TUMC 2026 Abstracts of Contributed Presentations

Morning Session

Cole STEM Building Room 201

How to Not Use Zorn's Lemma
Matthew Shank, LeTourneau University

It is well known that Zorn's Lemma, the Well-Ordering Principle, and the Axiom of Choice are all equivalent. Many proofs in other fields of mathematics use Zorn's Lemma. So, we want to create a framework to convert these proofs into proofs that use the Well-Ordering Principle. Since, proofs that use the Well-Ordering Principle are generally more instructive and give us a better idea of what is going on in the proof.

Affine Shapes and Generalized Weak Perspective Projections
David Gray, LeTourneau University

One can describe a polygon very simply by placing a point on each corner. Then the shape of this polygon can be described by a matrix up to some group of transformation, e.g. a rotation, translation, or scaling of this matrix. This idea can be generalized to any two-dimensional image or three-dimensional objects, by placing points on geographically significant locations on the image or object. For three-dimensional objects, if a picture is taken of this configuration, the points are projected onto a two-dimensional plane towards a projection point. We can model these focal point projections using linear transformations called Generalized Weak Perspective Projections. These match three-dimensional objects with two-dimensional images according to their shape up to an affine transformation.

In this talk I will give a brief explanation of these Generalized Weak Perspective Projections and the associated affine shapes. I will also define a metric to measure the distance between two affine shapes. In addition, we will investigate what happens to the measurements of distance when we perturb the configuration by adding “noise” to each point.

Irreducible Representations of the Symmetric Group
Patrick Price, University of Texas at Austin

Given a finite group G, a (complex) representation of G is defined as a group homomorphism G → GL(V), where V is a finite-dimensional complex vector space. Equivalently, this can be thought of as defining a group action of G on V by linear transformations. It is known that all (complex) representations decompose into a direct sum of building blocks called irreducible representations. In other words, if we can classify all of the irreducible representations of a group, then we understand any representation. In the case of the symmetric group S_n, it turns out that the irreducible representations correspond exactly to Young diagrams, which are diagrams with n boxes arranged into rows of weakly decreasing length. Furthermore, given a Young diagram, we can explicitly

construct the corresponding irreducible representation, giving us a complete classification of S_n-representations up to isomorphism. In this talk, we will explore this construction and why this unexpected connection between Young diagrams and S_n-representations is actually quite natural.

An Exploration of Collisions with Central Elements of Pascal's Triangle
Nathan Collins, Sam Houston State University

A "collision" in Pascal's triangle occurs when two distinct elements of the triangle yield the same value. In this talk, we explore whether a central element in Pascal's triangle can collide with another non-trivial element of the triangle. Such collisions are conjectured to not exist, a compelling still-open problem in Number theory. Our approach combines inequalities, prime divisibility (valuations) and residues and algebraic properties of polynomials to prove prerequisite conditions for such a collision. We derive many conditions, including criteria on divisibility and inequalities on the residues of the indices of the elements, and show them to eliminate a large number of possible collisions, yielding a significant step towards the conjecture.

Cole STEM Building Room 202

An upper bound for the codegree graph, and triangle-free codegree graphs
Samarth Das, University of Texas at Austin

For a finite group G and χ an irreducible character of G, the codegree cod(χ) is defined as |G : ker χ|/χ(1). The prime divisor graph of a set of integers has vertex set equal to the prime divisors of elements of the set, and p and q share an edge if and only if pq divides some element of the set. In [Isa11] it was discovered that the prime divisor graph Δ(G) over the set of element orders has a strong connection to the prime divisor graph Γ(G) over the set of character codegrees; namely, the vertex sets are equal and Δ(G) ⊆ Γ(G). In this paper, we expand upon that connection by further constraining the structure of Γ(G) in terms of Δ(G). We use this result among others to progress the classification of groups with triangle-free Γ(G), completing it for groups with low Fitting lengths.

