Michael Barbosu (RIT)
**Mathematical Methods for Modeling Landslides**

Abstract: Mass movements are very complex phenomena and there is no general consensus on what the best approach is when generating landslide susceptibility maps. The complexity of the problem comes from identifying the large number of factors involved in favoring or triggering the mass movements, choosing the deterministic and stochastic parameters, estimating their weight, introducing them into an appropriate model, and validating the model. In this paper we present and discuss a collection of mathematical methods used to address some of these questions, from fuzzy logic, logistic regression and the analytical hierarchy process, to soil mechanics, artificial neural networks and genetic algorithms.

Nate Barlow (SUNY Buffalo)
**Analytic continuation of the low-density (virial) expansion through a fluid’s thermodynamic critical point**

Abstract: A multi-point approximant method is used to construct critical isotherms (pressure as a function of density at the critical temperature) that have the same critical scaling behavior of a fluid, while still retaining the low density behavior of the virial equation of state (virial expansion). Additionally, these approximants provide a method for predicting the critical temperature, pressure, and density of a fluid. A discussion is given on the nature of the thermodynamic critical point as a branch-point singularity in density. Various model fluids are examined.

Ranil Basnayake (Clarkson)
**Analysis of Geospatial Fluid Systems from Satellite Imagery**

Abstract: Analysis of fluid systems such as ocean and atmosphere is an important topic in current research. To analyze global dynamics of such systems, such as coherent pairs and transport barriers, the vector fields of the system is required. However, more often we observe such systems by a satellite and hence there does not exist a model to determine the motion field of those systems. In the absence of a prior model, optical flow technique can be employed on remote data to determine the vector fields. In this work, we obtained the stream function of motion and derived the velocity components from the computed stream function.

Mishkat Bhattacharya (RIT)
**Applications of linear, multilinear and Lie algebra techniques to the ground state OH molecule in electric and magnetic fields**

Abstract: The electronic, vibrational and rotational ground state of the OH molecule is currently of great interest as a platform for quantum computation, ultracold chemistry and Bose-Einstein condensation. In this talk the use of linear, multilinear and Lie algebra techniques in obtaining the analytical solution to the ground state OH spectrum in noncollinear electric and magnetic fields will be described. An application to physics of root counting techniques from real algebraic geometry will also be presented in the same context.
David Bindel (Cornell)

**Spectral densities and social networks**

**Abstract:** In spectral geometry and spectral graph theory, the low-lying eigenvalues of a Laplacian give important information about a manifold or graph, e.g. via Cheeger’s inequality. The more distribution of eigenvalues plays an important role in spectral geometry (e.g. via Weyl’s law) and in physical applications (e.g. density of states and conduction bands in materials), but this perspective seems to be less common in spectral graph theory. In this ads, we describe an efficient method for estimating the density of eigenvalues for a general graph Laplacian, show some pictures from example graphs, and ask for help with the question: “Why are the spectra shaped like that?”

Silvia Jimenez Bolanos (Colgate)

**Nonlinear Neutral Inclusions: Assemblages of Confocal Coated Spheres and Ellipsoids**

**Abstract:** If a neutral inclusion is inserted in a matrix containing a uniform applied electric field, it does not disturb the field outside the inclusion. The well known Hashin coated sphere is an example of a neutral coated inclusion. In this talk, we consider the problem of constructing neutral inclusions from nonlinear materials. In particular, we discuss assemblages of coated spheres and ellipsoids.

Bernard Brooks (RIT)

**Modeling the Human Colonization of Eastern Polynesia**

**Abstract:** CACM’s "Easter Island Group" has teamed with archaeologists Terry Hunt and Carl Lipo to answer the question: "How could human growth rates and colonization events have led to multiple remote Polynesian archipelagos being successfully settled over just a century or less?" This question is both of current interest to the archaeologists and lends itself well to mathematical analysis. The system of islands is modeled as a system of differential equations similar to an SIR model. Because the human migration in Eastern Polynesia occurred relatively late (1100 CE) there still exists physical and cultural evidence with which to calibrate and validate the mathematical model.

   Joint with M Radin, T Wiandt, C Lipo, T Hunt).

Jiechen Chen (SUNY Buffalo)

**Realistic modeling and simulation of influenza transmission over an urban community**

**Abstract:** Infectious diseases that are spread through human contact can progress very rapidly in a population. One of the key factors in the spreading of contagion, and a main concern in attempting to stop the spread of illness, is the particular configuration of links among individuals in local communities within the larger population. This study uses a detailed individual-based, three-partite model comprising about 245,000 individuals located in an urban area in the Northeastern United States. Interactions among individuals are
divided into family, workplace and pastime (service places, shopping, etc.), each occurring during a separate time period (daytime, pastime, and nighttime). Thus, the network allows one to model the spatial and temporal heterogeneity in the transmission of communicable diseases and to capture the differences between various individuals’ vulnerability to infection. We performed Monte-Carlo simulations of the spreading of influenza through this network. Simulation results correspond well to the reported epidemic information. We expect that the findings will offer a valuable platform to devise spatially and temporally oriented control and intervention strategies for communicable diseases.

Elizabeth Cherry (RIT)
Comparison of Electrophysiological Properties of Cardiac Purkinje Models

Abstract: Cardiac arrhythmias are abnormal rhythms caused by disruptions in the initiation and propagation of electrical waves through the heart. Of particular interest is alternans, a beat-to-beat oscillation in action potential duration that often is a precursor to life-threatening arrhythmias. Alternans occur at fast rates in the Purkinje network, which is a specialized conduction system that helps to coordinate contraction by ensuring the proper activation sequence and timing. We use numerical simulation to quantify and compare the spatiotemporal dynamics of six mathematical models of Purkinje cells. These models are formulated as large coupled systems of differential equations that describe the ionic processes governing the formation and propagation of action potentials in excitable cells. Using appropriate electrical stimulation protocols, we examine the rate dependence of action potential duration and conduction velocity in these models along with the properties of alternans, if present. We compare quantitatively the measured electrophysiological properties of these models with experimental data. We find that despite increased ionic complexity, many of these models fail to reproduce alternans, which are readily found in experiments. Additionally, we find that the models exhibit different degrees of rate dependence and memory. Our findings should guide model selection for future studies of the role of the Purkinje network in the development of arrhythmias through the mechanism of alternans.

Zachary Clawson (Cornell)
Causal Domain Restriction for Eikonal Equations

Abstract: For shortest path problems on graphs, the techniques to restrict the computational domain are well-known. We consider similar A*-type domain restriction techniques for continuous optimal trajectory problems. Unlike in the discrete case, this results in additional errors depending on grid size and the aggressiveness of restriction. We explore computational efficiency and accuracy of several such techniques. The resulting methods are particularly useful for higher-dimensional problems, for which refining the mesh in the entire domain is prohibitively costly.

John Costanzo (RIT)
A Regularization of Dynamic Time Warping Barycenter Averaging with Applications in Sign Recognition

Abstract: Dynamic time warping was developed as a similarity measure between time series, but does not in itself provide a method of averaging. Recently, a method of averaging
called DTW Barycenter Averaging (DBA) was developed by Petitjean et al that is consistent with dynamic time warping. This method produces results suitable for classification and clustering of time series data, and is based on minimizing the within group sum of squares (WGSS) of the data.

