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

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POSTER ABSTRACTS

Posters by Undergraduate Students

Audrey Baumheckel, California State University, Fresno
[A][1] *Cheeger Constants of Planar Trivalent Graphs and Fully Augmented Links*

Fully augmented links are an important class of hyperbolic links that can be associated with perfect matchings on planar trivalent graphs. This project proves some results about Cheeger constants of planar trivalent graphs and makes initial investigations into how it relates to the Cheeger constant of associated fully augmented links.

Jessica Bennett, Brown University
[A] *The Finite Blocking Problem on Cyclic Covers of the Regular Octagon*

Finding when two points on a translation surface are finitely blocked under straight line flow is an open question for many translation surfaces. We investigated a specific instance of this problem: finite blocking on cyclic covers of the regular octagon. In this presentation, we answer the finite blocking problem in the case of double covers of the octagon and propose an approach for degree 3 covers of the octagon.

Allison Dennis, Texas A&M University
[A] *Multistationarity in Biochemical Networks*

Multistationarity, defined as the existence of positive equilibria, or steady-states, is significant in the research of many cellular processes. It is significant in crucial cell behaviors, ranging from differentiation, generating oscillatory responses, and remembering transitory stimuli. In my research, I hope to answer the research question regarding the number and conditions of the set of rate constants that give multiple positive equilibria for any chemical reaction network. In my research, I analyze three different, specific examples of smaller reaction networks and investigate the unique conditions regarding the potential existence and number of equilibria for each network. I address the issue of determining both the parameters in which a reaction network displays multistationarity and the number of positive steady-states for the reaction network. I implement my approach by studying the System of Ordinary Differential Equations that model the steady-state equations of a reaction network. I also investigate the roots of the steady-state equations using the Descartes' Rule of Signs to determine the number of positive roots. I apply the discriminant to determine the parameters of the reaction rate constants of the network that give multiple positive roots. By doing so, studying these positive roots of the steady-state equations allows me to understand the conditions of multiple positive equilibria (or MPE) for a reaction network, which is a widely researched problem in mathematical biology.

Chloe Griffin, Converse University
[B] *High-Order Operator Splitting Schemes for Stiff Differential Equations*

Scientists use differential equations to model physical, biological, and chemical phenomena. A differential equation relates a quantity of interest's dynamics to a function of its derivatives. We developed high-resolution operator splitting schemes to yield efficient, inexpensive solution approximations for stiff differential equations. Stiff differential equations are equations where fast dynamics require a strict stability restriction on our time step to prevent the error from magnifying uncontrollably. In general, stiff problems require expensive implicit solvers to avoid limiting time step restrictions. For large problems, the computational effort needed becomes increasingly prohibitive. To alleviate this cost, we apply splitting techniques to separate the problem into several components for simpler sequential implicit solves. We then use correction strategies to reduce errors caused by splitting, resulting in fast, accurate methods. Although the number of implicit solves increases, we show that the cost of each solve declines, resulting in an efficient scheme.

[1] [A] indicates poster session "A", [B] indicates poster session "B"

Sarah Harkins, Francis Marion University
[A] *Comparative Study of Gaussian Mixtures and Clustering on Health Data*

In this project, K-Means clustering and Gaussian Mixture Models (GMM) were compared and contrasted on their abilities to decipher clusters in 1-dimensional data sets. The K-Means is a popular clustering algorithm, but there are aspects that it fails to capture that possibly leave the GMM to be the superior algorithm. The abilities of the algorithms were compared and contrasted with a simulated data set. The algorithms were then further compared on a data set from the National Health and Nutrition Examination Survey. This data set includes 1,030 people ages 8 to 19 years old and their respective BMI. The goal of this application was to see if the algorithms would accurately discern between the group of males versus the group of females. GMM is typically used with higher-dimensional datasets. However, only one is used for this project, for example, features like BMI. The GMM delivers a more accurate distribution than K-Means due to the consideration of the standard deviation.

Anika Homan, Dordt University
Jocelyn Zonnefeld, Dordt University
[A] *Exploring the Min-Plus and Max-Plus Finite Tropical Semirings*

Recent work has characterized properties of algebraic structures by exploring their associated directed graphs, which can be thought of as a visual representation of the structure's Cayley tables. Our work expanded on previous efforts regarding the directed graph of the finite tropical semiring. Building on the previous analysis of the structure of the directed graph, we explore graph-theoretic implications of the minimum and maximum definitions of tropical addition. We give formulas for the in-degree of vertices in the directed graphs and the number of vertices with a given in-degree. We also analyze the connected components of the directed graphs and present formulas for the number of connected components and the greatest common divisor of the vertices in a given component.

