Abstracts

Morning Plenary Address

Pebbling Problems and Paradigms
Dr. Glenn Hurlbert, Virginia Commonwealth University

There are many areas in graph theory and optimization that could all go under the umbrella of Moving Stuff Around in Graphs — graph pebbling is one of them; domination, network optimization, cops and robbers, max flow, zero-forcing, and graph burning are among other examples. In graph pebbling we encounter a configuration of pebbles on the vertices of a graph and are allowed to make moves by removing two pebbles from some vertex and placing one pebble on one of its neighbors. For a specific target vertex we ask if it is possible to place a pebble on it after a sequence of pebbling moves. From here, a range of invariants (pebbling numbers of various types) can be explored, each measuring what size of initial configuration is required to reach a target. We will introduce the audience to this intriguing topic, share a few nice techniques and results, and leave you with a few problems to ponder.

Afternoon Plenary Address

The Finite Element Method: Engineering Advances Through Mathematical Research
Dr. Manil Suri, University of Maryland, Baltimore County

The Finite Element Method (FEM) is one of the most powerful and commonly used tools for mathematical modeling, with applications in such diverse fields as mechanical engineering, medicine, film animation and even shoe manufacturing. Although invented by engineers, the FEM has benefited immensely from the efforts of mathematicians who have cast the method in a theoretically sound framework, thereby providing improvements and many new insights. In this talk, we will highlight such FEM symbiosis between engineering and mathematics to show how mathematical research works in real life, and the successes (and failures!) a research mathematician might expect in terms of commercial applications of their results. We will also describe some of the new advances and challenges that AI is bringing. REFERENCE: This talk is partially based on an article for general readership the author has published in Scientific American magazine.

Student Presentations

Data Assimilation and Deep Learning for Turbulence Models
Dean Banzon, William Magrath, Nathan Ketterlinus, and Christopher Toomer, Towson University

In this study, we focus on studying Navier–Stokes–α turbulence models using data assimilation and deep learning. Our approach pairs data assimilation (nudging from coarse, noisy observations) with deep networks to drive the system toward the true solution. We outline the setup, describe the nudging implementation, and use Lorenz–63 as a baseline. We then apply these ideas to the Navier–Stokes–α models.

Ellipses in Spherical Geometry
Malcolm Black-Howell, Towson University

In Euclidean geometry, there are multiple equivalent definitions for ellipses. Three such definitions include (1) a constant sum of distances to foci, (2) a constant ratio of distance to a focus over distance to a directrix line, and (3) a cone and a plane that have an intersection that is bounded and not a singleton. Cones can be modeled, from a bilinear form S on $\mathbb{R}^3$, as the set of all vectors v such that $S(v, v) = 0$, called the isotropic cone of S. In the literature, conic sections in spherical geometry are defined as the intersection between such isotropic cones and a sphere centered at the origin. This parallels definition (3), and definition (1) holds as a property. However, definition (2) becomes a constant ratio of sines of distances. We shall investigate curves formed in spherical geometry from Euclidean definition (2) and determine if they are conic sections.

Sums of k-th Powers in Ramified 2-adic Rings
Anthony Cerone and Kenny Zeh-Ndelle, McDaniel College

Generalization of Waring's Problem - that for every natural number k there exists an integer $g(k)$ such that every natural number can be written as the sum of at most $g(k)$ k-th powers - have been studied in a variety of contexts from algebraic number fields to non-commutative groups. We will examine values of $g(2k)$ for rings of integers of certain families of ramified extensions of $\mathbf{Q}_2$.

Improved Confidence Intervals for Difference of Proportions with Mixed Paired and Unpaired Data
Izzy Cole, Towson University

Several adjustments are considered for creating the optimal confidence interval for the difference of two proportions with a mixed paired and unpaired sample design. New adjustments are proposed that include new combinations of previously explored data adjustments and are compared to the adjustments explored in Kathman et al. (2025). A scaled interval incorporating several different adjustments that differ based on paired sample size is the recommended interval estimator for a mixed paired and unpaired sample design.

Harmonic Mappings of Riemannian Manifolds
Jorge Gonzalez Acosta, Johns Hopkins University

In their 1964 paper *Harmonic Mappings of Riemannian Manifolds*, Eells and Sampson introduced the concept of harmonic maps: maps that are critical points of the energy functional. Classical examples include closed geodesics and isometric immersions whose images are minimal submanifolds. In this talk, we will characterize harmonic maps using the Euler–Lagrange equations associated with the Dirichlet energy and introduce the tension field. After introducing the basic notions of Riemann surfaces, we will discuss the existence of harmonic maps in two dimensions. If time permits, we will also touch upon aspects of regularity theory.