Because dynamic time warping is time scale invariant, the average is not unique; other warping of an average may also be averages. We propose a modification to DBA that allows for more flexibility in choosing the time scale of the resulting average. Time penalized DBA (TBA) adds a cooling regularization term to the WGSS functional. The regularization term penalizes the amount of total warping between the average and each other time series; hence features in the average appear closer to the average time at which they appear in the collection. We cool the regularization term to prevent it from altering the solution in undesirable ways.

Time penalized DBA is an effective method to average a collection both spatially and temporally, and also reduces the algorithm’s sensitivity to initial guess. Unfortunately, the extra parameters it requires make its use more complicated. We will show for a selection of parameters that TBA performs favorably over classical DBA on both artificial signals and on data captured from videos of signs from American Sign Language.

Michael Dunphy (Waterloo)

**Focussing and normal mode scattering of the first mode internal tide by mesoscale eddy interaction**

**Abstract:** The generation of the internal tide (via, for example, barotropic tide-topography interaction) has been studied by many authors, however, the fate of the internal tide (the propagation, interaction with other processes and ultimately its dissipation) is still under investigation. Here I will report on numerical experiments performed using the MITgcm to investigate the interaction of a mode-one internal tide with a barotropic and a baroclinic mode-one mesoscale eddy.

A suite of experiments are conducted varying the eddy size, velocity, and Coriolis parameter. The barotropic cases show hot and cold beams of energy flux, and the baroclinic cases yield the generation of higher mode internal tide beams. An energy budget analysis is performed to measure the scattering of energy between modes, and conversion efficiencies reach 13 percent for the parameters regime considered here.

Chris Earls (Cornell)

**Condition assessment and performance prognosis in complex structural systems**

**Abstract:** Complex structural systems abound within the realms of applied science and engineering. Examples include radio and optical telescopes, artificial satellites, robotic probes, aircraft, ships, etc. Frequently these systems are called upon to perform tasks for which they were not designed, or to operate in conditions, or for longer periods, than was initially intended. Questions concerning the condition and future performance of the structures that support these complex systems must then be answered. One way to pursue such answers is through the solution of an inverse problem: given measures of sparse and noisy inputs and outputs, make predictions about the nature of the underlying system. Given the inherent uncertainties in such problems, it makes sense to pursue Bayesian approaches to stochastic inversion.

The present discussion will be motivated by ship structures, and describe various stochastic inversion schemes that have proven useful in such contexts. Additionally, techniques from "manifold interpolation" will be described and applied, as a means to ameliorate computa-
tional bottlenecks that arise during such stochastic inversions.

Alan Edelman (MIT)

*Julia: A Fresh Approach to Technical Computing*

**Abstract:** Authors: Jeff Bezanson, Alan Edelman, Stefan Karpinski, Viral Shah and the vibrant open source community.

The Julia computing system is fast becoming the way to do technical computing. The community spirit, open source freely available nature of Julia makes it easy to try, the performance makes you find out what you have been missing, and the gentle road to new programming paradigms might just make you a better programmer. In this talk, I will describe a vision for parallel computing that is just beginning, but may just change the age old question of “How do we write parallel programs” to “How do we write serial programs” and construct primitives that give the parallel performance we hope to see.

Mohamed Elshrif (RIT)

*A Quantitative Comparison of the Behavior of Human Ventricular Cardiac Electrophysiology Models in Tissue*

**Abstract:** Mathematical modeling is an important tool for studying cardiac arrhythmias, but the large number of published models of cardiac electrical dynamics often disagree in their predictions of emergent properties of the heart. In addition, usually these models are validated in isolated cells, but they often are used to study behavior in tissue, where it is known that the effects of cell coupling can modify dynamics. Our aim is to validate the behavior of such models in tissue and to facilitate selecting a model suitable for the conditions to be studied by quantifying model properties. We assess the behavior of two recently published models of human ventricular cells in isolated cells (0d) and in tissue (1d and 2d). Several electrophysiological properties are assessed quantitatively for both models, including action potential duration and shape, steady-state and S1-S2 APD and conduction velocity restitution curves, existence and magnitude of alternans, short-term memory, and the behavior of reentrant waves that underlie arrhythmia. We extend our work by comparing the behavior of these models with that of several previously published models of human ventricular cells. Several possible explanations for the dynamical differences observed between the different models will be provided and the implications of their disagreement will be discussed.

Emily Fagerstrom (SUNY Buffalo)

*On the spectrum of the focusing NLS equation with non-zero boundary conditions and the Benjamin-Feir instability*

**Abstract:** Based on a joint work with Gino Biondini.

Benjamin and Feir noticed that perturbations of the constant background did not produce the behavior one would expect from a linear stability analysis. This has come to be known as the nonlinear stage of the Benjamin-Feir instability, or modulational instability. Zakharov and Gelash conjectured that the development of the modulational instability consists of quasi-Akhmediev breathers. That is, perturbations of the constant background produce particular zeros of the scattering coefficient that mediate the instability.

To this end, we study the spectral problem for the focusing NLS equation

\[ iq_t + q_{xx} + 2(|q|^2 - q_0^2)q = 0, \]
with the piecewise constant, box-like initial conditions

$$q(x, 0) = \begin{cases} 1, & |x| > L, \\ b \exp(i\alpha), & |x| < L, \end{cases}$$

where \( b > 0 \), using the recently formulated inverse scattering transform for the focusing nonlinear Schrödinger (NLS) equation with non-zero boundary conditions. In this talk, we discuss our findings.

Specifically, in the case of the potential well \((b < 1)\), with \( \cos \alpha > b \) we find there are no discrete eigenvalues, using Rouché’s theorem. In the case of the potential barrier \((b > 1)\), if \( \cos \alpha > 1/b \), there is always a discrete eigenvalue in \((1, b)\), and there are no eigenvalues off this interval. Thus, there exist arbitrarily small perturbations of the constant background for which there are discrete eigenvalues. Thus, for potentials with nonzero boundary conditions, no area theorem is possible. In the case of a potential barrier or a potential well, for sufficiently large \( \alpha \), we find conditions under which a zero exists on the continuous spectrum. Numerical evidence suggests these zeros travel as \( L \) increases, becoming discrete eigenvalues and heading towards the branch point \( ib \).

Raluca Felea (RIT)

*Microlocal analysis of SAR with moving objects*

**Abstract:** We consider four particular cases of Synthetic Aperture Radar imaging with moving objects. In each case we analyze the forward operator \( F \) which maps the image to the data and the normal operator \( F^*F \) which is used to recover the image. In general, by applying the backprojection operator \( F^* \) to the data, artifacts appear in the reconstructed image. We describe these artifacts and show how to microlocally reduce their strength to obtain a better image.

Pamela Fuller (RPI)

*Integrate-and-Fire model of Insect Olfaction*

**Abstract:** When a locust detects an odor, the stimulus triggers a series of synchronous oscillations of the neurons in the antenna lobe. These oscillations are followed by slow dynamical modulation of the firing rates which continue after the stimulus has been turned off. I model this behavior by using an Integrate-and-Fire neuronal network with excitatory and inhibitory neurons. The inhibitory response of both types of neurons contains a fast and slow component. The fast component, together with the excitation, creates the initial oscillations while the slow component suppresses them and aids in the creation of the slow patterns that follow. During the initial oscillations the stimulus can be identified by determining which excitatory neurons participate consistently in every cycle of the oscillations.

