Undergraduate Mathematics Research Symposium

University of Florida, Department of Mathematics

Organizers: K. Christodoulopoulou and S. Pollock,
co-chairs of the Undergraduate Research Committee

April 24, 2026

Schedule

Morning Sessions

Session 1.

- *9:00-9:15* Daniel Proenca, Avoiding infinite paths in countable graphs
- *9:15-9:30* Dominic Robinson, Row and column operations on $(0, 1)$-matrices
- *9:30-9:45* Tuyen Truong, Convergence of Stochastic Gradient Descent under heavy-tailed noise via Gradient Clipping
- *9:45-10:00* Pranav Kulkarni, Sanandan Ojha & Sharad Patel, Modeling AI model collapse using Markov chains and layered discrete distributions
- *10:00-10:15* Glenn Bruda, Generalized polygonal number representations

Coffee break: 10:15-10:45.
Session 2.

- *10:45-11:00* Dung Chu, Dat Le & My Pham, Vigilance-based predator detection model: A probabilistic framework for mixed-species groups
- *11:00-11:15* Ramsey Makan, Heavy tails in finance and the mathematics of catastrophe risk transfer
- *11:15-11:30* Aryan Tiwari, Interactive numerical analysis learning apps
- *11:30-11:45* Alex Czemerinski & Jonathan Nunes, Regularization independence in the one-dimensional Schrodinger equation with delta potential
- *11:45-12:00* James Watt, Symmetry reduction in the superpattern problem

Lunch: 12:00-1:00

Afternoon Sessions

Session 3.

- *1:00-1:15* Charlie Eggimann, Leon Grigoruk & Keon Moghaddam, 1xn PackIt! (Turn dependent Kayles)
- *1:15-1:30* Roberto Hogas Goras, An introduction to faber polynomials and applications

- *1:30-1:45* Lina Filkin, Singularity analysis of families of generating functions with fixed points
- *1:45-2:00* Sanandan Ojha, Mathematical modeling of intercalation in two cell layers during the gastrulation stage of embryonic development

Coffee break: 2:00-2:30.
Session 4.

- *2:30-2:45* Christophe Muracciole, Portfolio optimization under heavy-tailed distributions
- *2:45-3:00* Andersen Wall, A sheaf-based computational approach to equilibrium in assignment markets
- *3:00-3:15* Raymond Ying, Evasion paths in mobile sensor networks
- *3:15-3:30* Julian Carvajal, Entropy bounds on discrete s-concave distributions

Abstracts

Session 1

1.1 *Daniel Proenca.* **Mentor:** Valentino Vito

Title: Avoiding infinite paths in countable graphs

Abstract: Given a countable graph G, we say that an injective labeling of the edges to the natural numbers is infinity-evading if for any natural number n, there exists an increasing path of length n in G, but there exists no infinite increasing path in G. We show that a graph admits an infinity evading labeling as long as it contains finite paths of arbitrary lengths and some edge labeling without an infinite increasing path. We also present an equivalent condition for a graph to have any labeling be infinity-evading.

1.2 *Dominic Robinson.* **Mentor:** Peter Sin

Title: Row and column operations on $(0, 1)$-Matrices

Abstract: Suppose that A is a matrix whose columns are all of the possible columns with k ones and $v - k$ zeros (where v is the number of rows in A). How many different matrices can be obtained by performing row permutations and/or column permutations on A? Under what conditions will there not exist a row permutation P_r that reverses the action of a given column permutation P_c on A? Given $(0, 1)$-matrices X and Y, under what conditions can we say that there exist row and column permutation matrices P_r and P_c such that $P_r X P_c = Y$? For example, is it sufficient to suppose that the dot products of corresponding columns are equal? These are some of the many questions that we address.