Algebraic Structures on Sets of Partitions
Megan du Preez, University of Texas at Tyler

A partition of an integer n is a weakly decreasing sequence of positive integers which sum to n. Denote the set of all partitions by P. In this talk, we explore various binary operations on partitions to find an algebraic structure on P. In particular, we discover that P is an abelian group under modified versions of concatenation, component-wise addition, and component-wise multiplication. We extend two partition groups to vector spaces over the finite field Z_p, where p is a prime. We further discover that partitions are equipped with a commutative ring structure. Next, we consider subgroups, subspaces, and ideals of our algebraic partition structures to investigate properties of related types of restricted partitions. Finally, we explore various bijections between types of restricted partitions that appear in our algebraic structures.

Zeros of Eisenstein Series Generated by Jacobi Elliptic Functions
Daniel Gallegos, University of Texas Rio Grande Valley

The Laurent coefficients of elliptic functions can be expressed through modular forms. For example, the Laurent coefficients of the Weierstrass P function are Eisenstein series, whose zeros Rankin and Swinnerton-Dyer showed lie on a particular arc of the unit circle. Although Jacobi elliptic functions predate the Weierstrass P function, the locations of zeros of their Maclaurin coefficients have been less understood. We prove that all nontrivial zeros of the Maclaurin coefficients of the nine quotients of Jacobi elliptic functions analytic at the origin are simple and lie on hyperbolic geodesics connecting cusps of $\Gamma(2)$.

Our proof adapts the Rankin–Swinnerton-Dyer method. We express the coefficients for three representative quotients as Eisenstein series and parameterize the relevant geodesic to obtain real-valued functions. We separate each series into a dominant oscillating part and a remainder, choosing the dominant terms to establish alternating signs at selected points. We then derive bounds showing that the remainder cannot change these signs, even near the cusps. The Intermediate Value Theorem guarantees zeros between these points, while polynomial degree arguments establish that all nontrivial zeros have been found and are simple. Finally, modular transformations extend the result to the remaining six quotients. This strengthens earlier work of Garthwaite et al., which located at least 90% of the zeros for one Jacobi elliptic function on its corresponding geodesic.

Gerrymandering and the statespace of District Plans
Victor Estrada and Siri Borchert, Texas Lutheran University

District plans give voters the boundaries of single-member districts for elections. In this research, we explore the distance between district plans in the state space of all possible district plans. We use a program (in Python) to find an exhaustive list of district plans with as many districts containing three precincts as possible.

Using two distance metrics, we then describe the resulting state space for several simple regions. In addition, we fully describe the state space when the region is a cycle.

Cole STEM Building Room 206

Invisible Forces, Visible Effects: Mathematical Modeling of Protein-DNA Electrostatics
Alejandra Deshire Favela Santos, St. Mary's University

Electrostatic interactions play a critical role in protein-DNA recognition and binding, yet the mathematical modeling of these interactions presents several computational concerns due to the complexity of biological structures. This study investigates how applied mathematics and accessible computational methods can be used to examine the effects of monovalent salt concentration on protein-DNA electrostatic interactions. Through the linearized Poisson-Boltzmann equation and Debye-Hückel approximation, simplified electrostatic models were developed in MATLAB software and compared with structure-based numerical calculations, performed using the Adaptive Poisson-Boltzmann Solver (APBS). Five experimentally determined protein-DNA complexes were analyzed across varying ionic strengths to evaluate electrostatic screening and potential distributions.

Results from the simplified MATLAB models demonstrated that increasing ionic strength from 1 to 300 mM decreased the Debye screening length from approximately 9.62 nm to 0.56 nm and reduced the magnitude of electrostatic interaction energy by approximately 81.7 percent. Structure-based APBS calculations also showed reductions in electrostatic potential magnitude, with variations among molecular complexes. The agreement between these complementary approaches is consistent with Debye screening theory and supports the use of continuum electrostatic methods for investigating salt-dependent biomolecular interactions. Through the combination of mathematical theory, numerical computations, and molecular visualization, this study presents an accessible computational framework for exploring protein-DNA electrostatics. These findings highlight the importance of ionic conditions in biomolecular interactions and illustrate how applied mathematics, alongside accessible, low-cost computational methods, can provide undergraduate researchers with practical tools for investigating complex biological systems.