Kelum Gajamannage (Clarkson)

*Model Reduction of Collective Motion by Principal Manifolds*

**Abstract:** While the existence of low-dimensional embedding manifolds has been shown in patterns of collective motion, the current battery of nonlinear dimensionality methods are not amenable to the analysis of such manifolds. This is mainly due to the necessary spectral decomposition step, which limits control over the mapping from the original high-dimensional
space to the embedding space. Here, we propose an alternative approach that demands a two-
dimensional embedding which topologically summarizes the high-dimensional data. In this
sense, our approach is closely related to the construction of one-dimensional principal curves
that minimize orthogonal error to data points subject to smoothness constraints. Specifically,
we construct a two-dimensional principal manifold directly in the high-dimensional space
using cubic smoothing splines, and define the embedding coordinates in terms of geodesic
distances. Thus, the mapping from the high-dimensional data to the manifold is defined in
terms of local coordinates. Through representative examples, we show that the principal
manifold retains the original structure even in noisy and sparse data sets. The principal
manifold finding algorithm is validated on a dynamical system of multiple agents simulating
a complex maneuver called predator mobbing and the results are compared with a well-
established nonlinear dimensionality reduction method.

Harold M Hastings (Hofstra University)
\textit{Health Care Costs Follow a Power Law}
\textbf{Abstract:} The data shows that United States health care costs follow a power law, hence
the mean and variance are not defined in the absence of cutoffs. Thus, unlike the assumptions
behind insurance, the variance of population health care costs does not approach 0 with
increasing population size.

Amanda Hood (Cornell)
\textit{A Gershgorin theorem for the nonlinear eigenvalue problem}
\textbf{Abstract:} The eigenvalues of a matrix are often of interest in math and science, partic-
ularly for describing the solutions to linear differential equations. In studying systems with
delay, damping or radiation, however, the nonlinear eigenvalue problem arises: for an analytic
matrix-valued function $T : \Omega \to \mathbb{C}^{n \times n}$, the nonlinear eigenvalue problem is to find $\lambda \in \Omega$
such that the matrix $T(\lambda)$ is singular.

The Gershgorin circle theorem is a classical localization result, giving sets where the eigen-
values of a matrix must lie as well as eigenvalue counts for those sets. Until recently, tools such
as Gershgorin’s theorem have only been extended to special cases of the nonlinear eigenvalue
problem (where $T$ is polynomial, for instance). In this talk, I will present a generalized version
of Gershgorin’s theorem which applies to any type of nonlinear eigenvalue problem, and use
it to obtain localization regions and eigenvalue counts for a problem from delay differential
equations.

Sumedh Joshi (Cornell)
\textit{A deformed spectral multidomain penalty model for the incompress-
ible Navier-Stokes equation}
\textbf{Abstract:} To study the shoaling behavior of nonlinear internal waves, a collocation-
based variant of spectral element method has been developed to solve the incompressible
Navier-Stokes equations. As part of the computational challenges in solving the incompress-
ible Navier-Stokes equations, an inconsistent pseudo-pressure Poisson equation must be solved.
In solving the resulting matrix equation, we require a regularization technique which will be
presented here. The regularization employed involves computing the null singular vector of
the discrete operator by an inverse shifted power iteration. This method will be discussed,
along with preconditioning techniques for solving the resulting shifted linear system, and the computational challenges involved.

Daniel Kraus (SUNY Buffalo)
The focusing Manakov system with nonzero boundary conditions at infinity

Abstract: We consider the Manakov system with nonzero boundary conditions (NZBC) at infinity in the focusing case. The Manakov system, i.e., the 2-component nonlinear Schrödinger (NLS) equation,

\[ i\dot{q} + q_{xx} - 2\sigma \|q\|^2q = 0, \]

is extensively used as a model in optical fibers and Bose-Einstein condensates (BEC). The inverse scattering transform (IST) for Eq. (1) with vanishing potentials at infinity was done in the original work by Manakov [1] (see also [2]). On the other hand, the IST for the case with NZBC was done only recently [3] and only in the defocusing case (see also [4]), while the focusing case is completely open.

As in [3,4], we consider (1) with the boundary conditions \( q(x,t) \rightarrow q_{\pm} \) as \( x \rightarrow \pm\infty \), where \( \|q_{\pm}\| = q_0 \). We rigorously formulate the IST for the focusing case. Namely, we give: a rigorous proof of the analyticity of the scattering coefficients; a rigorous treatment of the discrete spectrum; symmetry relations between the analytic eigenfunctions; explicit soliton solutions, including both bright and dark-bright solitons. We develop the IST in such a way that the reduction \( q_0 \rightarrow 0 \) can be made throughout.

References


Tipaluck Krityakierne (Cornell)
ParDYCORS: Parallel DYnamic COordinate search using Response Surface models

Abstract: DYCORS (DYnamic COordinate search using Response Surface models) proposed by Regis and Shoemaker (2013) has been shown to be a computationally effective optimization algorithm especially for problems in a class of so called HEB (High-dimensional, Expensive, and Blackbox) functions. DYCORS is based on the idea that the next evaluated point is selected from random trial solutions obtained by perturbing only a subset of the coordinates of the current best solution. Because searching in high-dimensional spaces requires a large number of function evaluations, solving HEB problem with a serial algorithm can also be extremely time-consuming. Therefore, we implement a parallel DYCORS, namely, ParDYCORS. The iteration of the algorithm consists of building an RBF model to approximate an expensive objective function, making use of this computational inexpensive response surface to guide on how to select the next evaluation points which will be evaluated in parallel. Several numerical results are illustrated and compared against alternative methods. The results
demonstrate that our algorithm makes a fast decrease in objective function value on a limited computational budget and well suited for very high-dimensional problems.

Lilia Krivodonova (Waterloo)

*Numerical simulations of sound production in brass instruments*

**Abstract:** We will discuss sound production and propagation in brass instruments, specifically the trumpet. When notes that are being played are high pitched and loud, sound waves have a finite magnitude for which linear acoustics fails to model the problem properly. Nonlinear wave propagation effects such as wave steepening are important in sound production. For example, these nonlinear effects are responsible for bright, brassy sound of the trumpet. We will discuss the experimental set up and computational model aimed at understanding nonlinear phenomena of wave steepening and, ultimately, production of shocks within musical instruments. The model is based on the two dimensional Euler equations solved with the discontinuous Galerkin method.

Nitu Kumari (Clarkson)

*Turing Patterns and Long-Time behavior in a tri-trophic predator-prey model*

**Abstract:** We consider a spatially explicit three-species food chain model, describing generalist top predator-specialist middle predator-prey dynamics. We investigate the long-time dynamics of the model and show the existence of a finite dimensional global attractor in the product space. We perform linear stability analysis and show that the model exhibits the phenomenon of Turing instability, as well as diffusion induced chaos. Various Turing patterns such as stripe patterns, mesh patterns, spot patterns, labyrinth patterns and weaving patterns are obtained, via numerical simulations in 1d as well as in 2d. The Turing and non Turing space, in terms of model parameters, is also explored. Finally, we use methods from nonlinear time series analysis to reconstruct a low dimensional chaotic attractor of the model, and estimate its fractal dimension. This provides a lower bound, for the fractal dimension of the attractor, of the spatially explicit model.

