In cooperation with

Society for Industrial and Applied Mathematics

Conference Program

9th SIAM Annual Meeting of Central States Section

University of Missouri-Kansas City
October 5-6, 2024

Table of Contents

1 SIAM Central States Section

Welcome to the 8th annual meeting of the SIAM Central States Section at University of Missouri - Kansas City.

The SIAM-CSS was formed in 2014 to serve SIAM members in Arkansas, Colorado, Iowa, Kansas, Mississippi, Missouri, Nebraska, and Oklahoma. The purpose of this section is to enhance the communication among the section members, promote the collaboration for both basic research and applications of mathematics to industry and science, represent applied and computational mathematics in the entire proposed central region, and support the SIAM mission in the central region of the USA.

The SIAM-CSS Annual Meeting is one of the most important activities of the section. The SIAM-CSS Annual Meeting has been held annually since 2015, except for 2020 canceled due to the COVID-19 pandemic. The 9th SIAM-CSS annual meeting will be held at University of University of Missouri - Kansas City on October 5-6, 2024.

Local Organizing Committee

- **Majid Bani-Yaghoub**, University of Missouri - Kansas City
- **Liana Şega**, University of Missouri - Kansas City
- **Bowen Liu**, University of Missouri - Kansas City
- **Shuhao Cao**, University of Missouri - Kansas City

SIAM CSS Leadership (2024-2026)

- **President:** Xu Zhang, Ohklahoma State University
- **Vice President:** Dinh-Liem Nguyen, Kansas State University
- **Secretary:** Huijing Du, University of Nebraska - Lincoln
- **Treasurer:** Paul Sacks, Iowa State University

SIAM CSS Advisory Committee

- **Xiaoming He**, Missouri University of S&T, President of SIAM-CSS (2015-2016)
- **Jiangguo Liu**, Colorado State University, President of SIAM-CSS (2017-2018)
- **Ying Wang**, University of Oklahoma, President of SIAM-CSS (2019-2021)
- **Weizhang Huang**, University of Kansas, President of SIAM-CSS (2022-2024)

We are grateful that the conference has received generous supports from the following organizations

- **National Science Foundation (NSF)**
- **Society of Industrial and Applied Mathematics (SIAM)**
- **School of Science and Engineering**, University of Missouri - Kansas City
- **Division for Computing, Mathematics, and Analytics**, University of Missouri - Kansas City

2 Schedule at a Glance

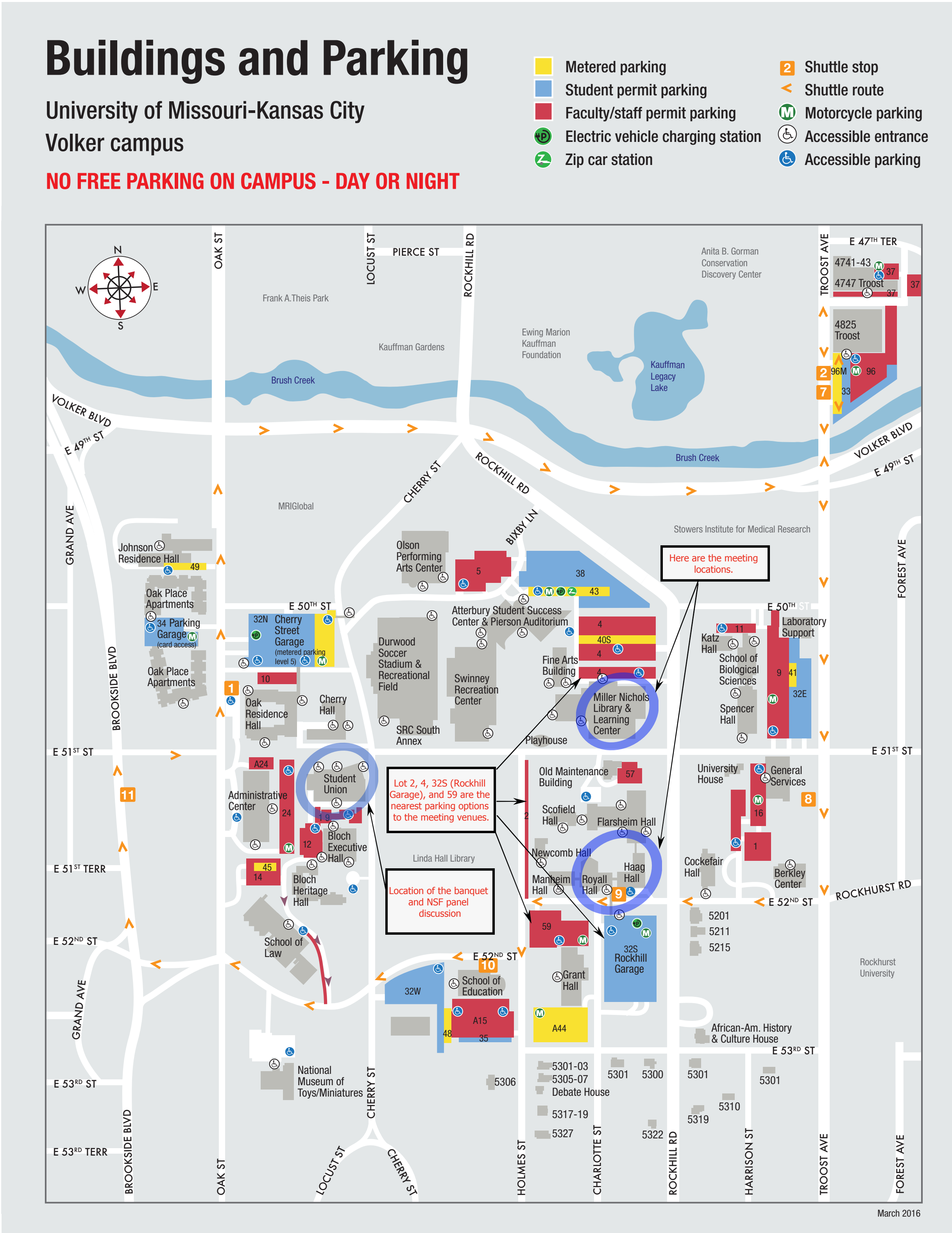
Saturday, October 5

Time	Event	Location
7:45am-2:00pm	Registration Table Opens	Outside of MNLC 115
8:15am-8:30am	Opening Remarks	MNLC 115
8:30am-9:30am	Plenary Talk 1: Hongkai Zhao Duke University	MNLC 115
9:30am-10:00am	Coffee Break	Outside of Haag 301
10:00am-11:20am	Mini-Symposium Session I and Contributed Talks	Haag, Royall Hall
11:20pm-1:20pm	Lunch	Nearby Restaurants
1:20pm-2:20pm	Plenary Lecture 2: Carol Woodward Lawrence Livermore National Laboratory	MNLC 115
2:30pm-3:50pm	Mini-Symposium Session II and Contributed Talks	Haag, Royall Hall
3:50pm-4:10pm	Coffee Break	Outside of Haag 301
4:10pm-5:30pm	Mini-Symposium Session III, Poster Session, and Contributed Talks	Haag, Royall Hall
5:45pm-6:30pm	NSF Panel Discussion Session	Student Union 401
6:30pm-6:40pm	Announcements	Student Union 401
6:40pm-9:00pm	Banquet Dinner	Student Union 401

Sunday, October 6

8:30am-11:00am	Registration Table Opens	Outside of MNLC 115
9:00am-10:00am	Plenary Lecture 3: Todd Arbogast University of Texas at Austin	MNLC 115
10:00am-10:40am	Coffee Break	Outside of MNLC 115
10:30am-12:10pm	Mini-Symposium Session IV and Contributed Talks	Haag, Royall Hall