Acknowledgement – This work was supported by St. Mary's University's McNair Scholars. Program award from Department of Education No. P217A220302.

Finite Element Simulation of Triple-Negative Breast Cancer with Stochastic Dynamics
April Castaneda, Tarrant County College District

Recent developments and improvements in breast cancer models have been motivated by the increasing demand for digital-twin-based technology, with the goal of using a digital version of the tumor to simulate how the real tumor will respond to treatment. However, many factors are not accounted for, such as unmeasurable physiological characteristics or ambient biological noise. This may lead to the accumulation of slight discrepancies between the model and the real-life tumor over time. Therefore, we introduce a novel model of breast tumor progression as a stochastic partial differential equation, incorporating temporal randomness to account for these differences. By doing so, we shift the model from a single point prediction to a probabilistic forecast of tumor progression, allowing the model capture variability in the tumor's response to treatment.

Understanding and Exploring Sudoku Boards and Related Grids
Aldo Garza, Southwestern University

Sudoku is a widely popular number game with history dating back to 1979. This analysis seeks to identify the number of possible valid Sudoku boards of sizes 1-9, the minimum number of squares required to make a board with a unique solution, and understand the relations that provide these numbers to study individual boards or identify permutations of the same board. Using logic, discrete mathematics, and proof techniques, isomorphic boards can be simplified into a variable-based format which can thus be used to easily extrapolate the total number of boards. To help understand the nature of Sudoku boards, this project also takes pivotal interest in Latin Squares and compares them to Sudoku boards.

Cracking the Code: An Attempt to Measure Gerrymandering
William Thornell, Trinity University

The measurement of partisan gerrymandering remains a challenging problem in electoral analysis, in part due to determining whether a districting plan is unusually biased requires an appropriate set of comparison plans.

This project aims to discover a mathematical quantification for gerrymandering. Current approaches to measure gerrymandering involve comparing current voting plans to randomly generated simulations, the goal is to more smartly generate these comparative plans to ensure we are accurately finding outliers.

The current phase of the project focuses on teaching a computer to gerrymander using two of the most common techniques: packing and cracking. Packing aims to concentrate voters from one political group into a district where they would be the supermajority. Cracking disperses minority voters across several districts to dilute their electoral influence. Using Texas 2024 election data at the Voting Tabulation District (VTD) level, our methods generate districts that deliberately apply these strategies while maintaining legal constraints such as population equality and geographic contiguity.

By generating a large ensemble of mathematically valid plans through intentional partisan manipulation we can better understand the range of achievable outcomes. Furthermore, by comparing the current map in place for Texas, we can better determine if it is consistent with typical districting patterns or in line with intentional partisan gerrymandering.

Cole STEM Building Room 314

Arithmetic Variations: Beyond the Triangle
Ioana Burlacu, Southwestern University

The Arithmetic Triangle, sometimes known as Pascal's Triangle, is a triangular array that has existed for centuries before Blaise Pascal and continues to be studied even in the modern era. In this talk, we will discuss variations of the Arithmetic Triangle that arise from changing structural properties of the triangle. One such instance is where the border entries outside the triangle's border change from 0 to 1. We will compare features of this new triangle to other known combinatorial objects. We shall conclude with open questions about where this inquiry can be taken next including other possible variations.

Propagation Time for Fault Tolerant Zero Forcing
Hayden Pegues, Tarleton State University

Zero forcing is an iterative graph coloring process that studies propagation time through vertex networks while highlighting optimization problems on graphs. If an initial blue vertex has exactly one white vertex neighboring it, the blue vertex forces that white neighbor to turn blue. Fault tolerant zero forcing adds to this process by ensuring that complete graph coloring is achieved even if any one vertex of the initially blue vertices from the forcing set is turned white. Propagation time refers to how many iterations it takes for a zero forcing set to force a graph. In this talk, we explore how propagation

time behaves on helm graphs and discuss the differences between standard and fault tolerant propagation time.