1.3 *Tuyen Truong.* **Mentor:** Arnaud Marsiglietti

Title: Convergence of Stochastic Gradient Descent under heavy-tailed noise via Gradient Clipping

Abstract: The fundamental convergence guarantees of Stochastic Gradient Descent (SGD) in linear regression traditionally rely on the assumption of light-tailed, finite-variance noise (e.g., Gaussian). However, in many modern datasets, noise distributions exhibit heavy tails where the second moment is infinite, causing the theoretical gradient variance to explode. Under these conditions, standard SGD suffers from catastrophic gradient jumps and fails to converge. This project synthesizes the theoretical breakdown of the SGD noise floor and empirically investigates Gradient Clipping as a robust optimization intervention. Through computational simulations across noise distributions with varying tail indices (Gaussian, Student-t, and Cauchy), this investigation verifies the failure to converge when the tail index $\alpha \leq 2$. Finally, we demonstrate that applying a gradient clipping operator artificially bounds the gradient variance, effectively restoring convergence.

1.4 *Pranav Kulkarni, Sanandan Ojha & Sharad Patel.* **Mentors:** Tracy Stepien, Youngmin Park & Hemaho Taboe

Title: Modeling AI model collapse using Markov chains and layered discrete distributions

Abstract: Artificial Intelligence (AI) model collapse is a phenomenon that occurs when models are recursively trained on the output of previous generations, leading to a feedback loop where probable events are overestimated and rare "tail" events are eventually lost. We aimed to model the emergent behavior that occurs when multiple AI models interact in this environment alongside human-generated content. We develop a Modified Markov Chain Model to simulate early-stage collapse, where information is retained across generations based on fraction of synthetic versus human data in the training set. We then transition to a Layered Discrete Distribution Model to model late-stage collapse where statistical approximation errors are compounded, causing loss of rare events. Our simulations demonstrate that while heavy reliance on AI-generated data accelerates collapse, increasing the number of models slows quality drift and improves event retention while saturating the environment with diverse AI tasks leads to a more uniform data distribution.

1.5 *Glenn Bruda.* **Mentor:** Krishnaswami Alladi

Title: Generalized polygonal number representations

Abstract: For $k \geq 5$ and $n \geq 4$, let $r_n^{(k)}(N)$ be the number of representations of N as the sum of n generalized k-gonal numbers and $r_n^{\square}(N)$ be the number of representations of N as the sum of n squares. By modifying the Heath-Brown circle method, we prove a closed-form asymptotic relation between $r_n^{(k)}(N)$ and $r_n^{\square}(N)$ for $k \not\equiv 0 \bmod 4$ and any $n \geq 4$. Consequently, we relate the number of representations of N as the sum of four ordinary k-gonal numbers to $r_4^{\square}(N)$ via a result of Bringmann–Jang–Kane–Tse.

Session 2

2.1 *Dung Chu, Dat Le & My Pham.* **Mentors:** Stepien Tracy & Park Youngmin

Title: Vigilance-Based predator detection model: A probabilistic framework for mixed-species groups

Abstract: We propose a probabilistic model for predator detection in mixed-species groups based on vigilance dynamics. Individual vigilance decreases with group size, while partial synchronization reduces the number of effective independent watchers. Collective vigilance is modeled as the probability that at least one individual is scanning, and detection probability is derived via a Poisson process with rate proportional to collective vigilance. The model predicts that detection probability increases with group size but exhibits diminishing returns due to synchronization effects. Optimal detection occurs in moderately sized groups, whereas high synchronization limits gains by reducing independent coverage.

2.2 *Ramsey Makan.* **Mentor:** Arnaud Marsiglietti

Title: Heavy tails in finance and the mathematics of catastrophe risk transfer

Abstract: This project studies the theory and a financial application of heavy-tailed probability distributions, which model phenomena where extreme outcomes occur more frequently than classical Gaussian assumptions predict. After highlighting key mathematical foundations, including the catastrophe principle, mechanisms for the emergence of heavy tails from stochastic processes, and extreme value estimation methods, the project examines catastrophe (CAT) bonds, financial instruments that transfer disaster risk from insurers to capital markets. It discusses a pricing framework for multi-trigger bonds and demonstrates how tail behavior, event frequency, and dependence structure influence catastrophe risk valuation.

