MAKO 2024: Abstracts

Invited Talk: “How and Why to Count Polynomial Roots”
Dr. Matt Wright, Missouri State University

This talk will discuss methods for estimating the number of real roots of certain families of polynomials, including a novel variation on Descartes’ Rule of Signs. Applications of these results to single variable and multivariable polynomial interpolation will also be included, as well as implications on classifying strictly positive definite functions.

“An SIR model for Colorectal Cancer with Curcumin Treatment”
AJ Agers, Aly Boyd, Kami Eslinger, and Kylie Warden, Drury University
Faculty Mentor: Dr. Colin Barker, Drury University

According to the American Cancer Society, colon cancer is the third most commonly diagnosed cancer and the second leading cause of cancer related deaths globally, with a particularly high incidence in the United States, and is expected to cause 53,010 deaths in 2024. The disease's high rates of recurrence and resistance to standard treatments result in a poor prognosis for advanced cases, highlighting the desperate need for innovative treatment strategies. Curcumin, a natural compound derived from turmeric, has demonstrated significant anti-cancer properties, particularly in targeting molecular pathways critical to colon cancer progression. However, its clinical application is severely limited by poor bioavailability and rapid metabolism. This project aims to overcome these limitations by using mathematical modeling to optimize the design and efficacy of curcumin and its different analogs for colon cancer treatment. We propose a comprehensive approach that integrates data from ELISA for EGFR protein quantification to develop and refine mathematical ODE models that predict the therapeutic potential of different curcumin analogs. Our goal is to identify the most promising analogs for further development, offering new hope for effective colon cancer therapies.

“Using the Schmidt Decomposition Method to Determine Quantum Entanglement and Its Application to Quantum Information Theory”
Lane Boswell, Drury University
Faculty Mentor: Dr. Ying Cao, Drury University

The Schmidt Decomposition (SD) method is a way of changing the basis that expresses a mathematical object, such as a function or a matrix. It has wide application in many science and engineering fields. This presentation will introduce an important application in quantum information theory; namely, how SD helps in determining quantum entanglement. Entanglement arises from quantum superposition, which in linear algebra terms is a linear combination of basis vectors (called states) with attached probabilities. Typically, we make these basis vectors orthonormal. Due to superposition, particles can be entangled with each other, meaning the state of an entangled particle is determined by a measurement on the other entangled particle, and vice versa. An information-theoretic application in quantum cryptography will also be discussed.

“An Elementary Exploration of Cryptography”

Benjamin Brewster, Evangel University
Faculty Mentor: Dr. Jeremy Osborne, Evangel University

This presentation will provide a brief overview of some of the major ciphers used in elementary cryptography and some of the history behind them. We will explore both the mathematical methods of encrypting messages and some of the methods of decrypting those same ciphers. This presentation desires to generate an understanding behind the development of cryptography leading up tot the 20th century. As this is just the tip of the cryptography iceberg, the presentation hopes to spark interest into a field that relies heavily on both pure and applied mathematics.

“Super Basic Palindromic Numbers”

Samuel Fulbright, Drury University
Faculty Mentor: Dr. Colin Barker, Drury University

Palindromes are most commonly known when expressed through words like racecar, madam, level, and many others. Palindromes can also be expressed numerically, like the numbers 35653 and 121. In my research, I explore palindromic numbers in various ways to understand the relationship between palindromes and the bases they are expressed in. First, I use a formula that reverses the digits of a number to mathematically define a palindromic number. Then, I develop formulas to convert a single number from one base to another and use the formulas to determine if and when numbers are palindromic when expressed in multiple bases given any integer. I conclude by coding all of these formulas in python to generate a program which determines how many times a number in base 10 is palindromic when expressed in bases 2-10.

“The HRT Conjecture in Finite Fields”

Christopher Housholder and Layna Mangiapello, Missouri State University
Faculty Mentor: Dr. Steven Senger, Missouri State University

We present a preliminary report on our pursuit of the HRT Conjecture in finite fields, which states that for any suitable function, any set of time and frequency shifts of that function should be linearly independent.

