Hope College
Development of a Non-Destructive Evaluation Method for FRP Bridge Decks

Open steel grids are typically used on bridges to minimize the weight of the bridge deck and wearing surface. These grids, however, require frequent maintenance and exhibit other durability concerns related to fatigue cracking and corrosion. Bridge decks constructed from composite materials, such as a Fiber-reinforced Polymer (FRP), are strong and lightweight; they also offer improved rideability, reduced noise levels, less maintenance, and are relatively easy to install compared to steel grids. Because FRP bridge decks are relatively new and little is known about their long-term durability, a non-destructive evaluation (NDE) method is necessary to monitor the health of FRP bridge decks over time. This research is aimed at developing an inspection protocol for FRP bridge decks using thermal imaging. The finite element method was used to simulate the heat transfer process and determine optimal heating and data acquisition parameters that will be used to inspect FRP bridge decks in the field.

Samantha Fuller
see **Suzanne Carter**

April Harry, Xavier University of Louisiana
Dynamics of the Sigmoid Beverton-Holt Population Model

The discrete Sigmoid Beverton-Holt population model, originally introduced in fishery science, is known to exhibit the so-called "Allee effect," that is the population becomes extinct if the population size falls below some threshold level. As a starting point in the project, the dynamics of the autonomous model, including asymptotic behavior of solutions, stability, and boundedness were studied. The obtained results are extended to the periodically-forced Sigmoid Beverton-Holt model where emphasis is placed on the existence and stability characteristics of periodic solutions.

Anne Ho, Regis University
An Analysis of Various Modular Origami Dodecahedra

During the Mathematics of Paper Folding REU at the University of Georgia, I examined various types of modular units and their links to make structurally stable and aesthetically pleasing regular dodecahedra. Analysis of crease patterns included determining the areas of paper used, the number of layers of papers used, and whether the links were locked or not. With some modifications on a design by Mio Tsugawa, I created a model for evaluating origami designs and an ideal module.

Rachel Keyser, Bellarmine University
A Demonstration of the Vigenère Cipher Using Frequency Analysis and Modular Arithmetic

This poster presentation will provide a history and encryption and decryption demonstration of the Vigenère Cipher created in 1586. The cipher was thought to be unbreakable for almost 300 years until it was broken by Charles Babbage and Fredreich Kasiski, separately. The presentation will demonstrate the Kasiski Method for decryption of the Vigenère cipher. The Kasiski Method uses frequency analysis and modular arithmetic to break a cipher text created with the Vigenère cipher. The poster will show the step by step decryption process of a lengthy piece of cipher text, first by finding the probable length of the ciphers keyword, and then using frequency analysis to determine the keyword itself. Finally, the entire cipher text will be deciphered to reveal the original plain text message.

Hannah Kolb, Illinois Institute of Technology
Reconstruction of a Family of Seperable Graphs

In the 1950's, Ulam and Kelly posed the reconstruction conjecture in graph theory: every graph with $n \geq 3$ vertices is uniquely determined by its collection of vertex-deleted subgraphs. While the problem remains open, many families of graphs have been shown to be reconstructible, such as disconnected graphs, regular graphs, and trees. In 1976, Manvel proved that graphs with connectivity 1 and no leaves are reconstructable. Here, we prove the reconstructability of graphs with connectivity 1 where no maximal end tree is a leaf.

Lauren Kraus, Wheaton College
Using Cluster Analysis to Identify Relationships Between Old English Poems

Long-standing linguistic and philological analyses of Old English poetry have identified many relationships among different poems. This work examines two Old English poems, Daniel and Azarias, where one section of Daniel, the "Song of Azarias" is closely related to the whole of Azarias. In order to determine if statistical techniques could be used to detect the similarity between these two poems, a hierarchical agglomerative cluster analysis on relative word frequencies within each text was performed. The resulting grouping provided by this analysis agrees with the conclusions made by scholars of Old English. In an attempt to identify which words explain the differences and similarities between the two poems Daniel and Azarias, we take a look at two methods, one parametric and one nonparametric, to try to determine which words may be associated with the groupings presented by the cluster analysis.