3 Campus Map



Buildings and Parking
University of Missouri-Kansas City
Volker campus
NO FREE PARKING ON CAMPUS - DAY OR NIGHT
Metered parking
Student permit parking
Faculty/staff permit parking
Electric vehicle charging station
Zip car station
Shuttle stop
Shuttle route
Motorcycle parking
Accessible entrance
Accessible parking
Here are the meeting locations.
Lot 2, 4, 32S (Rockhill Garage), and 59 are the nearest parking options to the meeting venues.
Location of the banquet and NSF panel discussion
Frank A.Theis Park
Kauffman Gardens
Ewing Marion Kauffman Foundation
Kauffman Legacy Lake
Anita B. Gorman Conservation Discovery Center
Brush Creek
MRIGlobal
Stowers Institute for Medical Research
Johnson Residence Hall
Oak Place Apartments
34 Parking Garage (card access)
Cherry Street Garage (metered parking level 5)
Olson Performing Arts Center
Atterbury Student Success Center & Pierson Auditorium
Durwood Soccer Stadium & Recreational Field
Swinney Recreation Center
SRC South Annex
Fine Arts Building
Miller Nichols Library & Learning Center
Playhouse
Katz Hall
School of Biological Sciences
Spencer Hall
Laboratory Support
Oak Residence Hall
Cherry Hall
Student Union
Administrative Center
Bloch Executive Hall
Bloch Heritage Hall
School of Law
Old Maintenance Building
Scofield Hall
Flarsheim Hall
Newcomb Hall
Manheim Hall
Royall Hall
Haag Hall
Linda Hall Library
University House
General Services
Cockefair Hall
Berkley Center
32S Rockhill Garage
Grant Hall
School of Education
African-Am. History & Culture House
National Museum of Toys/Miniatures
Debate House
4741-43
4747 Troost
4825 Troost
Rockhurst University
OAK ST
LOCUST ST
PIERCE ST
ROCKHILL RD
TROOST AVE
E 47TH TER
VOLKER BLVD
E 49TH ST
GRAND AVE
CHERRY ST
BIXBY LN
BROOKSIDE BLVD
E 50TH ST
E 51ST ST
E 51ST TERR
E 52ND ST
E 53RD ST
E 53RD TERR
ROCKHURST RD
FOREST AVE
HOLMES ST
CHARLOTTE ST
HARRISON ST
March 2016

4 Plenary Lectures

Hongkai Zhao

Prof. Hongkai Zhao received his PhD in Mathematics from the University of California, Los Angeles in 1996. In 1996-1999, he was on the faculty at Stanford University. He then joined the University of California, Irvine (UCI) as an Assistant Professor and was promoted to Associate Professor in 2003 and to Full Professor in 2007. He was the Chair of the Department of Mathematics at UCI in 2010-2013 and 2016-2019. He moved to Duke University in 2020 and is currently the Ruth F. DeVarney Distinguished Professor of Mathematics.

Prof. Zhao's research interest is in computational and applied mathematics that includes modeling, analysis and developing numerical methods for problems arising from science and engineering. He serves on the editorial boards of SIAM Journal on Imaging Sciences, Multiscale Modeling and Simulation, Journal of Computational Mathematics, and Geometry, Imaging and Computing. Prof. Zhao was elected a Fellow of the Society for Industrial and

Applied Mathematics in 2022. He is also the recipient of the 2007 Feng Kang Prize in Scientific Computing and the 2002 Alfred P. Sloan Fellowship.

Title: Mathematical and Numerical Understanding of Neural Networks: From Representation to Learning Dynamics

Saturday, October 5th, 8:30am-9:30am, Miller Nichols Learning Center (MNLC) 151

Abstract: In this talk I will present both mathematical and numerical analysis as well as experiments to study a few basic computational issues in using neural network to approximate functions: (1) the stability and accuracy, (2) the learning dynamics and computation cost, and (3) structured and balanced approximation. These issues are investigated for both approximation and optimization in asymptotic and non-asymptotic regimes.

Carol Woodward

Dr. Carol Woodward is a Distinguished Member of the Technical Staff at Lawrence Livermore National Laboratory. Her research interests include numerical methods for nonlinear partial differential equations, nonlinear and linear solvers, time integration methods, numerical software development, and parallel computing. Dr. Woodward serves on the editorial board for ACM Transactions on Mathematical Software and has served on numerous organizing committees for national and international meetings. She currently serves as the ICIAM (International Council on Industrial and Applied Mathematics) representative on the Standing Committee for Gender Equality in Science, an international committee of scientific professional unions formed to promote gender equality in sciences worldwide.

Dr. Woodward will start a term as President-Elect of the Society for Industrial and Applied Mathematics (SIAM) in 2024 and serve as its President in 2025-2026. She served as Vice President-at-Large of SIAM 2018–2021. In addition, she served as Numerical Methods Group Leader and Postdoctoral Program Manager in the LLNL Center for Applied Scientific Computing, four years as an At-Large Member of the Association for Women in Mathematics Executive Committee, and six years as an elected member of the SIAM Council. She has also held offices in the SIAM activity groups on Geosciences and Computational Science and Engineering and was the SIAM representative to the Joint Committee on Women in the Mathematical Sciences for three years (two as Committee Chair).

Title: From Algorithms to Applications: How Numerical Software Facilitates the Use of New Algorithms in Complex Science and Engineering Simulations

Saturday, October 5th, 1:20pm-2:20pm, Miller Nichols Learning Center (MNLC) 151

Abstract: With continued advances in computing system capabilities, many scientific areas are simulating increasingly complex physical systems. These new complexities give rise to a demand for more accurate numerical methods that can handle these systems while running efficiently on high performance computing platforms. Along with these increases in simulation complexity there has also been a similar increase in simulation software complexity. As a result, there is a strong need for reusable, efficient numerical software that can incorporate algorithmic innovations from the applied mathematics community while facilitating high performance science and engineering simulations. In this talk, I will discuss advances in numerical software, high performance computing, and coupled model simulation and address how these advances connect to result in highly complex simulations. Examples from the application of the SUNDIALS suite of nonlinear and differential algebraic integrators to science problems will be included.

Prepared by LLNL under Contract DE-AC52-07NA27344.

Todd Arbogast

Todd Arbogast earned his Ph.D. from the University of Chicago in 1987 under the direction of the late Professor Jim Douglas, Jr. After stops at Purdue and Rice Universities, he has been Professor of Mathematics at the University of Texas at Austin since 1995. He holds the W.A. "Tex" Moncrief, Jr. Distinguished Professorship in Computational Engineering and Sciences—Applied Mathematics. He is a core member of the Oden Institute for Computational Engineering and Sciences and associate director of the Center for Subsurface Modeling. He is a Fellow of the American Mathematical Society and a Fellow of the Society for Industrial and Applied Mathematics. He has published over a hundred technical papers in areas including the numerical analysis of partial differential systems, mathematical modeling, and scientific computation.