Katelyn Leisman (RPI)

*Maxwell-Bloch Equations in the Presence of Damping*

**Abstract:** In this poster, I present the results of numerically solving the Maxwell-Bloch Equations while varying two damping parameters.

Xiaolin Li (SUNY at Stony Brook)

*A Spring Model for Fabric Surface and Application to Parachute Inflation*

**Abstract:** We use front tracking to model the dynamic evolution of fabric surface. We represent the fabric surface by a triangulated mesh with preset equilibrium side length. The stretching and wrinkling of the surface are modeled by the mass-spring system. The external driving force is added to the fabric motion through the "Impulse method" which computes the velocity of the point mass by superposition of momentum. The mass-spring system is a
nonlinear ODE system. Added by the numerical and computational analysis, we show that the spring system has an upper bound of the eigen frequency. This upper bound plays an important role in determining the numerical stability and accuracy of the ODE system. The numerical model is convergent and is applied to the simulation of parachute inflation.

Tian Ma (Clarkson)

Differential geometry perspective of shape coherence and curvature evolution by finite-time non-hyperbolic splitting

Abstract: Mixing and coherence are fundamental issues of understanding transport in fluid dynamics and other non-autonomous dynamical systems. Here we define shape coherent sets and relate it to curve congruence by showing that points with zero-splitting between stable and unstable manifolds locally correspond to points where curvature will evolve only slowly in time. We then develop curves of points with zero-angle by continuation methods in terms of the implicit function theorem. Several examples are used to illustrate our method.

Kara Maki (RIT)

A Novel Model for the Suction Pressure Under the Contact Lens

Abstract: We study the dynamics of the contact lens to better understand how the design of the lens can be optimized for patient comfort and ocular fit. When a contact lens is inserted on an eye, it is subjected to forces from both the tear film in which it is immersed and the blinking eyelid. In response, the lens bends and stretches. These forces center the lens, and they produce the suction pressure that keeps the lens on the cornea. In this presentation, we couple fluid and solid mechanics to determine the most prominent forces acting on the lens. We present a mathematical model that predicts the suction pressure. We explore the influence of contact lens properties on the suction pressure.

Authors: Kara L. Maki*, David S. Ross*, Emily K. Holz# *School of Mathematical Sciences, Rochester Institute of Technology #Department of Chemical and Biomedical Engineering, Rochester Institute of Technology

Venkata Manem (Waterloo)

Mathematical modeling of radiation induced secondary malignancies for various particle therapies

Abstract: Several scientific advancements in anti-cancer therapies have significantly improved the survival rate of cancer patients. These significant improvements have proved vital for dose conformity and delivery to the primary tumor volumes using external beam radiation therapy (EBRT). However, radiation therapy acts as a double-edged sword leading to drastic side-effects, one of them being the manifestation of secondary malignant neoplasms in cancer survivors. The latency time for the occurrence of second cancer is around 10-20 years. Therefore, it is very important to evaluate the risks related with various clinically relevant radiation treatment protocols, to minimize the second cancer risks without hindering treatment to the primary tumor volume. A generalized biologically motivated mathematical framework to understand the second cancer risks associated with more contemporary treatments will be discussed. Overall, our study reflects the necessity to design an optimal treatment regimen to
minimize second cancer risks without hindering treatment of the primary tumor volume.

Derek Manuge (Guelph)

**Multi-Asset Option Pricing with Exponential Lévy Processes**

**Abstract:** To represent multi-asset option prices, we consider a partial integro-differential equation whose underlying variables are exponential Lévy processes. Exponential Lévy processes have been used for modelling financial derivatives because of their ability to exhibit many empirical features of markets; including excess skewness, kurtosis, an absence of autocorrelation in price increments, finite variance, aggregational normality, and the ability to change discontinuously. In a multidimensional setting, a general analytic pricing formula is obtained, allowing for the direct valuation of multi-asset options on \( n \in \mathbb{Z}^+ \) risky assets. By providing alternate expressions for multi-asset payoff functions in terms of Mellin transforms, the general pricing formula can reduce to many popular cases, including American basket options which are considered here. Within the context of Mellin transforms, this work extends basket option results to dimensions \( n \geq 3 \) and more generally, to payoff functions whose only requirement is Lipschitz continuity.

Antonio Mastroberardino (Penn State Erie)

**Mathematical Modeling of the HIV/AIDS Epidemic in Cuba**

**Abstract:** In this talk, I will present a nonlinear mathematical model for the transmission dynamics of HIV/AIDS in Cuba. Due to Cuba’s highly successful national prevention program, we assume that the only mode of transmission is through contact with people who do not know that they are HIV positive. We find the equilibria of the governing nonlinear system, perform a linear stability analysis, and then determine the threshold for global stability. We conclude with an application of optimal control to our model and present the corresponding optimality system.

James Melfi (Cornell)

**Dragonfly Flight: Kinematics and Dynamics**

**Abstract:** Dragonflies are amazing insects which use their mid-air agility to hunt and catch other flying insects. Using the custom dragonfly arena at Janelia farms, we record the kinematics of the insects, with a focus on discovering the quantitative differences can be seen between steady state flying, and unsteady maneuvering flight. Through this, we find that one of the keys to the dragonflies ability to fly is the torsional flexibility of the wings, which proves necessary for a dragonfly to produce sufficient force to remain in mid-air. This talk will be focused on the kinematics of the dragonfly during both free and tethered flights, and what we can learn about the dragonfly dynamics from the kinematics.

Alex Moore (Cornell)

**A Rod Model for the Developable Mobius Strip**

**Abstract:** Recent efforts to find the equilibrium shape of an inextensible Mobius strip have produced apparently conflicting approaches and results. While one approach uses a traditional one dimension elastic rod theory, another claims that the strip must be modeled as a two
Juliane Mueller (Cornell)

*A Surrogate Model Based Algorithm for Computationally Expensive Black-Box Nonlinear Integer Programming Problems*

**Abstract:** Most integer optimization problems arising in management and engineering applications are NP-hard and therefore difficult to solve. Typically, algorithms based on branch and bound methods or evolutionary strategies are used to solve these kinds of problems. If, however, evaluating the objective and constraints requires a computationally expensive black-box simulation, the number of function evaluations must be as low as possible in order to obtain solutions within an acceptable time. A surrogate model algorithm that uses radial basis functions is proposed. Experimental results on test functions and a computationally expensive watershed management problem show that the surrogate model algorithm is a promising approach.