Amanda Kriesel, Minnesota State University, Mankato
Mathematical Modeling of TBE

Tick-Borne Encephalitis is a virus that affects ones nervous system and is transmitted from tick to human through tick bite. In recent years, the number of cases of tick-borne encephalitis in Europe has been increasing. This mathematical biological model of Tick-Borne Encephalitis was created in order to further the understanding of such phenomenon, as well as study the relationship between vectors and their hosts. Specifically, this investigation will focus on the population model of ticks in certain regions and its correlation to tick-borne encephalitis infections in the region. Optimal Control for a vaccination will also be explored.

Florida Levidiotis, University of Mississippi
Classifying Zero Divisor Graphs

This project consists of examining the 21 connected, five-point zero divisor graphs, determining which are possible if they are constructed from equivalence classes of the zero divisors, and classifying them based on those assessments.

Emese Lipcsey-Magyar, Skidmore College
Modeling Time Dependent Electroosmotic Flow

Electroosmotic flow (EOF) is the motion of liquid induced by an applied potential across a capillary tube or microchannel. EOF has many applications including the purification of contaminated drinking water and in the analytical chemistry separation technique of capillary electrophoresis. However, EOF leads to inconsistencies in these separations, thus understanding the dynamics of EOF will lead to more reproducible analyses. Experimental data measuring time dependent flow in capillary electrophoresis indicates that a change in the buffer solution inside the capillaries clearly affects the bulk flow within the system. We have investigated several functions, $v(t)$, using least-squares optimization methods such as Newtons method and the Levenberg Marquardt method to model this flow as a function of time. As a result of our investigation we believe that EOF in a dynamic buffer setting is most appropriately modeled by a biexponential function, $v(t) = Ae^{r_1 t} + Be^{r_2 t}$.

Melissa Martinez
see **Belinda Cruz**

Laura McCormick, Louisiana State University-Shreveport
Square Products of Punctured Sequences of Factorials

The following problem is solved: for a positive integer n, for what m is $(\prod_{k=1}^{n} k!)/m!$ a perfect square $(1 \leq m \leq n)$? All solutions for even n will be presented. For odd n it will be demonstrated that no solution exists. Additionally, J. Nagura's under-appreciated improvement on Bertrand's Postulate will be highlighted, st helped facilitate the completion of these proofs.

Brittney Miller, University of Southern California
Representing Invariant Manifolds to Design Planet Finder Missions

Interest lies in calculating periodic Lyapunov orbits around the Lagrange point L2 in the Sun-Earth system. The objectives of this project include computing trajectories that approach these orbits and reconstructing the surfaces of invariant manifolds on which these trajectories are located using two different approaches, the level set method and fat trajectories. The goal is to select an ultra low-energy trajectory from the surface of the manifold, traveling from a parking orbit about the Earth to a Lyapunov orbit about L2. These ultra low-energy trajectories have been used in many recent space missions (for example, Genesis, Herschel, and Planck). The lower cost and weight of the fuel is more economical than the longer travel time for this kind of transfer compared to a conventional Hohmann transfer.

Krista Newell, University of Wisconsin-Oshkosh
A Geometric Mean Based SSD

There are several competing methods for portfolio selection. Haley and McGee (2006) showed that the Sum-of-Squared Divergence (SSD) portfolio is equivalent to the Safety First and Sharpe Ratio portfolios. Their portfolio rule was based on the arithmetic mean of the portfolio returns, so a reasonable alternative would be to explore the geometric mean. This paper investigates the relationship between the SSD selection rules based on the arithmetic mean and that based on the geometric mean. It shows that for small rates of return, the two selection rules are approximately equal; however, when the rate of returns deviate from zero, the two methods are fundamentally different.