Kayla Kenny, State University of New York at Geneseo
[B] *Rainwater Harvesting Potential on Geneseo's Campus*

One of the best ways that Geneseo can become more sustainable is by introducing a rainwater harvesting system. The first steps to introducing such an innovation to our campus is to start with a smaller scale project to set a measure for the costs, planning, and overall direct benefits. For this reason, the following poster focuses on what would be needed in order to maximize the harvesting potential by increasing the collecting area to provide for the campus's gardens from April to October each year.

This project shall focus on creating two aboveground tanks that will be used from April to October to provide water for the school's gardens during the summer. As these will only be used for plants rather than human consumption, the filtration needed for these is minimal to none; the most that could be needed is a mesh screening over the gutters to prevent large debris. One tank shall be placed near Brodie Hall while the other shall be placed between Newton Hall and the Integrated Science Center; since these latter two buildings are connected, it would make the most sense to use both to provide for one tank.

Presley Kimball, Creighton University
[B] *An ODE Model of Yaws Elimination in Lihir Island, Papua New Guinea*

Yaws is a chronic infection that affects mainly the skin, bone, and cartilage and spreads mostly between children. The new approval of a medication as treatment in 2012 has revived eradication efforts and now only few known localized foci of infection remain. The World Health Organization strategy mandates an initial round of total community treatment (TCT) with single-dose azithromycin followed either by further TCT or by total targeted treatment (TTT), an active case-finding and treatment of cases and their contacts. We develop the compartmental ODE model of yaws transmission and treatment for these scenarios. We solve for disease-free and endemic equilibria and also perform the stability analysis. We calibrate the model and validate its predictions on the data from Lihir Island in Papua New Guinea. We demonstrate that TTT strategy is efficient in preventing outbreaks but, due to the presence of asymptomatic latent cases, TTT will not eliminate yaws within a reasonable time frame. To achieve the 2030 eradication target, TCT should be applied instead.

Stephanie Marsh, University of Nebraska-Lincoln
[A] *The Synchronization of Oscillations in the Brain and Heart During Slow-Wave Sleep*

There are increased interactions between the brain and the heart during sleep. Previous research has shown directional coupling between oscillations in delta wave activity and heart rate variability during sleep. Because delta wave activity is especially prominent during slow wave sleep, we are studying the synchronization of physiological oscillations found in EKG and EEG data during slow wave sleep. We studied open-source 8-hour recordings of healthy controls and patients diagnosed with REM behavior disorder, insomnia, or nocturnal frontal lobe epilepsy during slow wave sleep. We collected over 1,400 occurrences of uninterrupted slow wave sleep in preparation for the time series analysis. The next step is to learn the phase of the waves via a Hilbert transform, which will be used to obtain the phase-locking index between the EEG and EKG waves. We will then implement a First Return Map to evaluate the fine temporal structure of the dynamics of the synchronization.

Hope Neveux, Marist College
Lesley Wu, Mount Holyoke College
[B] *Markov Chains and Abstract Strategy Games: Tapatan and Picaria*

Markov chains have been used to solve a variety of problems and are especially applicable for investigating abstract game play. We consider the traditional two-player abstract strategy games of Tapatan and Picaria from several perspectives: combinatorial exploration of board state spaces, Markov chain analyses of various strategies, and development of optimal strategies where possible. For an automatic upper hand in Tapatan, a player need only go first. Depending on the response of the second player in the early stages, the first player will have two possible strategies, either of which, when employed, will trap the opponent in an ultimately losing sequence of moves. It had previously been shown that there is no winning strategy for Picaria.

Imuseoluwa Obembe, University of Central Oklahoma
[B] *Identifying Predictors of Treatment Response from Electrocardiogram Data*

The goal of this research is to predict the response of patients with Paroxysmal Atrial Fibrillation (PAF) to a non-invasive treatment: low-level electrical stimulation of the vagus nerve. In particular, we are developing statistical models to identify possible predictors from PAF patient electrocardiogram (ECG) data. Our model features depend on using the Kors-Regression matrix to form the three-dimensional vectorcardiogram (VCG) from the filtered ECG data and then separating the waveforms into individual heartbeats using the well-known Pan-Tompkins algorithm. From this ECG and VCG data, we can calculate model input features such as the heart rate, heart rate variability, and QRS angle/magnitude to then apply statistical techniques to determine the role of these features in predicting PAF patient treatment response. This poster presents our preliminary work toward such feature derivation and model construction.