Title: High Order Approximation of Advection-Diffusion Problems on Polygonal Meshes

Sunday, October 6h, 9:00am-10:00am, Miller Nichols Learning Center (MNLC) 151

Abstract: We consider solving second order advection-diffusion PDEs on general computational meshes of polygons. We develop a general framework that includes both high order finite element and finite volume approximation techniques. Standard finite elements on polygonal elements are either not available or lose accuracy. We develop new finite elements that maintain accuracy on polygons by including undistorted polynomials defined directly on the element. They possess the minimum number of degrees of freedom subject to the accuracy and Sobolev space conformity. The direct serendipity finite elements approximate scalar functions (such as pressures, concentrations, and saturations), while the direct mixed finite elements approximate vector functions (such as velocities). Unfortunately, solutions to advective problems can develop shocks or steep fronts, and thereby lose Sobolev space conformity. We discuss the challenges of using finite volume weighted essentially non oscillatory (WENO) techniques on polygonal meshes. We also present a robust and efficient procedure for producing accurate stencil polynomial approximations. We develop a new multilevel WENO reconstruction with adaptive order that combines stencil polynomials. The nonlinear weighting biases the reconstruction away from both inaccurate oscillatory polynomials of high degree (i.e., those crossing a shock or steep front) and smooth polynomials of low degree, thereby selecting the smooth polynomial(s) of maximal degree of approximation. Extension of the framework to three dimensions is also discussed. Applications are given to tracer flow and Richards equation.

Coauthors: Maicon R. Correa, Chieh-Sen Huang, Danielle King, Zhen Tao, Chenyu Tian, Chuning Wang, and Xikai Zhao

5 Mini-Symposium and Contributed Talk Sessions

MS01. Advances in Mathematical Fluid Mechanics

Organizers: *Zachary Bradshaw*, University of Arkansas

Session A: Saturday, October 5, 2:30pm-3:50pm, Haag 312

- **MS01-A-1** (2:30pm) Finite-time blowup for the Fourier-restricted Euler equation. *Evan Miller*, University of Alabama in Huntsville
- **MS01-A-2** (2:50pm) Asymptotic properties of discretely self-similar Navier-Stokes solutions with rough data. *Patrick Phelps*, Temple University
- **MS01-A-3** (3:10pm) Some results on solutions to Primitive Equations. *Ning Ju*, Oklahoma State University
- **MS01-A-4** (3:30pm) Regularity, uniqueness and the relative size of small scales in supercritically dissipative SQG. *Zachary Akridge*, University of Arkansas

Session B: Saturday, October 5, 4:10pm-5:30pm, Haag 312

- **MS01-B-1** (4:10pm) Singularity Suppression by Rapid Mixing in a Non-Diffusive Aggregation Equation. *Nicholas Harrison*, Oregon State University
- **MS01-B-2** (4:30pm) Calmed 3D Navier-Stokes: An approximate model with physical boundary conditions, unmodified energy identity, and no singularity. *Adam Larios*, University of Nebraska-Lincoln
- **MS01-B-3** (4:50pm) Shear banding phenomenon of a thixotropic fluid model. *Taige Wang*, University of Cincinnati
- **MS01-B-4** (5:10pm) A regularity criterion for the 3D Navier-Stokes equations based on finitely many observations. *Abhishek Balakrishna*, University of Southern California

MS02. Advances in Mathematical Biology and Ecology: Current Insights and Future Directions

Organizers: *Nalin Fonseka*, University of Central Missouri; *Rana Parshad*, Iowa State University of Science and Technology

Session A: Saturday, October 5, 10:00am-11:20am, Royall 305

- **MS02-A-1** (10:00am) Some recent progress on additional food driven biocontrol, with application to the Soybean Aphid. *Rana Parshad*, Iowa State University
- **MS02-A-2** (10:20am) A patch-driven additional food model. *Urvashi Verma*, Iowa State University
- **MS02-A-3** (10:40am) Mathematical modeling of intracellular osmolarity and cell volume stabilization. *Zahra Aminzare* University of Iowa
- **MS02-A-4** (11:00am) Modeling and Optimizing Social Distancing for Epidemic Mitigation. *Zhijun Wu*, Iowa State University

Session B: Saturday, October 5, 2:30pm-3:50pm, Royall 305

- **MS02-B-1** (2:30pm) Leveraging mobility data to model drug overdose mortality in the United States during COVID-19 Pandemic. *Folashade Agusto*, University of Kansas
- **MS02-B-2** (2:50pm) Modeling the Impact of Climate Change on Intra- and Inter-Species Interactions Among Rodent Species. *Majid Bani-Yaghoub* University of Missouri-Kansas City
- **MS02-B-3** (3:10pm) Characterizing single-cell transcriptomic signatures with persistent homology and molecular cartography. *Erik Amezquita* University of Missouri
- **MS02-B-4** (3:30pm) A Time Scale Approach for Analyzing Pathogenesis of ATL Development associated with HTLV-1 Infection. *Neslihan Nesliye Pelen* Missouri University of Science and Technology

Session C: Saturday, October 5, 4:10pm-5:30pm, Royall 305

- **MS02-C-1** (4:10pm) Studying Infectious Diseases by Time Scale Approach. *Elvan Akin*, Missouri University of Science and Technology
- **MS02-C-2** (4:30pm) Effects of harvesting mediated emigration on a landscape ecological model. ". *Xiaohuan Xue*, University of North Carolina at Greensboro
- **MS02-C-3** (4:50pm) A Discrete-Time Model for TYC strategy. *Don Kumudu Mallawa Arachchi* Iowa State University
- **MS02-C-4** (5:10pm) A bifurcation diagram for a reaction-diffusion equation with nonlinear boundary conditions. *Nalin Fonseka*, University of Central Missouri

MS03. Applied and Computational Complex Analysis

Organizers: *Mohamed Nasser*, Wichita State University; *Green, Christopher*, Wichita State University

Session A: Saturday, October 5, 2:30pm-3:50pm, Haag 309

- **MS03-A-1** (2:30pm) Harmonic-measure distribution functions in various geometries.
- **MS03-A-2** (2:50pm) Numerical experiments with potential flow and vortices in multiply connected domains in the plane. *Thomas K DeLillo*, Wichita State University
- **MS03-A-3** (3:10pm) Numerical computation of Stephenson's g-functions in multiply connected domains. *Mohamed Nasser*, Wichita State University
- **MS03-A-4** (3:30pm) TBD. *Vijay Matheswaran*, Wichita State University

MS04. Advances in Mathematical and Computational Models in Biology, Health and Medicine

Organizers: *Majid Bani-Yaghoub*, University of Missouri-Kansas City; *Arash Arjmand*, University of Missouri-Kansas City

Session A: Saturday, October 5, 10:00am-11:20am, Haag 312

- **MS04-A-1** (10:00am) Utilizing Bayesian Inference to Understand the Evolution of MRSA Infection and Transmission in Urban Archor Hospital Settings. *Kiel Daniel Corkran*, University of Missouri-Kansas City
- **MS04-A-2** (10:20am) Evolution Dynamics of COVID-19 Variants: Transmission, Virulence, and Vaccination Impacting the Pathogen Fitness. *Barsha Saha*, University of Missouri-Kansas City
- **MS04-A-3** (10:40am) Dynamics of Math Anxiety and Minimal Efforts Required to Eradicate it. *Sara Sony*, Northwest Missouri State University
- **MS04-A-4** (11:00am) Modeling the Spread of Respiratory Infections in Universities and Colleges Using UWB RTLS Real-Time Movement Data. *Ravi Chandra Thota*, University of Missouri-Kansas City