“Machine Learning for The Game of Hex”

Justin Kroh, Drury University
Faculty Mentor: Dr. Bob Robertson, Drury University

The Game of Hex is a simple, turn-based, two-player board game that challenges players to connect opposing sides of a board by playing on hexagonal tiles. It is known that the player who goes first in a game of Hex has a winning strategy, but in general the strategies are unclear. In order to explore potential strategies, we have developed a rudimentary, reinforcement-based machine learning algorithm from scratch. Our algorithm uses probability distributions to determine moves for two simulated players and updates said distributions based on who wins and who loses each game. The algorithm has undergone multiple iterations, each of which improved the overall performance of both simulated players.

“Analysis of Braess’s Paradox using Lagrange Multipliers”

Jayson McDermott, Lyon College
Faculty Advisor: Dr. Wesley Perkins, Lyon College

Imagine a city planner decides to add a new road to alleviate traffic congestion. Surprisingly, instead of reducing travel times, the new route increases delays for everyone. This counterintuitive scenario, known as Braess’s paradox, reveals a paradoxical truth in networked systems: optimizing individual paths doesn’t always optimize the whole. To explore this further, we delve deeper into the toy model introduced by Braess. We utilized Lagrange multipliers for our optimization and extend the analysis of Braess’s paradox across any number of drivers, offering fresh insights into the underlying dynamics of traffic flow and the surprising consequences of infrastructure expansion.

“Toe Tac Tic - A Game and It's Winning Strategy”

Tori Risner, Evangel University
Faculty Mentor: Dr. Jeremy Osborne, Evangel University

This presentation discusses a different spin on a classic game. We will introduce and explain reverse Tic Tac Toe, which we will call Toe Tac Tic. We will then explain the strategy laid out by Daniel I. A. Cohen. Finally, we will prove why this strategy is successful and the uniqueness of this method.

“Mathematical Modeling of EGaIn Droplets Sliding Down an Inclined Plane”

Luis Schneegans, University of Missouri, St Louis
Faculty Mentor: Dr. Hangjie Ji, North Carolina State University

Eutectic Gallium-Indium (EGaIn) is a room-temperature liquid metal alloy that dramatically changes its surface tension and dynamics under an applied electric field. EGaIn has been used heavily in soft electronics engineering due to its high conductivity, malleability, and safety. However, the absence of mathematical modeling in the current literature makes its behavior difficult to understand and predict. In this study, we present a one-dimensional lubrication model for the dynamics of an EGaIn droplet moving along an inclined plane. Our model incorporates essential physical effects and parameters including oxidation, capillary action, diffusion, gravity, and Marangoni effects. In particular, we incorporate effects of the electric field, both through electric forces and changes in oxidation flux. We model the thin oxide skin of the droplet,which modulates the interfacial surface tension, as an insoluble surfactant at the surface. Oxidation, while observable in the physical setting, cannot be well measured, calling for an alternative method to quantify oxidation flux. Utilizing experimental data, we calibrate system parameters and qualitatively obtain numerical simulation results comparable to experimental observations. Stability analysis was conducted to understand the impacts of physical effects on our model. We find azimuthal curvature to be the main contributor in the process of threading that also promotes the formation of satellite droplets. Our model has demonstrated success in reproducing the observed dynamics of an EGaIn droplet and provides a valuable resource for further investigation and uses of EGaIn.

“Evaluation of Self-Outputting Functions”

Sam Stagner, Drury University
Faculty Mentor: Dr. Bob Robertson, Drury University

Define f to be a self-outputting function if:

$$f(f(x)) = f(x) \text{ for all } x.$$

The question I hope to answer is this: What are all of the self-outputting functions? In this talk, I will show that the only continuous functions $f : \mathbb{R} \to \mathbb{R}$ are $f(x) = x$ and $f(x) = k$, for some constant k. I will then demonstrate necessary restrictions on f for discontinuous self-outputting functions, namely that $f(x)$ must equal x at least once for all f, and that there are no discontinuous solutions for which $f(x)$ is equal to x for exactly one value of x. Then, I hope to illustrate the relationship between subintervals of the domain and range of f when f is discontinuous.