Nidhi Pai, Georgia Institute of Technology
[B] *Multi-Hypothesis Tracking of Space Objects and Targets*

Over 20,000 artificial satellites currently orbit the Earth, and thousands more are launched each year. As the sky becomes more cluttered, tracking the trajectories of objects in Earth's orbit is critical. Sensors such as radar are currently used to measure satellite locations; however, these measurements are inherently noisy. Dealing with this noise is especially challenging when tracking many objects in close proximity. Multi-Hypothesis Tracking (MHT) is a prevalent tracking algorithm for monitoring multiple objects based on a deferred decision-making approach. In this work, we empirically test a tree-based, track-oriented version of the MHT algorithm in difficult object tracking scenarios and develop improvements to overcome current shortcomings. These include a novel track scoring criteria based on the chi-squared test for variance. In addition, we develop heuristics for gating, thresholds for adding new tracks or incorporating missed measurements, and a modification to the traditional MHT algorithm that prevents new objects from being detected from false alarms prematurely. In light of simulation results, the benefits and drawbacks of MHT are discussed.

Muthuporutotage Perera, Wagner College
[A] *Analyzing New York City Shooting Data*

An issue that has been prevalent in the United States is gun violence. Some people believe that owning guns is necessary while others think that the presence of guns puts us in more danger; however, what everyone can agree on is that safety is important. Studying shootings can give us insight as to what common outcomes of shootings are and lead us to finding solutions to keep us safer. This project focuses on the issue of gun violence in New York City in order to see what commonalities there are to shootings in this specific city. By starting with one city, more and more locations can be studied and compared, which can help educate us on the issue as well as address ethical concerns. Through the use of Mathematica programming, an NYPD dataset was analyzed. The research found how the five boroughs compare and contrast, what dates and times shootings are likely to occur, and what the common traits of victims are. Based on the patterns found, one can interpret what can decrease their chances of getting shot in NYC and discover what underlying ethical issues need to be addressed.

Kaleigh Rudge, Colorado School of Mines
[B] *Understanding Energy Dissipation Through Nonlinear Waves on Quantized Vortex Filaments*

Vortex filaments are a fundamental structure in quantum fluid dynamics for transferring energy between length scales. Understanding their motion and the relationship between the transfer of energy and the helical patterns of the vortex lines are crucial in understanding the decay of free quantum turbulence. In order to understand these relationships, we need to find connections between the descriptions of classical and quantum fluids. We start with taking the Navier-Stokes equation to get the continuum mechanics model, we relate it to quantum mechanics through the Gross-Pitaevskii equation. This is done as the Gross-Pitaevskii equation gives a subset of rules for particles experiencing quantum behaviors. Taking these relationships ultimately will allow us to find how the Gross-Pitaevskii equation into hydrodynamics. Additionally, these relationships will help us understand what phenomenon in classical fluids continues into quantum fluids, leading us to understand the geometric properties of vortex filaments and how energy transfer mechanisms work within quantum fluids.

Ana Sammel, Humboldt State University
[A] *Modeling SARS-CoV-2 Interactions with the Immune System in COVID-19*

We propose and analyze a mathematical model for the interaction of immune cells and SARS-CoV-2 infected cells using a system of ordinary differential equations with the goal of understanding the immune mediated viral clearance of COVID-19. We numerically explore parameter sets that yield qualitatively different behavior such as viral clearance, viral resistance, and rebounding infection. We apply equilibrium and bifurcation analysis to the model and discuss results in the context of the biological pathways the model represents. A major goal of this work is the determination of parameters that play a critical role in disease outcome. Additionally, we develop an agent-based model that includes a spacial component to complement our dynamical systems approach.

Ashley Tran, Institute for Pure and Applied Mathematics
[A] *Applications of Regression Tree and Linear Model Evaluation in Quantitative Trading*

At the heart of automated quantitative stock trading is a model to forecast stock returns at a desired horizon. We developed a cutting-edge forecasting model that predicts stock returns 10 minutes into the future. We constructed one such model by using existing tools in statistical analyses and regression tree models. The algorithm was built to perform (1) data wrangling, (2) feature selection, (3) regression tree model training, and finally (4) future stock return predictions. All these processes require an extensive amount of computational power, and we utilized the supercomputer cluster provided by UCLA to perform these calculations. The poster will be aimed at a general audience.