Fault Tolerant Zero Forcing in Graph Operations
Mary Crain, Tarleton State University

Zero forcing is a graph theory coloring process in which we begin with a set of initially blue vertices on a graph. The color change rule allows a blue vertex with exactly one white neighbor to force that neighbor to become blue. Fault tolerant zero forcing is an extension of the zero forcing process that preserves the ability to color the entire graph even after the removal of any single blue vertex from the initial forcing set.

In this talk, we study fault tolerant zero forcing under graph operations, including coronas and Cartesian products. We examine how these operations affect fault tolerant zero forcing sets and use properties of the original graphs to understand the resulting graphs.

Competitive Zero Forcing on Paths and Cycles
Tung Vo, University of St. Thomas

Zero forcing is a graph coloring process in which a colored vertex with exactly one uncolored neighbor forces that neighbor to become colored. Competitive zero forcing extends this process by allowing red and blue vertices to force simultaneously, with tied competition producing purple vertices. In this talk, we explore competitive zero forcing on paths and cycles, focusing on how the placement of initial forcing sets affects the process. We highlight the relationship between graph structure and competing color propagation.

Cole STEM Building Room 318

Classifying Nearly All Graphs with Skew Zero Forcing Number of Zero
Daniel Knight, Angelo State University

The skew zero forcing game is an infection algorithm in graphs that can be encoded using a closure operator. The skew zero forcing number of a graph is the cardinality of the smallest set needed to infect the entire graph. Depending on the graph, this closure operator gives rise to a matroid called a skew zero forcing matroid. Matroids are used to generalize mathematical dependence. We will explore classes of graphs that have a skew zero forcing number of zero, and show they always give rise to a skew zero forcing matroid. We also discuss how adjusting these graphs can impact if there is an underlying matroid. This talk is intended for a general audience.

Skew Zero Forcing over Affine Geometry Suburbia
Carter Oxford, Angelo State University

Skew Zero Forcing (SZF), is an interesting algorithmic game played on graphs of edges and vertices which colors vertices depending on some initial coloring of the vertices. Occasionally, this game gives rise to a matroid; a mathematical object that generalizes dependence over some set of elements; in this case, the vertices of the graph. We call such matroids SZF-realizable. Considering the matroids generated from the affine linear independence of vectors over a finite field, we ask the question:

which of these affine matroids are SZF-realizable? Preliminary results show that higher rank affine matroids generally are not SZF-realizable, which validates some intuition on how the complexity of a matroid relates to its SZF-realizability. Very little literature has been published on this topic, and this ongoing project seeks to provide new insight into this interaction between graph and matroid theory.

How Can Spectral Clustering Be Fair?
Kamaile Hernandez, Lamar University

Spectral clustering is a mathematical method used to group similar data points based on how strongly they are connected. However, traditional spectral clustering does not consider fairness, which can lead to uneven representation of demographic groups within clusters. This research explores how fairness can be incorporated into spectral clustering while maintaining meaningful connections between data points. We begin by introducing graph Laplacians, RatioCut, and Normalized Cut to explain how spectral clustering works. We then examine group fairness and how mathematical constraints can ensure that each cluster reflects the demographic proportions of the overall dataset. Finally, we explore three approaches to fair spectral clustering: Kleindessner's method, Wang's scalable method, and an alternative Laplacian formulation using the Sherman–Morrison–Woodbury identity. Through these approaches, we examine how mathematics can help create clustering methods that balance fairness and computational efficiency.

The Picky Passenger Problem: A variation on parking functions
Ashlyn Cadena, Southwestern Southwestern

We study a new variant of parking functions inspired by airplane boarding, which we call the Picky Passenger Problem. An airplane has n rows and k columns split across an aisle. Each of the nk passengers has a preferred row r and a preferred column c, with passengers prioritizing their row preference. A preference vector is a list of these preferences and is valid if all passengers can sit on the plane without revisiting a row they've passed. Boarding rules are similar to the classical parking function problem withe the aisle acting as the one-way street, except when a passenger's preferred seat is taken, they follow a sequence of steps that lets them search for an open seat in row r before moving on to the next row. We ask: for which preference vectors does every passenger find a seat? In this talk, we discuss the number of valid preference vectors for small n x k cases.