Session B: Sunday, October 6, 10:30am-11:50am, Haag 312

- **MS04-B-1** (10:30am) Delayed Reaction-Diffusion Modeling of Hes1- mRNA Oscillations and Dispersal. *Mohammed Alanazi*, University of Missouri-Kansas City
- **MS04-B-2** (10:50am) Numerical Explorations of a Reaction-Diffusion Model of Vascular Tumor Growth: Bifurcation, Relapse and Cure. *Priscilla Owusu Sekyere*, University of Missouri-Kansas City
- **MS04-B-3** (11:10am) Machine Learning Approaches for Predicting Hospital- and Community-Acquired Urinary Tract Infections: A Comparative Analysis. *Arash Arjmand*, University of Missouri-Kansas City
- **MS04-B-4** (11:30am) Predicting Infectious Disease Vulnerability in Long-Term Care Facilities using Social Determinants of Health. *Julia Pluta*, University of Missouri-Kansas City
- **MS04-B-5** (11:50am) Infectious Disease Dynamics in Theme Parks: Challenges and Strategies. *Md Afsar Ali*, Tuskegee University

MS05. High-Dimensional Control and Hamilton-Jacobi Equations: Theory, Algorithms, and Applications

Organizers: *Christian Parkinson*, Michigan State University; *Edward Huynh*, University of Texas at Austin

Session A: Saturday, October 5, 10:00am-11:20am, Royall 404

- **MS05-A-1** (10:00am) A supervised learning scheme for computing Hamilton-Jacobi equation via density coupling. *Shu Liu*, UCLA
- **MS05-A-2** (10:20am) An Interpretable and Efficient Method for Collaborative Multi-Agent Path-Planning. *Christian Parkinson*, Michigan State University
- **MS05-A-3** (10:40am) Guarantees on State-Augmented Differential Games for Fast and Conservative High-Dimensional, Nonlinear Prediction and Control. *William Sharpless*, University of California, San Diego
- **MS05-A-4** (11:00am) Overview on constraints mean field games and new perspectives. *Rossana Capuani*, University of Arizona

Session B: Saturday, October 5, 2:30pm-3:50pm, Royall 404

- **MS05-B-1** (2:30pm) Convexifying State-Constrained Optimal Control Problems via Hopf-Lax Theory. *Donggun Lee*, North Carolina State University
- **MS05-B-2** (2:50pm) An invitation to high-dimensional non-potential mean-field games. *Levon Nurbekyan*, Emory University
- **MS05-B-3** (3:30pm) Pedestrian models with congestion effects. *Pedro Aceves Sanchez*, The University of Arizona
- **MS05-B-4** (3:30pm) A Particle Method for Mean-Field Control Problems with Terminal Constraints. *Karthik Elamvazhuthi*, Los Alamos National Laboratory

Session C: Saturday, October 5, 4:10pm-5:30pm, Royall 404

- **MS05-C-1** (4:10pm) Bayesian sampler for inverse problems of a stochastic process by leveraging Hamilton–Jacobi PDEs and score-based generative models. *Tingwei Meng*, UCLA
- **MS05-C-2** (4:30pm) Equations on the Wasserstein space and applications. *Benjamin Seeger*, University of North Carolina at Chapel Hill
- **MS05-C-3** (4:50pm) Optimal Path Planning on Manifolds. *Edward Duy Huynh*, University of Texas at Austin
- **MS05-C-4** (5:10pm) How Level Set Methods Are Key to Safety-Critical Vehicle Systems. *Matthew Kirchner*, Auburn University

Session D: Sunday, October 6, 10:30am-11:50am, Royall 404

- **MS05-D-1** (10:30am) Utilizing machine learning and game theory to find optimal policies for large number of agents. *Gökçe Dayanikli*, University of Illinois at Urbana-Champaign
- **MS05-D-2** (10:50am) Mean-Field Control Barrier Functions: A Framework for Real-Time Swarm Control. *Samy Wu Fung*, Colorado School of Mines
- **MS05-D-3** (11:10am) Hamilton-Jacobi Reachability Analysis for Hybrid Systems with Controlled and Forced Transitions. *Javier Borquez*, University of Southern California

MS06: Innovative Approaches with Numerical Methods and Data

Organizers: *Qiao Zhuang*, University of Missouri-Kansas City; *Min Wang*, University of Houston; *Changhong Mou*, Purdue University

Session A: Saturday, October 5, 2:30pm-3:50pm, Haag 307

- **MS06-A-1** (2:30pm) A uniform framework for fluid dynamics in porous media. *Seulip Lee*, Tufts University
- **MS06-A-2** (2:50pm) Two-scale Neural Networks for Multiscale Problems. *Qiao Zhuang*, University of Missouri-Kansas City
- **MS06-A-3** (3:10pm) Parametric reduced order modeling for nonlocal PDEs. *Yumeng Wang*, Missouri University of Science and Technology

Session B: Saturday, October 5, 4:10pm-5:30pm, Haag 307

- **MS06-B-1** (4:10pm) Stopping Criteria for the Conjugate Gradient Algorithm in High-Order Finite Element Methods. *Yichen Guo*, Virginia Tech
- **MS06-B-2** (4:30pm) Learning macroscopic parameters in nonlinear nonlocal upscaling. *Maria Vasilyeva*, Texas A&M University - Corpus Christi
- **MS06-B-3** (4:50pm) A Model-Based Approach for Continuous-Time Policy Evaluation with Unknown Lévy Process Dynamics. *Qihao Ye*, University of California, San Diego

Session C: Sunday, October 6, 10:30am-11:50am, Haag 307

- **MS06-C-1** (10:30am) Data Driven Modeling of Stochastic Systems. *Yuan Chen*, Ohio State University
- **MS06-C-2** (10:50am) Cloud Effects on Sea-Ice-Floe Data Assimilation in Idealized Models. *Changhong Mou*, Purdue University
- **MS06-C-3** (11:10am) The Runge-Kutta discontinuous Galerkin method with stage-dependent polynomial spaces for hyperbolic conservation laws. *Qifan Chen*, Ohio State University

MS07. Interactions among analysis, optimization and network science

Organizers: *Joan Lind*, University of Tennessee; *Nathan Albin*, Kansas State University; *Pietro Poggi-Corradini*, Kansas State University

Session A: Saturday, October 5, 10:00am-11:20am, Royall 402

- **MS07-A-1** (10:00am) A Neural Networks Approach to Learning Threshold Dynamics. *Luca Capogna*, Smith College
- **MS07-A-2** (10:20am) On the Relation between Graph Ricci Curvature and Community Structure. *Sathyanarayanan Rengaswami*, Army Research Lab
- **MS07-A-3** (10:40am) Enhancing Network Design and Dynamics through Spectral and Topological Analysis. *Heman Shakeri*, University of Virginia
- **MS07-A-4** (11:00am) Comparison of Dirichlet and Newtonian Sobolev spaces. *Ilmari Kangasniemi*, University of Cincinnati
- **MS07-A-5** (11:20am) Modulus for bases of matroids. *Huy Truong*, Kansas State University

Session B: Saturday, October 5, 2:30pm-3:50pm, Royall 402

- **MS07-B-1** (2:30pm) Self-improvement of fractional Hardy inequalities in metric measure spaces. *Josh Kline*, University of Cincinnati
- **MS07-B-2** (2:50pm) Fractional Hardy inequalities. *Lizaveta Ihnatsyeva*, Kansas State University
- **MS07-B-3** (3:10pm) Chromatic symmetric functions and polynomial tree invariants. *Jeremy L. Martin*, University of Kansas
- **MS07-B-4** (3:30pm) Balancing Graphs Using Geometric Invariant Theory. *Clayton Shonkwiler*, Colorado State University

Session C: Saturday, October 5, 4:10pm-5:30pm, Royall 402

- **MS07-C-1** (4:10pm) Factoring bi-Lipschitz mappings on large subsets. *Matthew Romney*, Stevens Institute of Technology
- **MS07-C-2** (4:30pm) Maximal Directional Derivatives and Universal Differentiability Sets. *Gareth Speight*, University of Cincinnati
- **MS07-C-3** (4:50pm) A topological approach to analyzing access to resources with heterogeneous quality. *Sarah Tymochko*, UCLA
- **MS07-C-4** (5:10pm) Optimal Experimental Design using Zero-suppressed Binary Decision Diagrams. *Michael Higgins*, Kansas State University