Catie Patterson, Furman University
Scheduling First Year Seminars

First-year seminars are designed to help incoming freshmen adjust to college-level material and work load. At Furman, students are asked to indicate at least five choices for seminars in which they have some interest. Here we look at the problem of determining how many choices to give students so as to ensure, with high probability, that a given percentage of students will be scheduled to a preferred class.

Katherine Poulsen, Columbia University
Asymptotics for Class Numbers and Strict Class Numbers for Fundamental Discriminants

Take $h(d), h_+(d)$ (respectively) to be the class number, strict class number associated to an integer d. The class number is typically defined in the context of equivalence or strict equivalence classes of ideals in the field $\mathbb{Q}(\sqrt{d})$, for d a fundamental discriminant. In its original context $h_+(d)$, for $d \equiv 0, 1 \bmod 4$ and not a perfect square, is the number of strict equivalence classes of binary quadratic forms of discriminant d. A major open question, conjectured by Gauss, asks, for $d > 0$, if $h(d) = 1$ infinitely often as $d \to \infty$. Using genus theory, one can greatly restrict the number of classical discriminants for which this can possibly occur. We investigate the question for such candidates among fundamental discriminants, and derive asymptotics for $h(d), h_+(d)$, and related functions in the range $d \leq 5.2 \times 10^7$.

Stephanie Reed, University of South Dakota
Controlling Plague Among Prairie Dogs

Commonly known as Bubonic Plague in humans, the Sylvatic Plague in prairie dogs is causing extinctions of numerous prairie dog towns across the Plains. The once thought extinct Black Footed Ferret feeds on prairie dogs almost exclusively, and South Dakota is a near perfect reintroductions sight. However, if the prairie dogs are dying, the Black Footed Ferrets risks extinction. By scaling logistic differential equations, we were able to find four equilibria: (1) Trivial, (2) Only healthy prairie dogs, (3) Only healthy prairie dogs and healthy fleas, and (4) Coexistence of healthy and plagued prairie dogs and fleas. The scaled parameter alpha (death rate of fleas divided by death rate of prairie dogs) is the control parameter. By changing alpha, we are able to obtain graphs of the aforementioned equilibrium points.

Lauren Schmidt, Murray State University
The Mathematics of Indian Drums

We will discuss the mathematics of Indian drums with a focus on the tabla and mridangam. These drums have evolved over many centuries and are the only known drums with harmonic properties, making them in some sense the ideal drums. We will discuss solutions of the wave equation modeling the vibration of these drums. We will formulate an optimal design problem for the mridangam drum, in an attempt to determine if the historic ideal drum is mathematical optimal.

Emily Sergel, Rutgers University
Biorthogonal Polynomials

Recently, Bertola, Gekhtman and Szmigielski generalized commutative orthogonal polynomials to obtain what they call biorthogonal polynomials over the real numbers.In this poster, I will present the results of my summer REU which are as follows: 1)A completely algebraic definition of biorthogonal polynomials that holds for noncommutative division rings. 2)A construction of biorthogonal functions with respect to some bimoments using quasideterminants. 3)A proof that finite recurrence relations exist for certain types of biorthogonal polynomials, as an analogue of a proof for commutative biorthogonal polynomials by Bertola, Gekhtman and Szmigielski. 4)A broad extension of Favard's theorem which states that any two sequences of polynomials is biorthogonal with respect to some inner product.