Afternoon Session

Cole STEM Building Room 201

Low-Degree Rational Maps that are Invariant Under Finite Group Symmetries
Mikayla Hill, Stephen F. Austin State University

The study of rational maps on the Riemann Sphere is closely connected to finite group symmetries. These finite group symmetries are subgroups of PGL2(C) that is bijective to distinct Möbius maps on the sphere. The finite groups that have symmetry realized by rational maps have been of great interest. Even though the types of groups that are possible have been completely classified, this work

takes the step to find explicit forms of rational maps of degrees up to four that are invariant under these symmetries.

Solving Sudoku Puzzles Using Groebner Bases
Rocio Diaz, Texas Woman's University

In this project, we analyze different Sudoku puzzles to determine if the puzzle has no solution, one solution, or multiple solutions. We use Groebner bases to calculate the number of solutions for a given puzzle. To complete this work, we implemented an algorithm in Python that can solve any given 4x4 Sudoku puzzle.

Fuchs Meets Fermat: A Tale of Two Open Problems
Ollie Watson, Texas Woman's University

In this talk, I will give an overview of open problems in abstract algebra and number theory: Fuchs' problem and the existence of additional Fermat primes. I will connect these two problems using elementary abstract algebra and number theory results as well as state original results involving multiplicative groups of integers. Finally, I will describe the implications of the existence of additional Fermat primes on our results.

Extending Rock-Paper-Scissors Infinitely
Yujin Yoshimura, University of North Texas

Rock-paper-scissors is a non-transitive game with 3 hand choices. We can add more choices and keep the game balanced. What if we add infinitely many hand choices; can the game still be balanced? We can construct an isomorphism to rock-paper-scissors using the Legendre symbol, where 1 means win, -1 means lose, and 0 means draw. I will explain how to construct an isomorphism, why it is beneficial to use the Legendre symbol, and the consequences.

Cole STEM Building Room 202

Matrix Representations of g-adic Numbers [M-adics], Modularity Lifting, and Affine Transforms
Edward V. Leigh, Jr., Baylor University

p-adics are among the most important tools in modern mathematics, but their generalized, composite-based counterparts, g-adics, remain an ill-studied class of objects, with their non-trivial zero divisors and complex composition rules on their Chinese Remainder Theorem-informed prime tuples. This paper presents a new approach to these g-adics by representing them using centrosymmetric hypermatrices instead of the standard tuple notation, producing Matrix-adics (M-adics), and illustrating their properties in a way that is both intuitive and informative, using the 10-adics as an example. Building on this notation, the concept of modularity lifting between different p-adic bases is explored using affine transforms, illuminating the power of this geometric, rather than group-theoretic, approach to the p- and g-adics.

Reciprocal Sums in t-Regular Partitions
Vanessa Medina, St. Mary's University

The asymptotic study of sums of reciprocals of parts in integer partitions was initiated by

Kim and Kim and has attracted considerable attention in recent years. Extending one of their results, we investigate the reciprocal sum of distinct parts in t-regular partitions for all $t \geq 2$. We employ Wright's circle method and related tools to derive asymptotic formulas for the first two raw moments, from which we obtain asymptotic expressions for the mean and variance with explicit dependence on t.

Manhattan Curves for One-Holed Tori
Jacqueline Sanchez and Abigail Schmidt, Sam Houston State University

This work aims at comparing two distinct hyperbolic structures on a one-holed torus. Specifically, we study their length functions on a set of closed curves. We produce words in an alphabet on four letter words and using explicit free group generators, we evaluate them using two different sets of matrices corresponding to the two hyperbolic structures. From there, we introduce weights to calculate weighted length functions and approximate the resulting weighted entropy. Varying the weights provides us with an approximation of the Manhattan curve of the two hyperbolic structures, a tool which captures their similarities.