Sums of k-th Powers in Ramified 3-adic Rings
Keyierra Harris and Ellie Riggs, McDaniel College

Generalization of Waring's Problem - that for every natural number k there exists an integer $g(k)$ such that every natural number can be written as the sum of at most $g(k)$ k-th powers - have been studied in a variety of contexts from algebraic number fields to non-commutative groups. We will examine values of $g(3k)$ for rings of integers of certain families of ramified extensions of $\mathbf{Q}_3$.

An Analysis of Badminton Smash Success Rates
Tanyasai Kadiyala, HCPSS

This badminton performance analysis project uses 2018-2023 Badminton World Federation match-play and rally data. We employed a Chi-Square test for homogeneity to verify the assumption that all categories of shots have an equal probability of winning a point, and the results show that certain shots may have higher probabilities of winning a rally. This study also predicts the success rate of smashes, based on the locations of the birdie and the racket. Players and coaches can use this analysis to inform both offensive and defensive strategies.

Group Law on Tropical Elliptic Curves and Valuated Matroids
Catie Lillja, Johns Hopkins University

Tropical geometry reimagines classical algebraic curves as piecewise-linear graphs. In this talk, I describe an algorithm that endows tropical elliptic curves with a natural group law. Using this structure, we found that the n-torsion subgroup E_n of a tropical elliptic curve is isomorphic to the expected cyclic group $\mathbb{Z}/n\mathbb{Z}$ precisely when $n = 1, 2$ or $6 \mid n$. Next, we construct a partially valuated matroid T_n on the points of the curve via the tropical Plücker relations. Finally, I discuss when this partial valuation extends uniquely to a full valuation on the entire matroid.

The Goldbeter-Lefever Model of Glycolytic Oscillation
Samuel Nemirovsky, Univeristy of Maryland, Baltimore County

Glycolysis, the process by which glucose is broken down, is critical for energy production in nearly all living cells. Experimental data shows that under some conditions the rate of glycolysis is periodic, which we analyze with the Goldbeter-Lefever model. This model takes the enzyme phosphofructokinase-1 (PFK1) as the source of this oscillatory behavior. The PFK1 enzyme binds with adenosine triphosphate (ATP) as both a substrate and an allosteric inhibitor. By assuming that each enzyme complex is in equilibrium, we obtain a quasi-steady-state approximation that effectively models the same behavior as the 14-dimensional system using only two differential equations. Further, a bifurcation analysis demonstrates where oscillatory behavior begins as the glucose input rate is varied. In this expository talk, I will develop the Goldbeter-Lefever model, derive the quasi-steady-state approximation, and demonstrate the efficacy of this reduced model to simulate the dynamics of experimentally observed glycolytic oscillations.

Convex Orderability in Groups
Allison Rogers, Towson University

Our goal is to study the properties of convex orderability and how it connects to other model-theoretic properties, such as dp-minimality. We want to find the properties that make a non-abelian, solvable group convexly orderable; we are currently looking at the infinite dihedral group, the group of upper triangular 2×2 matrices, and $S_3 \times \mathbb{Z}$ as examples. Additionally, we want to find under what circumstances the cross product of two groups, both convexly orderable, will be convexly orderable itself. We have found this to be untrue, in general, but wonder if there are certain cases where it is true.

"Nilpotent" Representations of Cyclic Quivers
Nicolas Rugo, Johns Hopkins University

This talk will first explore the notion of quivers, path algebras, and their representation theory. Then, we will discuss a classic result of Fine-Herstein, finding the probability that a matrix be nilpotent. We will finish it off with

A Cubic Multivariate Digital Signature Scheme Based on UOV and L-invertible Cycle System
Ian Thomas, Towson University

The Unbalanced Oil-Vinegar (UOV) scheme remains a reliable multivariate digital signature scheme, although its primary drawback lies in the large size of its public key. In 2015, Nie et al. proposed a cubic variant (CUOV) that achieved shorter signatures and faster signing at the same security level at the cost of a larger public key, The CUOV along with the later improved versions CSSv and SVSv proposed by Duong et al., were subsequently broken by Hashimoto. In this paper, we propose a new cubic multivariate signature scheme that combines the unbalanced Oil-Vinegar framework with the L-invertible cycle system. We show that our approach delivers fast signing and resists all known attacks, all while maintaining a public key size comparable to the Nie's CUOV proposal.