Session D: Sunday, October 6, 10:30am-11:50am, Royall 402

- **MS07-D-1** (10:30am) Robust Minicocyclicity. *Eric Babson*, UC Davis
- **MS07-D-2** (10:50am) Some applications of neural networks to modulus on networks. *Abhinav Chand*, Kansas State University
- **MS07-D-3** (11:10am) Conformal dimension of the Brownian graph. *Hrant Hakobyan*, Kansas State University
- **MS07-D-4** (11:30am) Perfect matchings in the random bipartite geometric graph. *Xavier Pérez-Giménez*, University of Nebraska - Lincoln
- **MS07-D-5** (11:50am) Large deviations of Dyson Brownian motion on the circle and multiradial SLE_{0+}. *Vivian Healey*, Texas State University

MS08. Nonlinear Data Assimilation and Parameter Estimation

Organizer: *Adam Larios*, University of Nebraska-Lincoln; *Erik Van VLeck*, University of Kansas

Session A: Saturday, October 5, 10:00am-11:20am, Haag 315

- **MS08-A-1** (10:00am) Data assimilation and UQ in coupled geosphysical models. *Elaine Spiller*, Marquette University
- **MS08-A-2** (10:20am) TBD. *Adam Larios*, University of Nebraska-Lincoln
- **MS08-A-3** (10:40am) Data Assimilation for the Nonlinear Richards Equation. *Amanda Rowley*, University of Nebraska-Lincoln
- **MS08-A-4** (11:00am) Data Assimilation On Adaptive Meshes for a Coupled Kuramoto-Sivashinsky System. *Jeremiah Buenger*, University of Kansas

Session B: Saturday, October 5, 4:10pm-5:30pm, Haag 315

- **MS08-B-1** (4:10pm) Approximations of the implicit particle filters. *Xuemin Tu*, University of Kansas
- **MS08-B-2** (4:30pm) A Hybrid Tangent Linear Model in The Generic JEDI Data Assimilation System. *Christian Sampson*, UCAR/JCSDA
- **MS08-B-3** (4:50pm) From Nudging to Synchronization: The Infinite Nudging Limit. *Collin Victor*, Texas A&M University
- **MS08-B-4** (5:10pm) Decomposition of Likelihoods and Projection Techniques for Multi-Scale Data Assimilation. *Erik Van Vleck*, University of Kansas

MS09. Numerical Methods for PDE Interface Problems

Organizers: *Xiaoming He*, Missouri University of Science and Technology; *Xu Zhang*, Oklahoma State University

Session A: Saturday, October 5, 10:00am-11:20am, Royall 403

- **MS09-A-1** (10:00am) Oscillation-free numerical schemes for Biot's model and their iterative coupling solution. *James H Adler*, Tufts University
- **MS09-A-2** (10:20am) Decoupled Finite Element Method for a novel phase field model of two-phase ferrofluid flows. *Youxin Yuan*, Missouri University of Science and Technology
- **MS09-A-3** (10:40am) Shape Optimization with Unfitted Finite Element Methods. *Shawn W. Walker*, Louisiana State University
- **MS09-A-4** (11:00am) Dynamically regularized Lagrange multiplier schemes with energy dissipation for the incompressible Navier-Stokes equations. *Kha Doan*, Auburn University

Session B: Saturday, October 5, 2:30pm-3:50pm, Royall 403

- **MS09-B-1** (2:30pm) Addressing Numerical Challenges in Frictional Contact Simulation for Finite-Deformation Solid Mechanics. *Zachary Atkins*,University of Colorado Boulder
- **MS09-B-2** (2:50pm) Finite Element Exterior Calculus for Hamiltonian PDEs. *Ari Stern*, Washington University in St. Louis
- **MS09-B-3** (3:10pm) A practical error indicator for TraceFEM discretizations of material interfaces. *Vladimir Yushutin*, University of Tennessee, Knoxville
- **MS09-B-4** (3:30pm) A decoupled, linear, and unconditionally energy stable finite element method for a two-phase ferrohydrodynamics model. *Xiaoming He*, Missouri University of Science and Technology

Session C: Saturday, October 5, 4:10pm-5:30pm, Royall 403

- **MS09-C-1** (4:10pm) Solving Navier-Stokes Equations with Stationary and Moving Interfaces on Unfitted Meshes. *Xu Zhang*, Oklahoma State University
- **MS09-C-2** (4:30pm) Continuous data assimilation and long-time accuracy in a FEM for the Cahn-Hillard equation. *Amanda E. Diegel*, Mississippi State University
- **MS09-C-3** (4:50pm) An HDG/DG method for fractured porous media. *Jeonghun Lee*, Baylor University

Session D: Sunday, October 6, 10:30am-11:50am, Royall 403

- **MS09-D-1** (10:00am) Thermodynamically consistent hydrodynamic phase-field computational modeling for fluid-structure interaction with moving contact lines. *Jia Zhao*, Binghamton University (SUNY)
- **MS09-D-2** (10:20am) TBD. *Yiming Ren*, The University of Alabama
- **MS09-D-3** (10:40am) An optimization-based coupling of reduced order models with efficient reduced adjoint basis generation approach. *Paul Kuberry*, Sandia National Laboratories

MS10. Partial Differential Equations and Deep Learning: Advances and Applications

Organizers: *Jiahui Chen*, University of Arkansas

Session A: Saturday, October 5, 10:00am-11:20am, Haag 309

- **MS10-A-1** (10:00am) 3D Generative Adversarial Networks for Precision Synthesis of Pancreatic Cancer Tumor Images. *Huijing Du*, University of Nebraska-Lincoln
- **MS10-A-2** (10:20am) A Deep Learning Model for Predicting Biophysical Properties Using Topological and Electrostatic Features. *Md Abu Talha*, Southern Methodist University
- **MS10-A-3** (10:40am) Integrating differential operators and deep learning in biology application. *Jiahui Chen*, University of Arkansas
- **MS10-A-4** (11:00am) A priori error analysis and greedy training algorithms for neural networks solving PDEs. *Qingguo Hong*, Missouri University of Science and Technology

MS11. Recent Advances in Numerical Algorithms for Computational Fluid Dynamics

Organizers: *Chen Liu*, University of Arkansas; *Zheng Sun*, University of Arkansas

Session A: Saturday, October 5, 2:30pm - 3:50 pm, Haag 315

- **MS11-A-1** (2:30pm) Efficient Energy-Stable Numerical Schemes for Cahn-Hilliard Equations with Dynamic Boundary Conditions. *Xinyu Liu*, Ohio State University
- **MS11-A-2** (2:50pm) Advances in Front Tracking Simulations of the Richtmyer-Meshkov Instability. *Ryan Holley*, University of Arkansas
- **MS11-A-3** (3:10pm) Constraint Optimization-based High-order Accurate Bound-preserving Limiter for time-dependent PDEs. *Chen Liu*, University of Arkansas
- **MS11-A-4** (3:30pm) High-order exponential time differencing multi-resolution alternative finite difference WENO methods for nonlinear degenerate parabolic equations. *Ziyao Xu*, University of Notre Dame