Investigating Embodied Theatrical Approaches and Humor in Experiencing and Communicating Undergraduate Mathematics:
Johnson Tran, University of Houston Downtown

Math Connections Theatre (MCT) is a collaborative initiative involving students of diverse majors who create comedy skits on various mathematical topics – from GEMDAS to topology. Although there were prior examples of integrating mathematics and performing arts, MCT is the first to deliberately fuse humor and mathematics on the stage. Thus, the purpose of this study was to explore the phenomenon of MCT by investigating how MCT actors experienced and communicated abstract mathematical ideas from the stage. Drawing on the Theatrical Embodiment Framework, we analyzed seven MCT skit recordings, focusing on verbal and non-verbal humor, to capture the actors' body motions, gestures, tone of voice, use of props, and dialogue. Our analysis revealed that the actors employed embodied theatrical techniques, such as breaking the fourth wall, between-actor dialogue, and using props to communicate mathematical ideas from the stage, while simultaneously engaging with the mathematics during each performance. For each skit we created diagrams, depicting how mathematical ideas evolved and were embodied by the actors. The thematic analysis of these diagrams showed that these theatrical strategies allowed the actors to ground abstract mathematical ideas into a concrete experience for the audience without sacrificing mathematical rigor. These findings contribute to the discussion of the intertwinement of teaching and acting. We therefore invite educators to consider incorporating theatrical techniques into their instruction, including lesson planning and assessment. Such approaches may enhance student engagement and broaden access to mathematics education.

Cole STEM Building Room 206

Failed Vertex Covering Set Reconfiguration
Rogelio Tovar, Angelo State University

A vertex cover of a graph is a set of vertices, S, such that every edge is incident with some vertex in S. A failed vertex cover (FVC) is a set of vertices that is not a vertex cover. Using a special type of graph called a token addition and removal (TAR) graph, we can visualize the relationships between the different failed vertex cover sets in a given graph. In this talk, we prove the uniqueness of FVC-TAR graphs for star graphs and prove an Isomorphism Theorem for failed vertex covers. This talk will be accessible even to those who have not taken a graph theory course or have limited knowledge in graph theory.

Optical Implementation of the Deutsch-Jozsa Quantum Algorithm in A Mach-Zehnder Interferometer
Khoi Nguyen, University of Texas at Austin

The Deutsch algorithm is one of the earliest algorithms to demonstrate quantum advantage over a classical deterministic approach. In this study, we physically simulate the Deutsch quantum algorithm using a Mach–Zehnder interferometry, with the optical paths and phase shifts representing the different quantum mechanical phenomena such as oracle, superposition, and interference steps of the quantum algorithm. In addition, the different oracle configurations represent either constant or balanced functions, which could be distinguised by comparing the measured optical powers. Overall, the Mach-Zehnder interferometry shows how fundamental ideas of quantum computing could be illustrated with a simple optical setup.

On Hulls of Linear Codes
Luca Iovino, University of Texas at San Antonio

Linear codes are fundamental objects in coding theory due to their applications in error correction and, more recently, in the construction of quantum error-correcting codes and code-based cryptosystems designed to resist quantum attacks. In both settings, an important object of study is the intersection of a code with its Euclidean dual, known as the hull of the code. For general linear codes, relatively little is known about this object. In this talk, we investigate the dimension of the hull of an arbitrary linear code, present several general results, and highlight a number of open research questions.

A Baseline Mathematical Model for Understanding Spotted Lanternfly Population Dynamics
Brent Morrison, Stephen F. Austin State University

Lycorma delicatula, commonly known as the spotted lanternfly (SLF), is an invasive species native to parts of Asia that poses a serious threat to agriculture and forestry in the northeastern United States. First detected in Berks County, Pennsylvania, in 2014, it has been difficult to contain because it spreads both naturally and by hitchhiking on vehicles and transported materials. In Pennsylvania alone, its annual economic impact is projected to reach approximately $324 million—and up to $554 million under a worst-case scenario—with nearly 5,000 jobs potentially at risk. Despite this threat, relatively few studies have mathematically modeled SLF population dynamics, and most existing

models focus on geographic spread. To address this gap, we formulate a baseline continuous-time, stage-structured model consisting of three equations representing the egg, nymph, and adult stages. We investigate the existence and stability of the model's equilibria and use numerical simulations to illustrate its dynamics. This framework may provide a foundation for investigating potential control strategies in future work.