Laura Munoz (RIT)

*Predicting Cardiac Arrhythmias with a 1D Nonlinear Dynamical Model*

**Abstract:** Sudden cardiac arrest, which is a leading cause of death in the industrialized world, frequently results from an uncoordinated cardiac rhythm called ventricular fibrillation (VF). VF sometimes emerges after a normal rhythm is interrupted by a short sequence of premature, irregularly-timed beats. To gain an improved understanding of the relationship between premature beats and VF formation, a 1D nonlinear dynamical model of electrical wave propagation was developed. In previous studies, this model was shown to successfully predict which sequences of premature beats were more likely to produce VF in canine hearts in vivo. The more recent phase of the study has focused on comparing the predictions of the model with more detailed observations obtained from in vitro cardiac data sets. We applied a likelihood ratio test to logistic regression results to confirm that the effect of the model prediction is significant ($p < 0.0001, \text{coeff.} = 1.26, n = 184$ sequence categories) in vitro, and we also determined that the predicted spatial changes in wave duration are positively correlated with the observed values. These results are encouraging, and may serve as a basis for developing improved methods for anticipating and preventing VF.

Robert Noest (Cornell)

*Hunting patterns of a Tiger beetle*

**Abstract:** We study the hunting behavior of a tiger beetle when it is presented with a human-controlled fake prey. Using video recordings of each hunt we attempt to discover the beetle’s neural algorithm. I will introduce our control model for the beetle body orientation and discuss our initial findings. These findings suggest that the beetle can deduce the distance
to the prey from visual information, which has never been shown before.

Daniel Otero (Waterloo)

**Denoising of hyperspectral images: an examination of different approaches**

**Abstract:**

Briefly, hyperspectral images (HI) are "data cubes" that contain a collection of images taken at different wavelengths. They are usually taken by a hyperspectral camera and may contain from tens to hundreds of frequency bands depending on the spectral resolution of the camera’s sensor. The sensor measures the reflectance values of different wavelengths at each pixel location, which is a measure of the ratio of reflected energy to incident energy. Reflectance is important since different materials exhibit different spectral "fingerprints", so that by taking a look at the spectrum (entire set of reflectances) at a pixel, it is possible to determine the composition/nature of material represented by that pixel. This characteristic makes HI useful for a wide range of applications such as agriculture, mineralogy, physics and surveillance.

As with any image, HI are also prone to be contaminated with noise. Therefore, reconstruction techniques are desirable in order to recover good approximations of the original noise-free hyperspectral data. In this study, we compare four different approaches that address the inverse problem when HI are contaminated with white Gaussian noise. The main difference between these methods is how they process the hyperspectral image, i.e., if they treat the hyperspectral data as a whole, as a collection of frequency bands (often referred to as "channels"), as a set of spectra, or as both a collection of frequency bands and spectra.

In the first approach, we consider HI as collections of spectra. This method allows us to perform either filtering (e.g., wavelet) or regularization (e.g., sparsity) in the spectral domain.

As for the second approach, we view HI as sets of frequency bands or "channels". In this case, the denoising process "occurs" in the spatial domain. In particular, we carry out the regularization by using the standard channel-by-channel Total Variation (TV) denoising.

Along these lines, for the third approach, a formulation of vectorial TV denoising (e.g., Bresson and Chan’s vectorial TV), allows us to denoise the entire hyperspectral image at once. In this case, HI are viewed as a whole.

Finally, for the fourth approach, HI are seen as both collections of spectra and frequency bands. This method involves a combination of the first two approaches, therefore, the denoising is carried out by regularizing in the spatial domain, and by either filtering or regularizing in the spectral domain. This inverse problem can be solved by algorithms such as the Alternating Direction Method of Multipliers (ADMM) and Split Bregman.

Stephen Pallone (Cornell)

**A Randomized Cutting Plane Algorithm for Minimizing Pseudoconvex Functions**

**Abstract:** We consider two different algorithms for minimizing a pseudoconvex function. These algorithms are based on cutting plane methods, a generalization of one-dimensional bisection algorithms. The first is a center of gravity method originally proposed by Yudin and Nemirovsky. Although it has many desirable properties, it is impossible to implement. As an alternative, we consider a randomized cutting plane algorithm which is much more tractable and retains many of those same properties, including geometric convergence of the sequence of volumes. We will also give preliminary ideas to generalize this randomized cutting plane method to utilize the information from noisy gradient estimates.

Colin Ponce (Cornell)
Multilevel Preconditioning for Solving Large Graph Laplacian-Based Linear Systems

Abstract: In a wide range of disciplines today, computational techniques are being employed to analyze larger and larger networks, from power grids to protein-protein interaction networks. Due to the size of these networks, specialized techniques often must be employed to make the analysis computationally feasible. One common operation is to represent the network as a Graph Laplacian and perform a linear solve. I present in this talk a multilevel preconditioner for the conjugate gradient method inspired by well-known finite element preconditioners. The key operation in this preconditioner is to approximate the problem over a smaller graph, fully solve the linear system over that graph, and then interpolate the solution back to the original problem. Preliminary tests indicate that this technique allows the number of conjugate gradients iterations to remain stable as the graphs grow large.

Ruibin Qin (Waterloo)

Linear Stability Analysis of the Discontinuous Galerkin Method on Uniform and Non-Uniform Grids

Abstract: Applying a discontinuous Galerkin spatial discretization to a hyperbolic PDE results in a system of ODEs for the unknown solution coefficients. This system can be solved with a time integration scheme such as, for example, a Runge-Kutta method. The largest allowable time step depends on the eigenvalues of the spatial discretization matrix and the absolute stability region of the ODE solver. In this talk we present an analysis of the eigenvalues of the DG scheme with the upwind flux applied to the one-dimensional scalar advection equation. We derive a formula for the eigenvalues on an $N$ element uniform grid in terms of the sub-diagonal $[p, p+1]$ Pade approximation of $e^{-z}$, where $p$ is the order of the finite element basis. This allows us to draw a number of conclusions about the CFL number and stability of the scheme, for example, a bound on the largest in magnitude eigenvalue. Then, we analyze the eigenvalues of the DG method on non-uniform grids and demonstrate that a CFL condition less than the one prescribed by the local stability condition (and commonly assumed) can be used. Finally, we extend this analysis to two-dimensional problems on rectangular grids and show how we can relax the CFL condition in certain cases.

Michael A. Radin (RIT)

Dynamics of a Discrete Population Model for Extinction and Sustainability in Ancient Civilizations

Abstract: We investigate the history of the problem such as the Standard Logistic Growth Model, the Basener-Ross Model and the Invasive Species Model, from which we construct the Discrete Model. In addition, we will compare the similarities and differences between the discrete and continuous models.

Benjamin Ritz (Clarkson)

A Hybrid Genetic Algorithm with Implicit Filtering for Mixed-Integer Optimization Problems

Abstract: We have constructed a novel optimization tool for nonlinear mixed-integer problem-solving. The algorithm is a hybrid of the NSGA-II genetic algorithm with implicit
filtering. The new algorithm performs derivative-free optimization, which expands the breadth of its application to simulation-based modeling and problems with difficult or unknown derivatives. It is also novel in its application of implicit filtering to problems with integer variables. This allows the use of a powerful, noise-sensitive optimization technique with the simulation-based mixed-integer optimization prevalent in engineering and the sciences.