Session B: Sunday, October 6, 10:30am-11:50am, Haag 315

- **MS11-B-1** (10:30am) Cell-average-based Neural Network Method for time-dependent Problems. *Jue Yan*, Iowa State University
- **MS11-B-2** (10:50am) Local-variation based ENO type polynomial reconstruction for high order finite volume methods. *Yuan Liu*, Wichita State University
- **MS11-B-3** (11:10am) The Runge-Kutta discontinuous Galerkin method with compact stencils for hyperbolic conservation laws. *Zheng Sun*, The University of Alabama
- **MS11-B-4** (11:30am) HRIDG schemes and their application to kinetic Vlasov systems. *James Rossmanith*, Iowa State University

MS12. Recent Advances in Numerical Methods for Partial Differential Equations I

Organizer: *Li Zhu*, Portland State University; *Jorge Reyes*, Virginia Tech

Session A: Saturday, October 5, 10:00am-11:20am, Haag 301

- **MS12-A-1** (10:00am) An Adaptive Safeguarded Newton-Anderson Algorithm for Solving Nonlinear Problems Near Singular Points. *Matt Dallas*, University of Dallas
- **MS12-A-2** (10:20am) Numerical Analysis of a Stabilized Hyperbolic Equation Inspired from Models of Bio-Polymerization. *Jorge Reyes*, Virginia Tech
- **MS12-A-3** (10:40am) A Second-order Correction Method for Loosely Coupled Discretizations Applied to Parabolic-parabolic Interface Problems. *Sijing Liu*, Worcester Polytechnic Institute
- **MS12-A-4** (11:00am) On the stability and convergence of finite element solutions to the Gay Lussac incompressible natural convection model *Sean Breckling*, Nevada National Security Site

Session B: Saturday, October 5, 2:30pm-3:50pm, Haag 301

- **MS12-B-1** (2:30pm) Computing of Eigenpairs of the Magnetic Schrödinger Operator. *Li Zhu*, Portland State University
- **MS12-B-2** (2:50pm) On The Sharpness Of A Korn's Inequality For Piecewise H^1 Space And Its Applications. *Qingguo Hong*, Missouri University of Science and Technology
- **MS12-B-3** (3:10pm) Regularized Reduced Order Models for Turbulent Flows and Parameter Scalings. *Ping-Hsuan Tsai*, Virginia Tech
- **MS12-B-4** (3:30pm) Continuous Data Assimilation and Long-time Accuracy of a FEM for the Barotropic Vorticity Equation. *Amanda E. Diegel*, Mississippi State Univeristy

Session C: Saturday, October 5, 4:10pm-5:30pm, Haag 301

- **MS12-C-1** (4:10pm) High-order Interface Tracking Methods for Simulating Mean Curvature Flows in Two Dimensions. *Linjie Ying*, University of Nevada, Las Vegas
- **MS12-C-2** (4:30pm) Stabilized numerical simulations for the transport equation in a fluid. *Seulip Lee*, Tufts University
- **MS12-C-3** (4:50pm) Stabilized SAV ensemble algorithms for parameterized flow problems. *Nan Jiang*, University of Florida
- **MS12-C-4** (5:10pm) A Stochastic Precipitating Quasi-Geostrophic Model. *Changhong Mou*, Purdue University

MS13. Recent Development on Mathematical and Numerical Analysis of PDEs

Organizers: *Songting Luo*, Iowa State University; *Zhuoran Wang*, University of Kansas

Session A: Saturday, October 5, 10:00am-11:20am, Haag 306

- **MS13-A-1** (10:00am) Finite element methods for thermo-poroelasticity with Brinkman flows. *Jeonghun Lee*, Baylor University
- **MS13-A-2** (10:20am) BDDC algorithms for the Brinkman problems with HDG discretization. *Xuemin Tu*, University of Kansas
- **MS13-A-3** (10:40am) Convergence analysis of GMRES with inexact block triangular preconditioning for saddle point systems with application to weak Galerkin finite element approximation of Stokes flow. *Weizhang Huang*, University of Kansas
- **MS13-A-4** (11:00am) Learning domain-agnostic Green's function for variable coefficient elliptic PDEs. *Pawan Singh Negi (advised by Shuwang Li)*, Illinois Institute of Technology

Session B: Saturday, October 5, 2:30pm-3:50pm, Haag 306

- **MS13-B-1** (2:30pm) Efficient uncertainty quantification for scientific machine learning via Ensemble Kalman Inversion. *Xueyu Zhu*, University of Iowa
- **MS13-B-2** (2:50pm) A grid-overlay finite difference (GoFD) method for the fractional Laplacian on arbitrary bounded domains. *Jinye Shen*, Southwestern University of Finance and Economics
- **MS13-B-3** (3:10pm) Asymptotic methods for some fractional partial differential equations. *Songting Luo*, Iowa State University
- **MS13-B-4** (3:30pm) Positivity and maximum principle preserving discontinuous Galerkin finite element schemes for a coupled flow and transport. *Young Ju Lee*, Texas State University

Session C: Saturday, October 5, 4:10pm-5:30pm, Haag 306

- **MS13-C-1** (4:10pm) Pressure-robust WG solvers for Stokes flow based on a lifting operator. *Zhuoran Wang*, University of Kansas
- **MS13-C-2** (4:30pm) Novel Numerical Solvers for Transport in Porous Media with Mass Conservation and Positivity Preserving. *Jiangguo 'James' Liu*, Colorado State University
- **MS13-C-3** (4:50pm) Efficient High-Order Methods for Wave Propagation. *Ian Morgan*, Iowa State University
- **MS13-C-4** (5:10pm) Front-tracking based Rayleigh-Taylor Instability simulations with adaptive mesh refinement. *James Burton*, University of Arkansas

MS14. Recent Progress in Applied Inverse Problems and Imaging

Organizers: *Dinh-Liem Nguyen*, Kansas State University; *Thi-Phong Nguyen*, New Jersey Institute of Technology; *Thu Le*, University of Wisconsin-Madison

Session A: Saturday, October 5, 10:00am-11:20am, Haag 302

- **MS14-A-1** (10:00am) Reconstruction of Extended Regions in EIT with a Generalized Robin Transmission Condition. *Govanni Granados*, University of North Carolina at Chapel Hill
- **MS14-A-2** (10:20am) A direct reconstruction method for radiating sources in Maxwell's equations with single-frequency data. *Thu Thi Anh Le*, University of Wisconsin-Madison

- **MS14-A-3** (10:40pm) A discretization invariant operator learning method for inverse problems. *Ke Chen*, University of Delaware
- **MS14-A-4** (11:00am) Regularized Least Squares under Nonlinear Dynamics Constraints with Applications to Optimal Control in Epidemiology. *Alexandra Smirnova*, Georgia State University

Session B: Saturday, October 5, 2:30pm-3:50pm, Haag 302

- **MS14-B-1** (2:30pm) On Learning-to-Optimize via Implicit Networks. *Samy Wu Fung*, Colorado School of Mines
- **MS14-B-2** (2:50pm) Direct Sampling for recovering a clamped cavity from biharmonic far field data. *Heejin Lee*, Purdue University
- **MS14-B-3** (3:10pm) Fast and stable imaging of objects in 2D acoustic waveguides using scattering data. *Nhung Nguyen*, Kansas State University
- **MS14-B-4** (3:30pm) A Tikhonov-based regularization method for Inverse Source Problems for Fractional Parabolic Equations. *Thi Phong Nguyen*, New Jersey Institute of Technology