2.3 *Aryan Tiwari.* **Mentor:** Sara Pollock

Title: Interactive numerical analysis learning apps

Abstract: This talk presents a suite of interactive, browser-based visualizers developed to help students gain intuition behind root-finding, fixed-point and numerical integration methods that are introduced in courses in numerical analysis. The tools cover three topics: the Newton–Raphson method, animated step-by-step alongside each tangent line iteration; numerical quadrature, where students can watch approximation schemes such as the midpoint, trapezoid, and Simpson's rules improve as the number of subintervals increases; and fixed-point iteration, where diagrams illustrate convergence and divergence in a way that stability conditions alone cannot capture. We discuss the motivations behind each tool and how dynamic, parameter-driven visualization can complement traditional instructional materials.

2.4 *Alex Czemerinski & Jonathan Nunes.* **Mentor:** Sergei Shabanov

Title: Regularization independence in the one-dimensional Schrodinger equation with delta potential

Abstract: We study the regularization independence of the bound state energy and scattering coefficients in the one-dimensional Schrodinger equation with a sequence of potentials which converge to the Dirac delta-distribution potential. While there is a standard result for the delta potential in 1D, many methods of obtaining this result involve employing some regularization of the delta-function. We're interested in finding the biggest class of sequences of functions which converge to the delta dirac distribution for which the bound-state energy and scattering amplitudes can be shown to converge to the known results. We demonstrate that for regularizations satisfying some mild assumptions—boundedness, integrability, decay, normalization—the observables converge to the well-known results. We also demonstrate the existence of regularizations, which break some of our assumptions, for which the bound state energy does not converge to the known result.

2.5 *James Watt.* **Mentor:** Miklos Bona

Title: Symmetry reduction in the superpattern problem

Abstract: A permutation $\pi \in S_n$ of length n is a k-superpattern if it contains every permutation of length k as a pattern. It is known that the minimal length, $m(k)$, for such a permutation satisfies $k^2(1/e^2 + o(1)) \leq m(k) \leq \lfloor (k^2+1)/2 \rfloor$, however, its exact value is unknown. We introduce two relaxations of the problem by exploring the dihedral, D_8, symmetries acting on S_k. A weak superpattern must contain at least one representative of each reversal pair, σ, σ^{rev}, and a very weak superpattern must contain at least one representative of each full D_8-orbit. We prove $m(k) \geq w(k) \geq m(k-1)$, for minimal weak superpatterns, $w(k)$; $v(3) = m(2) + 1$ for very weak superpatterns, $v(k)$, and reinforce the lower bound of $v(k) \geq k^2(1/e^2 + o(1))$ via a corner-point argument on permutation plots. We further introduce a family of symmetry-reduced superpattern numbers $a_G(k)$, where $G \leq D_8$. For this number family, we use a transversal construction to establish the uniform bound $a_G(k) \leq k \cdot |S_k/G|$, and we identify when $a_G(k)$ admits a level-reduction to the classical problem at a lower index. The transversal bound falls short of the Engen-Vatter bound as it lacks pattern overlap; however, its generality is of interest.

Session 3

3.1 *Charlie Eggimann, Leon Grigoruk & Keon Moghaddam.* **Mentor:** Thomas Garrison

Title: 1xn PackIt! (Turn dependent Kayles)

Abstract: Abstract: 1xn PackIt! is an impartial combinatorial game equivalent to a variant of Kayles where the number of pins knocked over changes after each turn. We will discuss how the game works and the different results we've found from analyzing it. Our results include, but are not limited to, how different first-moves affect the outcome of the game and our analysis of a simplified version of the game.

3.2 *Roberto Hogas Goras.* **Mentor:** Sara Pollock

Title: An introduction to Faber polynomials and applications

Abstract: In this talk we will discuss the Faber polynomials. We will motivate them in terms of the Chebyshev polynomials, and we will see how they satisfy similar properties including recurrence relations, bounded regions, and exponential growth outside of those regions. One of the key properties of the Faber polynomials is that they can be bounded in regions of the complex plane. We will look at some key properties and applications in numerical analysis.