Joseph Rosenthal (RPI)
A mathematical model of the effect of Bexarotene on Alzheimer’s Disease treatment
Abstract: Amyloid-beta (Aβ) has long been associated with the pathology of Alzheimer’s Disease (AD). Aβ removal via apolipoprotein E (ApoE) has been shown to be upregulated by a retinoid X receptor-agonist, Bexarotene. A mathematical model of AD in APP/Presenilin-1 mice was constructed in order to better understand the Bexarotene-based Aβ-clearance mechanism and direct treatment for AD. In this model, low dosages of Bexarotene were unable to stem neuronal death, but a critical dosage was found to recover healthy neurons.

Gili Rusak (Siena College)
Analysis of Twitter Teenager Networks
Abstract: The teenage years are a formative period in young people’s lives where they form their first lasting social relationships. Some teenagers get involved, then, in unfortunate activities such as drug use. Yet the properties of communities of teenagers have been mostly unknown and unexplored. Shedding light on such properties can help us understand teenage behavior and help guide teenagers towards positive endeavors.

The teenage years are a formative period in young people’s lives where they form their first lasting social relationships. Some teenagers get involved, then, in unfortunate activities such as drug use. Yet the properties of communities of teenagers have been mostly unknown and unexplored. Shedding light on such properties can help us understand teenage behavior and help guide teenagers towards positive endeavors.

This research identifies unique characteristics of Twitter teenager communities. We researched communities of two distinct school districts, 200 members each. We utilized Twitter’s API and analyzed this data using methods from probability theory, statistics, and network theory such as breadth first search, degrees of separation, graph density, and homophily. Our approach is unique since, to the best of our knowledge, it is the first attempt in the literature to quantitatively analyze teen behavior on social networks through applied mathematics.

When compared with general population users, results show that teenagers behave uniquely. Teens tend to follow more users, and increase friendships over time. They tend to friend individuals online who they already know offline. Teenagers also use Twitter as a news media and form supportive communities. These networks are dense and have two degrees of separation: within a tweet and retweet, the entire community can see a message. These results found traits of teenager communities and can be channeled to find solutions to emerging problems involving the massive use of social media. For example, Twitter can be used as a positive tool for prevention bad habits among teens.

Tuhin Sahai (UTRC)
Iterative methods for propagating uncertainty through complex networks
Abstract: Polynomial Chaos based methods are used extensively for propagating uncer-
tainty through smooth dynamical systems. Though useful for systems of small to moderate dimension, the curse of dimensionality restricts the applicability of these methods to high dimensional dynamical systems. In this work, we develop a parallel framework for simulating a large set of differential equations that can be used to propagate uncertainty. Our approach first uses a novel decentralized clustering approach, based on propagating waves in the graph, for partitioning the system of equations obtained using polynomial chaos based methods. The partitioned system is then simulated using adaptive waveform relaxation, an efficient approach for the distributed simulation of differential algebraic equations. The efficacy of this two step approach for propagating uncertainty is demonstrated on models of building systems and electrical circuits.

Michael Schwarz (RPI)

Waveaction Spectra for Modified MMT Model

Abstract: The Majda-McLoughlin-Tabak (MMT) model describes a one-dimensional system that exhibits dispersive wave turbulence. The original MMT model includes linear and nonlinear terms. I am investigating a modified version of the model where the linear term is absent. This model, like the original MMT model, has three conserved quantities: wave-action, energy, and momentum. I am interested in the long-time average of the distribution of waveaction throughout the system as a function of wavenumber. This average is called the waveaction spectrum. I discuss methods for predicting this spectrum and compare with numerical results. I consider both the case where driving and damping are present and the case where they are absent. The theoretical predictions make use of dimensional analysis, and an effective dispersion relation obtained using the Zwanzig-Mori projection method. The numerical results are obtained using the fourth order Runge Kutta method and the Metropolis algorithm for Monte Carlo simulation.

Qiangqiang Shi (SUNY at Stony Brook)

Application of GPU to Three Computational Models

Abstract: In this talk, we will introduce application of Graphics Processing Unit (GPU)-based algorithms for high performance computation of mathematical models in FronTier++. In the first case, the one-dimensional gas dynamics problem is solved by Weighed Essentially Non-Oscillatory (WENO) scheme, we achieved 7-20x speedup for different mesh sizes on 1 GPU. In the second case, the spring model for fabric dynamics is studied, the GPU speedup is about 10-20 times faster than the non-GPU code for different mesh sizes. In the last case, a GPU enhanced numerical algorithm for American option pricing under generalized hyperbolic distribution was studied. Using one GPU, we have achieved 2x speedup for the price of single option and 100x speedup for multiple options.

Alex Shum (Waterloo)

Direction-Dependent Optimal Path Planning for Rovers

Abstract: Planning optimally safe and energy efficient paths is important for rovers in extraterrestrial exploration. Shortest path and obstacles are often considered. Risk and solar energy are also important factors to consider when solving this problem.

Using the Ordered Upwind Method, the anisotropic, static Hamilton- Jacobi-Bellman equation (HJB) is solved. A more accurate model of the environment is provided than using
the isotropic Eikonal equation. An error bound is proven for the rate of convergence of the OUM algorithm to the viscosity solution. Finally, this approach is compared to other approaches.

Mutiara Sondjaja (Cornell)
A quadratic cone relaxation-based algorithm for linear programming
Abstract: We present and analyze a linear programming (LP) algorithm based on replacing the non-negative orthant with larger quadratic cones. For each quadratic relaxation that has an optimal solution, there naturally arises a parameterized family of quadratic cones for which the optimal solutions create a path leading to the LP-optimal solution. We show that this path can be followed efficiently, thereby resulting in an algorithm whose complexity matches the best bounds proven for interior-point methods.

Steven Strogatz (Cornell)
Doing math in public
Abstract: In the spring of 2010, I wrote a 15-part series on the elements of math for the New York Times. To my surprise – and my editor’s – each piece climbed the most emailed list and elicited hundreds of appreciative comments. In this talk I’ll describe my adventures in bringing math to the masses, with thoughts about what worked ... and what didn’t.

Amy Strosser (Mount Saint Mary’s University)
Walk Modularity for Detecting Communities in Networks
Abstract: A community within a graph is a highly connected subgraph. Finding communities within large graphs, similar to cluster detection, is a topic of practical interest in biology, computing, social sciences, and statistical mechanics. Many techniques for community detection in a large graph G are designed to maximize modularity, Q, a measure of the quality of a partition of G into two or more communities. Intuitively, modularity measures the difference in edge density found within communities and the edge density expected in a suitably chosen random model. In this talk, we present a natural generalization of modularity based on the difference between the actual and expected number of walks of length k in the graph, which we call walk-modularity, Q_k. We develop a novel community-detection algorithm designed to maximize Q_k using spectral graph theory. Finally, we apply this algorithm to both synthetic and real-world graphs and find that the results favorably compare against cluster-detection algorithms established in literature.

Allen Tesdall (CUNY)
Glancing weak Mach reflection
Abstract: We study the glancing limit of weak shock reflection, in which the wedge angle tends to zero with the Mach number fixed. Lighthill showed that, according to linearized theory, the reflected shock strength approaches zero at the triple point in reflections of this type. To understand the nonlinear structure of the solution near the triple point in nearly glancing reflections, then, it is necessary to understand how the reflected shock diffracts nonlinearly into the Mach shock as its strength approaches zero. Towards this end, we formulate a half-
space initial boundary value problem for the unsteady transonic small disturbance equations that describes nearly glancing Mach reflection. We solve this IBVP numerically, and we find in the solutions a complex reflection pattern that closely resembles Guderley Mach reflection. This is joint work with John Hunter.