Azlan Tubbs, Colorado School of Mines
[B] *Mathematical Modeling to Investigate Dual-Pathway Inhibition by Anticoagulant Drugs*

The purpose of blood coagulation is to halt the flow of blood from a damaged vessel for the vessel to heal and repair. Overlapping enzymatic events that take place on platelet surfaces control the process of coagulation, beginning when the wall of the blood vessel is injured and ending when aggregated platelets seal the injury without disrupting blood flow. Dual pathway inhibition, in which both antiplatelet and anticoagulant drugs are used in combination, promises therapies for reducing risks of developing harmful clots that lead to coronary and cerebrovascular ischemia. Although information exists concerning the effectiveness and success of dual pathway inhibition therapies, the mechanism of such approaches remains ambiguous due to a lack of ability to observe the detailed biochemical interactions during the dynamic clotting process. Mathematical modeling is a powerful tool that allows for efficient simulations of the clotting process and provides access to the dynamic concentrations of all proteins, cells, and their interactions within the system, under the influence of flow. This project will build on an experimentally validated, mechanistic mathematical model of flow-mediated coagulation and platelet deposition. A combination of the antiplatelet aspirin and the anticoagulant rivaroxaban will be considered in the model and the clotting process will be simulated for various concentrations of drugs and injury types. Further exploration with the model will determine the underlying mechanisms of the dual-pathway inhibition.

Kaila Uyeda, Haverford College
[A] *Modeling Foodweb Interactions based on Predator Movements and Habitat Use*

Insect and food web interactions are determined by behavior patterns, body size, non-competitive predator effects, and microhabitat use. Mathematical models have predicted locations of insect and arachnid predators in microhabitats that incorporate those parameters, but movements of predators over time are often not incorporated into these models. Data from laboratory observations of location of ground beetles, wolf spiders, pirate bugs, and ladybugs in cages containing aphid prey were used to determine movement patterns of predators. We create a mathematical model of the observations made to investigate the relationship between predators and their cage location (wall, ground, bean plant, barley plant, under leaves of bean plants) and their behavior (active, walking, resting, or feeding) over time. By gaining a stronger understanding of predator behavior and movements, food web dynamics can be better represented over longer periods of time, especially as food sources may change during those periods.

Tanvi Vishwanath, Texas A&M University
[B] *A Tensor SVD-based Classification Algorithm Applied to fMRI Data*

To analyze the abundance of multidimensional data, tensor-based frameworks have been developed. Traditionally, the matrix singular value decomposition (SVD) is used to extract the most dominant features from a matrix containing the vectorized data. While the SVD is highly useful for data that can be appropriately represented as a matrix, this step of vectorization causes us to lose the high-dimensional relationships intrinsic to the data. To facilitate efficient multidimensional feature extraction, we propose a projection-based classification algorithm using the t-SVDM, a tensor-based extension of the matrix SVD. We describe the tensor framework and this algorithm for general higher-order tensors and apply the algorithm to the StarPlus fMRI dataset. Our numerical experiments demonstrate that there exists a superior tensor-based approach to fMRI classification than the best possible equivalent matrix-based approach. Our results illustrate the advantages of our chosen tensor framework, provide insight into beneficial choices of parameters, and could be further developed for classification of more complex imaging data.

Abigail Voronyak, Concordia College, Moorhead
[B] *Virtual Knots and Zero Crossing Weights*

Knot theory is a subfield of low-dimensional topology that studies knots and links using combinatorial, geometric, and algebraic techniques. Virtual knot theory is a generalization of the classical theory that rapidly expands the number of objects of study. For example, there is only one unique classical knot with 4 crossings, but there are over 500 unique virtual knots with 4 crossings. We can represent virtual knot diagrams by Gauss codes, from which we can extract the "weight" of each crossing. It is well known that for classical knots, every crossing has weight zero, but there also exist nonclassical knots with this property. By investigating zero crossing weight knots, we found several local diagrammatic moves that preserve crossing weights. All virtual knots with 6 or fewer crossings and all zero crossing weights are related to a classical knot by these moves.

Lesley Wu, Mount Holyoke College
[B] see **Hope Neveux**

Jocelyn Zonnefeld, Dordt University
[A] see **Anika Homan**