Cole STEM Building Room 314

A Comparative Study of Bayesian and Frequentist Nonparametric Hypothesis Testing Methods Using Real Data Applications

Ricardo Balvanera, Amalia Garcia, University of Texas Rio Grande Valley

When the assumptions required for parametric hypothesis tests are violated, nonparametric methods such as the Wilcoxon signed-rank test, the Mann–Whitney–Wilcoxon test, and the Kruskal–Wallis test are commonly used for statistical inference. While these tests are traditionally conducted within the frequentist framework using test statistics, critical values, and p-values, Bayesian counterparts provide the additional advantage of quantifying the strength of evidence through the Bayes factor. This paper presents Bayesian testing procedures for these three nonparametric tests by constructing Bayes factors and corresponding Bayes factor cutoffs that are calibrated to the significance levels of the associated frequentist tests. As a result, the Bayesian procedures produce decisions that are consistent with the corresponding frequentist tests while also providing a quantitative measure of the evidence supporting the alternative hypothesis relative to the null hypothesis. The proposed methods are illustrated using three real-data applications involving paired observations, two independent groups, and multiple independent groups, demonstrating their practical implementation and interpretability.

Analyzing DNA Co-Methylation Networks and Assessing Their Properties

Sahasra Jasti, The University of Texas at Austin

DNA methylation is an epigenetic modification in which a methyl group (CH_3) is added to DNA, typically at CpG sites. This epigenetic event can affect gene expression without altering the underlying DNA sequence. Abnormal methylation patterns can contribute to cancer development and progression through mechanisms such as silencing tumor suppressor genes or altering oncogenic pathways.

In this study, we construct co-methylation networks using both hard-thresholding and soft-thresholding approaches. Hard-thresholding establishes connections between CpG sites based on a specified correlation cutoff. While soft-thresholding assigns continuous connections to correlations using the R package Weighted Gene Co-expression Network Analysis (WGCNA).

We assess scale-free properties of hard-thresholded networks using log–log scatter plots of degree distributions and coefficients of determination (R^2). For soft-thresholded networks, we investigate power-law behavior using the R package poweRlaw. Our results suggest that the methylation networks examined do not provide strong evidence of scale-free structure.

Hierarchical Clustering For Forensic Data Analysis
Anna Grogan, The University of Texas at Austin

In forensic source identification problems, there are often few high-dimensional samples or objects per source and a large number of sources. Due to the high-dimensionality of the data, it is common to use a score function on all pairs of sources and then analyze the pairwise scores rather than the original objects. However, the issue of small sample size per source remains. The common assumption is that all within-source scores follow the same distribution, which allows for pooling all within-source scores across all sources together to estimate the within-source distribution. However, recent work provides a goodness-of-fit test that evaluates whether this assumption is valid. The test is only performed on two sources at a time, and so to aggregate results, they use hierarchical clustering on the p-values from all pairs of tests to determine clusters of within-source distributions. The authors admit that the selection of clusters (unique distributions) in this way is a subjective and ad-hoc approach. This research project empirically validates the use of selecting clusters from hierarchical clustering. An in-depth simulation using functional data is considered for a variety of different numbers of unique distributions, corresponding to different numbers of clusters that should be selected by the hierarchical model. To determine the number of clusters, the upper and lower Kolmogorov–Smirnov statistics are considered for selecting too few, too many, or the correct number of clusters.

Assessing the Influence of Demographic, Clinical, and Lifestyle Factors on Stroke Risk
Jacqueline Rangel, Tarleton State University

This study analyzes factors associated with stroke risk using 10 variables: gender, age, hypertension, heart disease, marital status, work type, residence type, average glucose level, body mass index (BMI), and smoking status. Stroke remains one of the leading causes of death and long-term disability worldwide, making it important to identify the factors that contribute to its occurrence. Using statistical analysis, the study will evaluate the relationship between each variable and stroke risk and identify the strongest predictors of stroke. By incorporating demographic, socioeconomic, clinical, and lifestyle characteristics, this research aims to contribute to the development of more comprehensive and effective stroke risk assessment models.