3.3 *Lina Filkin.* **Mentor:** Jeremy Booher

Title: Singularity analysis of families of generating functions with fixed points

Abstract: In analytic combinatorics, many enumeration problems involve generating functions whose coefficients are not explicitly accessible. Singularity analysis provides a powerful framework for extracting asymptotic information about these coefficients from the local behavior of the generating function near its dominant singularity. However, classical techniques apply primarily to individual functions and do not directly extend to parameterized families. In this thesis, we review the classical framework of singularity analysis and extend it to families of generating functions depending on an additional parameter. Using Cauchy's coefficient formula along a Hankel-like contour, we establish transfer theorems that make explicit the dependence on this parameter. We then apply these results to families of generating functions encoding mappings with a specified number of fixed points, and analyze how the coefficient asymptotics behave when this parameter varies with the size of the function. We show that, when the number of fixed points grows sufficiently slowly, the asymptotic order of the coefficients is preserved, with parameter dependence appearing only in the leading constant. This combinatorial problem is motivated by attempts in mathematical cryptography to produce random supersingular elliptic curves.

3.4 *Sanandan Ojha.* **Mentor:** Tracy Stepien

Title: Mathematical modeling of intercalation in two cell layers during the gastrulation stage of embryonic development

Abstract: A dual layer continuum mechanical model of cell migration during gastrulation is developed to describe the migration and intercalation between the mesenchymal and epithelial cell layers. Forces incorporated in the model include the adhesion/cohesion forces between layers and the migrating forces of lamellipodia driving the moving boundary. Approximate Bayesian computation (ABC) and sensitivity analysis are used to obtain parameter estimates of resting density, adhesion constants, and stretching modulus for both layers, and additionally to compare between various model formulations.

Session 4

4.1 *Christophe Muracciole.* **Mentor:** Arnaud Marsiglietti

Title: Portfolio optimization under heavy-tailed distributions

Abstract: It is well known that light-tailed distributions fail to accurately model equity returns, yet most financial models assume multivariate normal returns due to their tractability and closure under convolutions. Several industry-relevant risk measures are considered under both asymptotically Pareto and Skewed Generalized T return distributions. Notably, there exist pathological behaviors and equivalences between certain heavy-tailed distributions and their light-tailed counterparts, indicating a preference for light-tailed distributions.

4.2 *Andersen Wall.* **Mentor:** James Fairbanks (UF, MAE)

Title: A sheaf-based computational approach to equilibrium in assignment markets

Abstract: This talk presents a framework for studying equilibrium in overlapping assignment markets. These markets are characterized by buyers being able to buy multiple units of an indivisible good while sellers supply exactly one unit of the good. Using ideas from sheaf theory, we can model these overlapping markets as various local regions that must agree over multiple continuous variables to form a global equilibrium. I present the computational framework necessary to compute these local and global equilibria using the local-to-global idea from sheaf theory.

4.3 *Raymond Ying.* **Mentor:** Henry Adams

Title: Evasion paths in mobile sensor networks

Abstract: A sensor network is a collection of points varying in space and time, designated by a set $N \subset \mathbb{R}^2 \times [0,1]$. About each point in the sensor network, there is an area of 'detection' for which the sensors are capable of detecting other sensors and a potential 'intruder' within the bounded region that the sensors move in. We construct abstract simplcial complexes on the sensors based on their mutual detection of each other. Utilizing this information, we discuss the determination of the existence of evasion paths under different assumptions.

4.4 *Julian Carvajal.* **Mentor:** Arnaud Marsiglietti

Title: Entropy bounds on discrete s-concave distributions

Abstract: Heavy-tailed distributions are a large class of distributions that are harder to study analytically. This project focused on s-concave distributions, a class of distributions that is often heavy-tailed. The current literature primarily focuses on continuous s-concave distributions; by using proofs for entropy bounds of discrete log-concave distributions as a model, we extend some entropy bounds on continuous s-concave distributions to discrete s-concave distributions.

Acknowledgments

Thanks to Libin Rong and the Department of Mathematics for their support, and for providing coffee and lunch! Thanks to all of our graduate and faculty mentors, and to our presenters! Thanks to Jason Nowell for teaching us all how to compile accessible pdfs! Special thanks to Margaret Somers for all her help in organizing the symposium!