Session C: Sunday, October 6, 10:30am-11:50am, Haag 302

- **MS14-C-1** (10:30am) An algorithm for computing scattering poles based on dual characterization to interior eigenvalues. *Dana Zilberberg*, Rutgers University
- **MS14-C-2** (10:50am) Inverse gravimetry by multipole expansions. *Tianshi Lu*, Wichita State University
- **MS14-C-3** (11:10pm) Numerical algorithms for nonlocal imaging problems. *Jeremy Hoskins*, University of Chicago
- **MS14-C-4** (11:30am) Hybrid Learning of Spatiotemporal Neural Operators in Forward and Inverse Problems for Turbulent Flows. *Shuhao Cao*, University of Missouri-Kansas City

MS15. Recent Advances in Numerical Methods for Partial Differential Equations II

Organizers: *Yang Yang*, Michigan Technological University

Session A: Saturday, October 5, 2:30pm-3:50pm, Royall 312

- **MS15-A-1** (2:30pm) A Generalized Direct Discontinuous Galerkin Method for a Doubly Nonlinear Diffusion Equation in Shallow Water Modeling. *Stephanie Berg*, Iowa State University
- **MS15-A-2** (2:50pm) Second Order in Time Bound-Preserving Implicit Pressure Explicit Concentration Methods for Contaminant Transportation in Porous Media. *Yang Yang*, Michigan Technological University
- **MS15-A-3** (3:10pm) A high-order well-balanced discontinuous Galerkin method for hyperbolic balance laws based on the Gauss-Lobatto quadrature. *Ziyao Xu*, University of Notre Dame

- **MS15-A-4** (3:30pm) Well-balanced positivity-preserving high-order discontinuous Galerkin methods for Euler equations with gravitation. *Fangyao Zhu*, Michigan Technological University

CT1. Contributed Talks-1

Session A: Saturday, October 5, 10:00am-11:20am, Royall 206

Session-Chair: *Yiran Wang*, University of Alabama

- **CT1-A-1** (10:00am) Physics-preserving IMPES based multiscale methods for immiscible two-phase flow in highly heterogeneous porous media. *Yiran Wang*, University of Alabama
- **CT1-A-2** (10:20am) Semigroup well-posedness of a Biot-Stokes Interactive System. *Sara McKnight*, Colorado Mesa University
- **CT1-A-3** (10:40am) Intrinsic Projection of Implicit Runge-Kutta Methods for DAEs. *Nikita Kapur*, The University of Iowa
- **CT1-A-4** (11:00am) Starting Approximations for SIRK Methods Applied to Index 2 DAEs. *Joseph Small*, University of Iowa
- **CT1-A-5** (11:20am) Fluid Dissipation Gevrey Class Estimates for a Problem in Fluid Structure Interaction. *Dylan McKnight*, Colorado Mesa University

Session B: Saturday, October 5, 2:30pm-3:50pm, Royall 206

Session-Chair: *Xianping Li*, Arizona State University

- **CT1-B-1** (2:30pm) Starting approximations of implicit Runge-Kutta methods for ODEs and DAEs. *Laurent O. Jay*, University of Iowa
- **CT1-B-2** (2:50pm) Moving Mesh SUPG Method for Time-dependent Convection-Dominated Convection-Diffusion Problems. *Xianping Li*, Arizona State University
- **CT1-B-3** (3:10pm) Fourier Continuation Method for Nonlocal Boundary Value Problems. *Ilyas Mustapha*, Kansas State University
- **CT1-B-4** (3:30pm) Regularity of Solutions for the Peridynamic Equation on Periodic Distributions. *Thinh Dang*, Kansas State University

CT2. Contributed Talks-2

Session A: Saturday, October 5, 4:10pm-5:30pm, Royall 314

Session-Chair: *Asma Azizi*, Kennesaw State University

- **CT2-A-1** (4:10pm) Machine Learning Integrated with In Vitro Experiments for Study of Drug Release from PLGA Nanoparticles. *Shuhuai Qin*, Colorado State University
- **CT2-A-2** (4:30pm) TBD. *Sahil Chindal*, Virginia Commonwealth University
- **CT2-A-3** (4:50pm) TBD. *Bidemi O. Falodun*, Missouri University of Science and Technology, Missouri
- **CT2-A-4** (5:10pm) TBD. *Asma Azizi*, Kennesaw State University

Session B: Sunday, October 6, 10:30am-11:50am, Royall 314

Session-Chair: *Yukun Yue*, University of Wisconsin-Madison

- **CT2-B-1** (10:30am) Penalty Adversarial Network (PAN): A neural network-based method to solve PDE-constrained optimal control problems. *Yukun Yue*, University of Wisconsin-Madison
- **CT2-B-2** (10:50am) Maximal volume matrix cross approximation for image compression and least squares solution. *Zhaiming Shen*, Georgia Institute of Technology
- **CT2-B-3** (11:10am) Shallow ReLU Neural Networks and their Representations of Piecewise Linear Functions. *Sarah McCarty*, Iowa State University
- **CT2-B-4** (11:30am) Multifidelity Operator Learning with Learned Neural Input Basis. *Jacob Hauck*, Missouri University of Science and Technology

P. Poster Presentations

Session A: Saturday, October 5, 4:10pm-5:30pm, Third Floor of Haag

- **P-A-1** Sampling Bounds for Topological Descriptors. *Maksym Makarchuk*, Montana State University
- **P-A-2** Numerical Solution and Methods of Differential Equations. *Yafang Hei*, Missouri S& T
- **P-A-3** Traveling Wave Solutions of a Competitive Lotka-Volterra Reaction-Diffusion Model Influenced by Extreme Weather Events. *Barsha Saha*, University of Missouri-Kansas City
- **P-A-4** Hamilton-Jacobi Reachability Analysis for Hybrid Systems with Controlled and Forced Transitions. *Javier Borquez*, University of Southern California
- **P-A-5** Circumferentially pressure-driven flow in a two-layer system: a Riemann-sum approximation. *Dauda Gambo*, Iowa State University
- **P-A-6** Simple Exact Solution of Laser-induced Thermal Transport in Supported 2D Materials. *Seyed Mohammad Hossein Goushehgir*, Missouri S& T
- **P-A-7** Reduced Order Modelling for Atmospheric Reentry Applications. *Shafi Al Salman Romeo*, Oklahoma State University
- **P-A-8** Immersed Finite Element Applications Applied To Electrospray Propulsion. *Guy Easton Brawley*, Missouri University of Science and Technology
- **P-A-9** Modeling population mobility during COVID-19 era for mental health across the United States. *Vamsi Kommineni*, University of Kansas
- **P-A-10** Modeling spatial distribution of drug overdose death during COVID-19 pandemic years in the United States. *Venkata Naga Ramesh Solasa*, University of Kansas
- **P-A-11** Convergence of the Semi-Discrete WaveHoltz Iteration. *Amit Rotem*, Virginia Tech
- **P-A-12** Implementation of a Weak Galerkin Finite Element Method in C++ with Eigen Library. *Yingli Li*, Colorado State University

6 Abstracts of Mini-Symposium and Contributed Talks

MS01-A-1: Finite-time blowup for the Fourier-restricted Euler equation

Evan Miller, University of Alabama in Huntsville

Abstract:In this talk I will discuss finite-time blowup for a model equation the Euler and hypodissipative Navier-Stokes equations, where, in addition to the divergence free constraint, the constraint space now requires the velocity to be supported at a specific set of Fourier modes. While the Helmholtz projection is replaced with a projection onto a more restrictive constraint space, the nonlinearity is otherwise unaltered, and the divergence free constraint still holds.