Cole STEM Building Room 318

Perfect Card Shuffles and Return Times
Robert Karcher, Southwestern University

Although card shuffling is usually associated with randomness, a perfect card shuffle follows a pattern that can spark curiosity. This pattern involves dividing a deck into two halves and then alternating cards according to a fixed rule. This type of rearrangement can be represented mathematically as a permutation, and repeating it creates a cycle that eventually returns the deck to its original order. To explore what determines the cycle length, this project aims to answer: How do deck size and shuffle type affect the number of shuffles required to return the deck to its starting arrangement?

This project examines several perfect shuffle rules for even- and odd-sized decks by following how individual cards move through repeated rearrangements. These movements reveal relationships between different shuffle rules, including cases where decks of different sizes have the same return time. By examining their cycle structures, the investigation aims to explore how these relationships can determine return times without repeating every shuffle.

Minesweeper: More Than Just Guessing
Sofia Valenzuela, Southwestern University

Minesweeper is a game that combines logical reasoning, combinatorics, and probability. Players use clues on revealed squares to determine where mines may be located, creating a problem of counting and eliminating possible mine configurations. This project investigates how combinatorics and probability can be used to determine the likelihood that an unrevealed square contains a mine. Beginning with small Minesweeper boards, possible mine configurations can be counted and compared to determine how the available information changes the set of possible outcomes. The effects of the number and location of mines, revealed clues, and symmetry can then be examined to determine how they affect the probability of a mine being in a particular square. The goal of this project is to develop a mathematical approach for identifying safer moves in Minesweeper and to investigate when mathematical reasoning can determine a move without guessing. The project will also consider how effective these methods are as the complexity of a Minesweeper board increases.

Thermoelectric Modelling Explained With Chess
Clay Elliott, Southwestern University

Powering deep space probes is one of the hardest problems in probe design, since space cuts off access to nearly every resource. One solution is thermoelectric materials, which generate electricity directly from a heat source and allow a probe to produce power entirely onboard. The ideal thermoelectric follows the phonon-glass electron-crystal (PGEC) paradigm: it conducts electricity well while blocking heat. One approach is a random grid of conducting nodes embedded in a larger grid of insulating nodes. Quantum tunneling is represented by a path formed between two conducting nodes, skipping over insulating nodes, and heat transport is represented by direct contact between conducting nodes. The conjecture is that such a composite has a unique minimum area or volume fraction at which electrical conduction spans the material and a separate, higher one at which heat conduction does. To visualize this, consider chess pieces on a board where they may only move on black squares. If each white square turns black with some probability, each piece (king, queen, rook, bishop, knight, and pawn) will reach a unique probability at which it can cross the board, given unlimited moves on black squares only. Electricity and heat behave the same way: each follows different rules for moving through a grid of connected nodes, so there exist grids that carry electricity but not heat. This talk defines the underlying concepts, presents simulations testing the chess conjecture and discusses their implications.

Growing Graphene: Graph Growth and Spectral Structure in Finite Hexagonal Lattices

Brooke Ramey, Southwestern University

Finite hexagonal lattices provide a natural setting for studying how local growth influences global graph structure. Inspired by graphene, a two-dimensional material with extraordinary electronic properties, this project examines finite polyhex graphs generated from a single hexagon and studies them using adjacency and Laplacian spectra. Spectral moments show that graphs with the same numbers of hexagons and vertices can still differ, with higher-order moments depending on finer local structure such as the arrangement of degree-three vertices. The growth process also produces a triangular pattern of equivalence classes when graphs are organized by hexagon count and possible vertex counts. The upper and lower boundaries of this pattern follow predictable extremal growth laws, while the lower boundary exhibits a staircase behavior associated with minimum-perimeter polyhex configurations. These results provide a framework for describing how coarse growth parameters and finer local connectivity work together to distinguish finite hexagonal graphs. By developing a graph-theoretic description of these structures, this work provides a combinatorial perspective on the hexagonal network's underlying graphene and related lattice systems.