Ryan Thompson (RIT)
*Using Delay Differential Equations for Modeling Calcium Cycling in Cardiac Myocytes*

**Abstract:** The cycling of calcium at the intracellular level of cardiac cells plays a key role in the excitation-contraction process. The interplay between ionic currents, buffering agents, and calcium release from the sarcoplasmic reticulum (SR) is a complex system that has been shown experimentally to exhibit complex dynamics including period-2 states (alternans) and higher-order rhythms. Many of the calcium-cycling activities involve sensing, binding, or the diffusion of calcium between intracellular compartments; these are physical processes that take time and typically modeled by relaxation equations where the steady-state value and time course of a particular variable are specified through an ordinary differential equation (ODE). An alternative approach is to use delay differential equations (DDEs), where the delays in the system correspond to non-instantaneous events. In this study, we utilize a DDE to model the diffusion of calcium through the SR in place of the relaxation ODE typically used for this process. We analyze the dynamical behaviors of the system and compare them with those of other models of intracellular calcium cycling. Finally, we suggest promising avenues for further development of our preliminary work.

George Thurston (RIT)
*A Hessian geometric construction that aids analysis of nonmonotonic effects in ternary mixture phase separation*

**Abstract:** Joint work with David S. Ross (RIT).

Ternary, quaternary, and multi-component phase separations are common in biological systems, and their properties have many physiological and pathological consequences. As one example, understanding the molecular origins of the phase boundaries of eye lens protein solutions can help understand loss of transparency of the eye lens in cataract, a leading cause of blindness. The phase boundaries respond in a sensitive and non-monotonic fashion to small changes in molecular interaction strengths. We show how the geometry of relevant intersections, in the space of the components of the Hessian of the intensive Gibbs free energy with respect to relative compositions, can assist in comprehending the origins of such non-monotonic and sensitive changes of the phase boundaries.

Michael Todd (Cornell)
*Smoothing the largest and the kth-largest of a set of smooth functions*

**Abstract:** We provide a technique for smoothing the pointwise-largest or pointwise-kth-largest of a set of n smooth functions in $\mathbb{R}^d$. In contrast to convolution methods, our smoothing is in the range rather than the domain of the functions; for the more general
problem, evaluation requires a summation of n-choose-k terms.

Seyed Ali Madani Tonekaboni (Waterloo)
Modeling and Analysis of the Buckling Phenomena in the Homogeneous and Heterogeneous Biomembranes
Abstract: In this project, nonlinear behavior of biomembrane are modeled as heterogeneous elastic biological systems. In addition to the static behavior of the membranes, their dynamic behavior are modeled to be able to investigate time-dependency of the variables of the systems. Some of the available models are used and some new ones are developed to study static and dynamic analysis of monolayer and bilayer membranes as well as circular axisymmetric biomembranes. The presented models are developed based on the Euler-Bernoulli constitutive law and employed to investigate buckling phenomena in the membranes as one of the most important physical phenomena in biological environment. The new mathematical modeling of this project can be considered as a new tool in Biophysics to model the physical behavior of biological systems.

Danielle Toupo (Cornell)
Cycles of cooperation and defection in Replicator-mutator equation with cost
Abstract: The replicator-mutator equations are a set of deterministic nonlinear ODEs that have served as a model to study evolutionary game dynamics and population dynamics as well as the evolution of language, behavior, fashion, and decision making in multi-agent social networks. This model has been widely studied, yet an important open question concerns the existence of stable limit cycles in the model. Previous researchers have answered this question by either assuming a circulant payoff matrix (1) or that the populations interact only finitely many times (2). We propose a simple replicator-mutator model with cost where the populations interact infinitely many times and in which the payoff matrix is not assumed to be circulant, and prove the existence of supercritical Hopf and homoclinic bifurcations in this simple model.


Charlie Van Loan (Cornell)
A Higher Order Generalized Singular Value Decomposition
Abstract: The HOGSVD is a simultaneous diagonalization of a collection of matrices, each having the same number of columns. We discuss the computation and mathematical properties of the decomposition.

Alexander Vladimirsky (Cornell)
Computational Challenges of Homogenization
Abstract: I will highlight the computational challenges and the key ideas in 2-scale and 3-scale computations of geometric optics. This will be based on an efficient homogenization of first-order Hamilton-Jacobi PDEs. I will illustrate the approach with the effective velocity
profiles for a number of periodic and “random” composite materials with 2D and 3D micro-geometries. The first part is based on a joint work with R.Takei and A.Oberman; the newer experimental results in 3D were obtained by A.Chacon.

Joseph Vokt (Cornell)
*Approximating matrices with multiple symmetries: with an application to quantum chemistry*

**Abstract:** The Electron Repulsion Integral (ERI) fourth-order tensor is essential to all ab initio electronic structure calculations, with applications ranging from computational battery design to computational therapeutic medicine design. This fourth-order tensor has eight different symmetries corresponding to eight permutations of the indices. After unfolding the tensor as a block matrix, the matrix is positive semi-definite, is relatively low-rank, and has symmetric blocks, block symmetry, and perfect shuffle permutation symmetry. We develop an algorithm, StructLDLT, to utilize this structure to improve the efficiency of certain calculations and obtain a low-rank approximation which preserves the original symmetries. We also extend this algorithm to sixth-order tensors with analogous structure. This is joint work with Charles Van Loan.

Jialei Wang (Cornell)
*Bayesian Multi-information Source Optimization with Expensive Function Evaluations*

**Abstract:** We propose a knowledge-gradient policy for noisy global optimization with multiple information sources. The policy uses value of information calculations and Bayesian statistics to decide, at each point in time, both at which point in the design space to evaluate, and which information source to use in this evaluation. We present an application to materials science, in which one information source is a computationally expensive simulator, and the other is a physical experiment.

Tamas Wiandt (RIT)
*Basins of attraction of coexisting stable ECM solutions of the Lang-Kobayashi equation*

**Abstract:** The Lang-Kobayashi system of delay differential equations describes the behavior of the complex electric field and inversion of external cavity semiconductor lasers. This system has a family of periodic solutions known as External Cavity Modes (ECMs). It is well known that these ECM solutions appear through saddle-node bifurcations, then lose stability through a Hopf bifurcation before new ECM solutions are born through a secondary saddle-node bifurcation. Employing analytical and numerical techniques, we show that for certain short external cavity lasers the loss of stability happens only after the subsequent saddle-node bifurcations, which means that stable ECM solutions can coexist in these systems. We also investigate the basins of attraction of these ECM attractors.

