Fall 2024

James Cummins, Ph.D. Candidate

- **Date:** Friday, Sept. 20, 2024
- **Title**: *Radial, Vortex, and Spiral Solutions of the Nonlinear Schrödinger Equation*
- **Abstract:** In this presentation, we will explore solutions to the nonlinear Schrödinger equation, beginning with its relevance to ground-state solutions and the Bose-Einstein condensate. We will focus on three distinct types of solutions: radial, vortex, and spiral. Using a novel approach to finding stationary states, we examine solutions that permit both positive and negative eigenvalues in a trapped particle scenario. Our results demonstrate that eigenfunctions with negative eigenvalues exhibit behavior distinct from those associated with positive eigenvalues. Finally, we present spiral solutions of the nonlinear Schrödinger equation without a potential, showing that these are a special case of a broader family of reaction-diffusion equations, constrained to constant-phase solutions.

Dr. Thien Le, Assistant Professor

- **Date:** Friday, Sept. 27, 2024
- **Title:** *Temporal Configuration Model: Statistical Inference and Spreading Processes*
- **Abstract:** We introduce a family of parsimonious network models that are intended to generalize the configuration model to temporal settings. We present consistent estimators for the model parameters and perform numerical simulations to illustrate the properties of the estimators on finite samples. We also develop analytical solutions for basic and effective reproductive numbers for the early stage of discrete-time SIR spreading process. We apply three distinct temporal configuration models to empirical student proximity networks and compare their performance.

Dr. Xiunan Wang, Assistant Professor

- **Date:** Friday, Oct. 18
- **Title:** *Discrete Inverse Method for Extracting Disease Transmission Rates From Accessible Infection Data*
- **Abstract:** In this presentation, I will introduce a data-driven inverse method leveraging discretization of differential equation models to estimate time-varying transmission rates for infectious diseases. Our approach, applied to three distinct classes of diseases (seasonal, nonseasonal periodic, and aperiodic), reveals valuable insights from pandemic or epidemic incidence data. The method is intuitive, facilitating rapid implementation even with multiyear datasets. Integrated with machine learning, it offers a tool for forecasting disease dynamics based on future conditions such as weather, policy decisions, and human mobility trends. Our findings provide actionable guidance for public health authorities.

Dr. Ziwei Ma, Assistant Professor

- **Date:** Friday, Nov. 1
- **Title:** *The Development and Application of Generalized F Distribution*
- **Abstract:** The F distribution is central to many classical inferential statistical methods that rely on the assumption of normality. However, when data exhibit multimodality or skewness, this assumption can lead to a lack of robustness, resulting in invalid or inefficient statistical inferences. Consequently, there is considerable interest in relaxing the normality assumption to improve inference about unknown parameters. In this talk, I will first introduce the development of a generalized F distribution based on the skew-normal family of distributions. Following that, I will discuss its application in estimation and hypothesis testing within the framework of skew-normal distributions. Finally, I will highlight some potential research directions in this area.

Anjuan Biswas

- **Date:** Friday, Nov. 8
- **Title:** *Quasi-Stationary Quantum Gaussons With Arbitrary Intensity*
- **Abstract:** This presentation is on the dynamics of optical solitons with log—law nonlinearity, also known as optical quantum Gaussons, in the presence of perturbation terms. The governing model is the nonlinear Schrodinger's equation that carries logarithmic form of self—phase modulation. A few perturbation terms, with arbitrary intensity, are included to get a better understanding of the quantum Gausson transmission dynamics. These include multi—photon absorption, Raman scattering, self—steepening eHects, self—frequency shift, nonlinear dissipation, saturable amplifiers, and others. The multiple— scale perturbation analysis, together with the Wentzel—Kramers—Brillouin— JeHrey's (WKBJ) hypothesis are implemented to retrieve the quasi—stationary optical Gausson solution. The WKBJ definition of the phase that is introduced reveals a couple of resonant conditions which cannot be otherwise recovered.

Dr. Russell Milne, Postdoctoral Researcher

- **Date:** Tuesday, Nov. 12
- **Title:** *Hybrid Modeling Approaches in Quantitative Lake Science*
- **Abstract:** As the amount of data available to researchers has increased, so has the amount of data-driven methods that can be used to answer research questions. In this presentation, I use such methods to tackle three problems related to harmful blooms of algae and cyanobacteria. I use Shapley Additive Explanations, a data-driven technique rooted in game theory, to find the primary driving factors for algal blooms in Liangzi Lake, China. I use a stoichiometric dynamical system fitted and validated on in-situ lake measurements to model how increases in lake temperature and nutrient input could exacerbate cyanobacterial blooms and alter lake food webs. I use a recently developed machine learning framework and techniques from graph theory to identify local hot spots of cyanobacteria concentration within a given lake.

Dr. F. Ayça Çetinkaya, Assistant Professor

- **Date:** Friday, Nov. 15
- **Title:** *Results on an Inverse Coefficient Problem*
- **Abstract:** Inverse spectral problems focus on reconstructing the properties of an operator from spectral data, with significant applications in physics and engineering. In this talk, we investigate an inverse problem for the Sturm–Liouville equation on a finite interval, emphasizing the recovery of a real-valued integrable potential from specified output boundary values and known initial conditions. This problem includes special cases, such as the inverse two-spectra problem. Our approach relies on special Neumann series of Bessel functions representations for solutions of Sturm–Liouville equations, providing a strong framework for addressing this class of inverse problems.