Ngoc Thai, Truman State University
An Epidemiological Agent-Based Model of Tuberculosis

Latent TB patients may become clinically ill with active TB as a consequence of exogenous reinfection ,in addition to primary TB infection.HIV/latent TB infected individuals are also at a much greater risk of developing active TB.The growing burden of TB worldwide is also linked to Multidrug-resistant TB. We use NetLogo to design and implement an epidemiological agent-based model of TB. First,we simulate a two-strain TB model to determine epidemiological transmissions of non MDR-TB and MDR-TB in a homogeneous mixing. We then incorporate HIV and exogenous reinfection into our model to study their effects on different qualitative aspects of TB. The basic reproductive number, R0, a metric in epidemiology to determine whether an infectious disease will spread,is directly calculated from our model. Our sensitivity analysis of R0 suggests that the probability that an immunecompetent individual contacts an infectious individual and receives infection is the most significant factor for the disease to sustain.

Jasmin Uribe, University of Arizona
Modeling Transcriptional Regulation

Many fundamental questions in biology boil down to the relationship between genotype and phenotype. We are working towards a computational model of this relationship, starting with an arbitrary cis-regulatory genotype, and generating a computational phenotype in terms of transcription factor protein concentrations over time. The ultimate goal is to simulate the evolution of this "toy" gene regulatory network. As a component of this larger goal, our model mechanistically simulates transcriptional regulation through interacting transcription factors (TFs) that bind and unbind to available portions of DNA. We must track TF binding configurations for all nucleosome-free regions. This requires the storage of a huge number of potential configurations. This project presents a statistical approach, using a Boltzmann Chain, combined with a thermodynamic framework and dynamic programming to overcome this challenge.

Nicole Williams, Sam Houston State University
Computerized Tomography and Some Mathematics Behind it

Computerized Tomography is a technology that enables one to see inside of a non-transparent body. The basic problem in computerized tomography is the reconstruction of a function f, describing for instance a particular organ or a tumor, based on some partial information which is values of integrals over a set of lines, planes, or circles . Some methods involved in reconstructing this function include the Radon transform and Fourier transform. Applications of these processes can be found not only in medicine but also astronomy, GPS, archeology, and electron microscopy.

Kan Wu, Purdue University Calumet
A Time-Varying Drug Efficacy Model for the HIV Drug Resistance during Antiretroviral Treatment

The severe and deadly impacts of AIDS virus have motivated scientists to investigate them in the sequential stages of HIV (Human Immunodeficiency Virus) infection. Studies are focusing on finding the most effective therapeutic treatments/strategies. A combination of several antiretroviral drugs usually contributes to a substantial decrease in the viral concentration and, therefore, an increase in CD4+ T-cell concentration. However, continuing virus mutations lead to the emergence of drug resistant strains, that in turn, if not treated in time, leads to the progression of the disease. We will develop a mathematical model that incorporates the effect of healthy T-cells, infected T-cells, virus concentration, and immune effectors, to investigate how the time-varying drug efficacy affects the antiviral response. Using mathematical modeling we will test HIV resistance and will be able to provide information allowing the design of effective individual strategies of Highly Active Antiretroviral Therapy.

Guangtao Zhang, Clarkson University
Differential Mobility Analyzer Testing

Differential Mobility Analyzer (DMA) is a device that was used to classify sub-micrometer aerosol particles according to mobility while keeping them suspended in air. Aerosol size distribution measurements are critical for health-related and global climate assessments, as the impact posed by particles is often related to their size, mass, and number. The used instruments only allow low aerosol flow rate; in order to reduce the measurement error, a higher flow rate DMA is needed. The purpose of this experiment is to determine the accuracy of a new high-flow DMA that has been developed in the lab and prepare for the aerosol measurements in the upper atmosphere. The instrument was characterized by a Tandem DMA setup which the voltage of the upstream DMA was kept constant while the downstream DMA was changed continuously. Thus, a nanometer range of particle size was selected with the upstream DMA and the size distribution was analyzed by the downstream DMA. Data under different voltages was analyzed by MATLAB.

Jingyu Zhao, Stony Brook University
Curves and Surfaces

Surfaces from a topological point of view; Examples: Cylinders and Moebius bands; The sphere, the torus and the Klein bottle; Construct surfaces; Deformation classes of surfaces.