He Yang (RPI)
*Error Estimates of Runge-Kutta Discontinuous Galerkin Methods for*
the Vlasov-Maxwell System

Abstract: In this paper, error analysis is established for Runge-Kutta discontinuous Galerkin (RKDG) methods to solve the Vlasov-Maxwell system. This nonlinear hyperbolic system describes the time evolution of collisionless plasma particles of a single species under the self-consistent electromagnetic field, and it models many phenomena in both laboratory and astrophysical plasmas. The methods involve a third order TVD Runge-Kutta discretization in time and upwind discontinuous Galerkin discretizations of arbitrary order in phase domain. With the assumption that the exact solution has sufficient regularity, the $L^2$ errors of the particle number density function as well as electric and magnetic fields at any given time $T$ are bounded by $C h^{k+\frac{1}{2}} + C \tau^3$ under a CFL condition $\tau/h \leq \gamma$. Here $k$ is the polynomial degree used in phase space discretization, satisfying $k \geq \lceil \frac{d+1}{2} \rceil$ (the smallest integer greater than or equal to $\frac{d+1}{2}$, with $d$ being the dimension of spatial domain), $\gamma$ is the time step, and $h$ is the maximum mesh size in phase space. Both $C$ and $\gamma$ are positive constants independent of $h$ and $\tau$, and they may depend on the polynomial degree $k$, time $T$, the size of the phase domain, certain mesh parameters, and some Sobolev norms of the exact solution. The analysis can be extended to RKDG methods with other numerical fluxes and to RKDG methods solving relativistic Vlasov-Maxwell equations.

He Yang (RPI)

Stability Analysis and Error Estimates of an Exactly Divergence-Free Method for the Magnetic Induction Equations

Abstract: In this talk, we consider an exactly divergence-free scheme to solve magnetic induction equations. This problem is extracted from the numerical simulations of ideal Magnetohydrodynamics (MHD) equations, which contain nonlinear hyperbolic equations as well as a divergence-free condition for the magnetic field. Numerical methods without satisfying such condition may lead to numerical instability. One class of methods called constrained transport schemes is widely used as a divergence-free treatment. However, why these schemes work is still not fully understood. In this work, we take the exactly divergence-free schemes proposed by Li and Xu as a candidate of the constrained transport schemes, and analyze the stability and errors when solving magnetic induction equations. This is the most significant part to understand the divergence-free treatment in MHD simulations. Our result can not only explain the stability mechanism of this particular scheme and the role of the exactly divergence-free condition in that, but also provide the insight to understand other constrained transport schemes.

Yiyang Yang (SUNY at Stony Brook)

A GPU-Accelerated Numerical Algorithm for American Option Pricing under Generalized Hyperbolic Distribution

Abstract: In this talk, I will introduce a numerical method for the computation of American option pricing based on Levy processes. On the basis of the Black-Scholes equation which set the foundation on geometric Brownian motion, we explore the partial integro-differential equation (PIDE) derived from the exponential Levy model under generalized hyperbolic distribution. This model is highly flexible and more realistic for the simulation of high frequency market trading. However, the complexity and costs limit its application when compared with
other simplified models, such as the variance gamma process and the CGMY process. We propose a highly efficient and accurate numerical method to solve PIDE. In addition, we compare the numerical solutions of PIDE with the solutions from the Black-Scholes equation to gain insight into the option pricing based on exponential Levy model. Finally, GPU is incorporated to improve the efficiency of pricing single American option and multiple American options to the scale of seconds.

Erdal Yilmaz (Cornell)
Designing Micro-gyroscopes: Geometric Imperfections and Selection Rules
Abstract: The working principle of vibrating structure gyroscopes is based on the splitting of degenerate frequencies of axisymmetric shells due to rotational effects. Micro-scale prototypes of these gyroscopes suffer from geometric imperfections caused by various fabrication processes. The perturbative effects of these imperfections also result in frequency splittings. For design purposes, we identified selection rules to describe how perturbation and vibration modes interact. Understanding mathematical reasons behind these rules helps mitigate undesired perturbations. In this talk, we illustrate how group theory can be used to define selection rules for frequency splittings by providing examples from other physical phenomena.

Michael Yodzis (Guelph)
Inverse Problems for Delay Differential Equations Using the Collage Theorem
Abstract: Recent research has established a solution framework for differential equations inverse problems via the Collage Theorem. This theorem first proved useful in fractal imaging and is a relatively simple consequence of Banach’s Fixed Point Theorem. In an appropriate setting, the solution framework allows us to solve for the unknown parameters of an ODE system by minimizing the $L^2$ collage distance between a given target solution, which may be the interpolation of observational data, and its image under the associated Picard operator integral mapping, which can be shown to be contractive on a suitable complete metric space.

In our current work, we have developed a similar framework for delay ODE inverse problems, which may involve either discrete (additive) delays, distributed (integral) delays, or both. Such terms introduce a dependence on past time states in the system, which affects the conditions for the boundedness and contractivity of the associated integral mapping.

I will begin this talk by presenting the theory for the mathematical framework. A numerical example with simulated data will follow, with the goal of showing how the theory is implemented and the computational issues that can arise in practice. I will also discuss future applications to a model problem for pollution feedback effects in a human-environmental system.

This is joint research with C. Bauch and H. Kunze, Mathematics and Statistics, University of Guelph.

Wendy Zeng (Cornell)
Visualizing Economic Data via Diffusion Maps and Clustering
Abstract: In the past 15 years, nonlinear dimensionality reduction techniques have been successfully used to analyze high dimensional data in low dimensional representation. In this presentation, I examine historic economic data (1950 – 2012) using country/year data
points (e.g., Kenya, 1990), measured using a large number of economic indicators. Using Diffusion Maps, a particular dimensionality reduction technique that approximates heat flow through the data, I explore the intrinsic nonlinear geometry of the data. I compare growth and recession periods of the US to those of other countries and look for correlations between economic indicators to predict future periods of growth and recession. Using Clustering, a technique that groups sets of similar objects in clusters, I observe correlations between both country/year data points and economic indicators.

Xiaoting Zhao (Cornell)
Exploration vs. Exploitation in the Information Filtering Problem
Abstract: In information filtering, a computer filters irrelevant items from a stream of information too voluminous to process by hand (e.g., scientific papers, blog posts, satellite photos). Such systems face the exploration vs. exploitation tradeoff, in which it may be beneficial to present an item that is likely to be irrelevant, because feedback allows the system to learn and improve. We present an analysis of this problem using stochastic dynamic programming, and an application to the arXiv.

Zhengyi Zhou (Cornell)
A Spatio-Temporal Mixture Model with Application to Ambulance Demand
Abstract: Spatio-temporal point processes modeling is often needed at fine time and location scales. Our motivating application is estimating ambulance demand over space and time; management decisions such as dynamic fleet deployment require estimates for every two hours and every locality. Modeling at such high resolutions poses several challenges. First, the number of observations per time period per locality is low. Second, there may also be complex short-term and long-term seasonality and serial dependence across time, perhaps even unique to each locality.

In this talk, I will introduce a novel class of mixture models to address these challenges. In this approach, the mixture component distributions are assumed common to all time periods while the mixture weights evolve over time. This allows efficient learning of the underlying spatial structure, yet enough flexibility to capture dynamics over time. We further include constraints on the mixture weights to capture temporal patterns, and apply autoregressive priors on mixture weights to represent location-specific temporal dynamics. Our method is efficient and accurate on a large-scale, complex dataset, and can be easily generalized to a wide range of settings.