Dr. Lakmali Weerasena, Associate Professor

- **Date:** Friday, Nov. 22
- **Title:** *Revisiting Compactness: A Multiobjective Approach for Ecological Conservation*
- **Abstract:** This study develops a new measure of compactness, a vital spatial attribute. In psychology, compactness relates to pattern perception; in machine learning, it is used for clustering approaches; and in ecology, it is applied in the design of reserves for conservation. This talk focuses on ecological applications using a multiobjective approach. We introduce a novel metric that assesses reserve compactness based on both size and shape. By employing multiobjective optimization, we generate Pareto-optimal solutions, offering decision makers various high-quality reserve configurations. Our focus on compactness is crucial when habitats have limited biological interactions. We compare different compactness measures, such as boundary length and pairwise distance, assessing their effectiveness in optimization models.

Emard Hernandez Lopez

- **Date:** Monday, Nov. 25
- **Title:** *Dynamics of Cancer With a Minimal Model*
- **Abstract:** In this talk, we will explore the phases of cancer through a minimal model of the immune system's dynamics in elimination, equilibrium, and escape. We will also perform some simulations using pulse injections in an immunotherapy scheme.

Spring 2025

Dr. Lingju Kong

- **Date:** Fri., Jan. 31
- **Title:** *Modeling the dynamics of adoption and abandonment of multiple products. Joint work with Roger Chen and Min Wang*
- **Abstract:** We propose a compartmental differential equation model aimed at analyzing the dynamics of user adoption and abandonment across two products. This model captures two distinct abandonment processes: infectious abandonment, influenced by interactions among current and past users, and noninfectious abandonment, triggered by factors like mass media, advertisements, or the introduction of new products. We define critical thresholds, represented as R1 for product one and R2 for product two, and explore the existence and local stability of various equilibrium states, including user-free scenarios, dominance of product one, and dominance of product two, based on these thresholds. We prove the global stability of these equilibria under specific conditions and identify a necessary criterion for the coexistence equilibrium. We find conditions under which one product persists while the other fades away. Additionally, we conduct a comprehensive analysis of an associated optimal control problem. We first prove the existence of an optimal control pair and then determine the system conditions necessary for this optimal control pair. Extensive numerical simulations are conducted to validate our theoretical findings. Finally, we demonstrate the effectiveness of the model by fitting it to historical data on the daily active users of Facebook and Instagram. By calibrating the model with derived parameter values, we make predictions regarding the future user counts for both platforms.

Dr. Roger Nichols

- **Date:** Fri., Feb. 21
- **Title:** *A Spectral Theorist's Proof of the Riesz Composition Formula*
- **Abstract:** The famous Riesz composition formula is a multivariable integration formula with connections to operator theory. According to the formula, the composition of two Riesz potential operators (i.e., operators of convolution in Rn with Riesz potentials of the form $\gamma_{\alpha,n}^{-1}|\cdot|^{2\alpha-n}$, with $\gamma_{\alpha,n}$ an appropriate constant and $0 < \alpha < n/2$) is also a Riesz potential operator. Formally, the Riesz composition formula embodies the additive property of exponents when composing inverse powers of minus the Laplacian. Motivated by these formal connections to the Laplacian, we explore properties of Riesz potential operators, including their connections to the Laplacian, and provide a proof of the Riesz composition formula that is entirely natural from the point of view of spectral theory. This talk is based on joint work with Christoph Fischbacher and Fritz Gesztesy.

Min Wang

- **Date:** Fri., Mar. 21
- **Title:** *A Physics-Informed Neural Network Model for Social Media User Growth*
- **Abstract:** In this talk, a physics-informed neural network (PINN) model is proposed to predict the growth of online social network (OSN) users. The OSN user growth is modeled by a stochastic process and the associated Kolmogorov forward equation (KFE) is derived. Then a PINN model is built based on the KFE and trained using the real-world data. By combining mathematical modeling with machine learning, our approach provides a practical and interpretable methodology that harnesses the strengths of both physical laws and machine learning advancements, while minimizes the opacity in machine learning models.

Silvia Gazzola

- **Date:** Fri., Mar. 28
- **Title:** *Classic and data-driven numerical solvers for inverse problems*
- **Abstract:** Inverse problems are ubiquitous in many areas of Science and Engineering, including imaging problems: their solution is typically quite challenging because of their ill-posed and large-scale nature. During this talk we will start from the basic ideas underlying classical regularization methods for linear inverse problems, such as Tikhonov, and we will introduce some efficient hybrid projection methods that combine linear solvers such as Krylov methods and Tikhonov regularization. We will then consider a nonlinear inverse problem such as Full Waveform Inversion, and introduce a framework for compute data-driven optimal solutions.

Dr. Lani Gao

- **Date:** Fri., Apr. 4
- **Title:** *Bridging AI and clinical practice: A hybrid model for predicting large vessel occlusion in stroke*
- **Abstract:** Rapid detection of large vessel occlusion (LVO) in stroke is crucial due to its high mortality and narrow window for intervention. Machine learning and deep learning-based AI tools show promise for LVO prediction, yet clinical use is limited by the inconsistent pre-hospital data with varying LVO rates, the hard-to-interpret "black box" nature of many ML algorithms, and high costs of the AI tools. To address this gap, this study proposes a novel hybrid neural network (HNN) model that integrates classical statistical methods with neural networks, combining the structured framework and interpretability of statistical learning with the flexibility and regularization of ML. To evaluate the performance of models, we simulate stroke data with different LVO rates and sample sizes using NIHSS scores, patient demographics, medical history as factors in the simulated model. Performance was evaluated by sensitivity, specificity, accuracy, PPV, NPV and AUC against base models including logistic regression, Naïve Bayes, Random Forest, Decision Tree, and Neural Network. Simulation study shows the HNN outperforms these, exceeding logistic regression and neural networks by at least 3% in sensitivity and positive predictive value. This hybrid approach provides a robust and interpretable tool for pre-hospital LVO detection, integrating AI with clinical practice to enhance decision-making and patient outcomes.