MS01-A-2: Asymptotic properties of discretely self-similar Navier-Stokes solutions with rough data

Patrick Phelps, Temple University

Abstract: We investigate discretely self-similar (DSS) solutions to the 3D Navier-Stokes equations with rough data. We review previously demonstrated decay rates for DSS solutions evolving from subcritical data, and show that these solutions can be further decomposed into a term satisfying the optimal decay, and one with the decay previously shown with a pre-factor than can be made arbitrarily small. We then show that solutions with critical data can be decomposed into a term satisfying the optimal decay and a constant term that can be taken to be arbitrarily small in a scaling invariant class. This leads to an application which quantifies how conjectured non-unique solutions evolving from the same data in this critical class might separate at short times. Joint work with Zachary Bradshaw.

MS01-A-3: Some results on solutions to Primitive Equations

Ning Ju, Oklahoma State University

Abstract: TBD.

MS01-A-4: Regularity, uniqueness and the relative size of small scales in supercritically dissipative SQG

Zachary Akridge, University of Arkansas

Abstract: The problem of regularity and uniqueness are open for the supercritically dissipative surface quasi-geostrophic equations. In this talk, we discuss recent work of Akridge and Bradshaw which examines the extent to which small scales are necessarily active both in hypotheti- cal blowup scenerios and for the error in hypothetical non-uniqueness scenarios, all within the class of Marchand's solutions. This extends prior work for the 3D Navier-Stokes equations. The extension is complicated by the fact that mild solution techniques are unavailable for supercritical SQG, which forces us to develop a new approach using energy methods and Littlewood-Paley theory.

MS01-B-1: Singularity Suppression by Rapid Mixing in a Non-Diffusive Aggregation Equation

Nicholas Harrison, Oregon State University

Abstract: The regularization effect of diffusion in scalar evolution problems is well known to potentially be enhanced by the presence of an advecting velocity field. This cooperation has even been shown to suppress the singularity formation in nonlinear equations which otherwise exhibit blowup. In this talk, we'll discuss the prevention of singularity formation in the parabolic-elliptic Keller-Segel system with estimates which are uniform in the diffusivity parameter. In taking this diffusivity to zero, we consider weak solutions to an aggregation equation for which all sufficiently smooth solutions necessarily form a singularity by some finite time. We'll see that weak solutions in-

deed have the potential to be global given the ambient velocity is sufficiently strong and well-mixing.

MS01-B-2: Calmed 3D Navier-Stokes: An approximate model with physical boundary conditions, unmodified energy identity, and no singularity

Adam Larios, University of Nebraska-Lincoln

Abstract: We present a new modification of the 3D incompressible Navier-Stokes equations (NSE) based on a smooth truncation function applied to the velocity in the rotational form of the nonlinear term. We call this modification the "Calmed Navier-Stokes" equations. This new model is globally well-posed, even in the case of physical (no-slip) boundary conditions, and enjoys exactly the same energy identity as strong solutions to the NSE. Moreover, its solutions converge to strong solutions of the Navier-Stokes equations on the time interval of existence and uniqueness of the latter as the "calming parameter" tends to zero. We also show that the calmed equations have a global attractor. The calming approach was first used by the same authors in the context of the 2D Kuramoto-Sivashinsky equations (KSE) of flame fronts, although the 3D NSE case is significantly more challenging due to the lower-order dissipation and higher dimension of the 3D NSE compared to the 2D KSE. We will discuss these analytical results for both the calmed versions of the 3D NSE and 2D KSE and also present simulation results to illustrate the dynamics.

MS01-B-3: Shear banding phenomenon of a thixotropic fluid model

Taige Wang, University of Cincinnati

Abstract: In this talk, I will focus on the phenomenon and analysis of shear band phenomenon arising in shearing of non-Newtonian planar Poiseuille flows, i.e., coexistence of yielding and unyielding in shearing can be observed, and it forms an interface across the flow, which is called shear band. The analysis is to use multiscale analysis to predicting this shear band; there are numerical simulations which could verify the analysis.

MS01-B-4: A regularity criterion for the 3D Navier-Stokes equations based on finitely many observations

Abhishek Balakrishna, University of Southern California

Abstract: Data assimilation is a technique that combines observational data with a given model to improve the model's accuracy. We first discuss the application of a particular data assimilation technique (AOT algorithms) to the 3-D Navier-Stokes equation (3D NSE); we then describe how a data assimilated solution approximates the true solution. Then we observe the data assimilated solution is, in fact, regular (i.e., a strong solution) when the observed data satisfies a condition we present for only a finite collection of data. This result suggests a connection between our condition and the regularity of solutions to the actual 3D NSE. We pursue this line of inquiry to confirm this hypothesis, and formulate such a regularity criterion for the 3D NSE purely in terms of finitely-observed data.

MS02-A-1: Some recent progress on additional food driven biocontrol, with application to the Soybean Aphid

Rana Parshad, Iowa State University

Abstract: The theory of "Additional food" states that a predator's efficacy in keeping a pest population in check, can be improved by providing the predator with additional food. In this talk we survey recent results that show how such biocontrol works if mechanisms such as predator competition, landscape ecology and climate change are taken into consideration. We aim to apply our results to the control of the pestiferous Soybean Aphid, and are also motivated by

the current STRIPS project, a conservation practice at Iowa State University.

MS02-A-2: A patch-driven additional food model

Urvashi Verma, Iowa State University

Abstract: Climate change is projected to increase flooding in the North Central United States over the coming years, which could lead to species drifting, especially during floods, particularly if the land tilts from an additional food patch (at a higher elevation) toward a crop field patch (at a lower elevation). In this paper, we observed that introducing a patchy environment improves the controllability of pests within the system. This talk will focus on the dynamics of a new 4-dimensional patch model for a prey-predator system with additional food provided in a single patch. Our findings indicate that pest extinction in the crop field is globally asymptotically stable with drift while other populations persist. Additionally, unbounded growth of the predator population (without drift) in the additional food patch can be mitigated via sufficient drift in the patch model.

MS02-A-3: Mathematical modeling of intracellular osmolarity and cell volume stabilization.

Zahra Aminzare, University of Iowa

Abstract: The presence of impermeant molecules within a cell can lead to an increase in cell volume through the influx of water driven by osmosis. This phenomenon is known as the Donnan (or Gibbs-Donnan) effect. Animal cells actively transport ions to counteract the Donnan effect and regulate their volume, actively pumping Na+ out and K+ into their cytosol using the Na+/K+ ATPase (NKA) pump. The pump-leak equations (PLEs) are a system of algebraic-differential equations to model the membrane potential, ion (Na+, K+, and Cl-), and water flux across the cell membrane, which provide insight into how the combination of passive ions fluxes and active transport contribute to stabilizing cell volume. In this talk, after introducing PLEs and demonstrating how effectively this model describes cell volume stabilization, I will apply methods from contraction theory and sensitivity analysis to prove the model's stability and robustness.

MS02-A-4: Modeling and Optimizing Social Distancing for Epidemic Mitigation

Zhijun Wu, Iowa State University

Abstract: In a severe epidemic such as the COVID-19 pandemic, social distancing can be a vital tool to stop the spread of the disease and save lives. However, social distancing may induce profound negative social/economic impacts as well. How to optimize social distancing is a serious social, political, as well as public health issue yet to be resolved. This work investigates social distancing with a focus on how every individual reacts to an epidemic, what role he/she plays in social distancing, and how every individual's decision contributes to the action of the population and vice versa. The collective behavior of social distancing is thus modeled as a population game, where every individual makes decision on how to participate in a set of social activities, some with higher frequencies while others lower or completely avoided, to minimize his/her social contacts with least possible social/economic costs. An optimal distancing strategy is then obtained when the game reaches an equilibrium. The game is simulated with various realistic restraints including (i) when the population is distributed over a social network, and the decision of each individual is made through the interactions with his/her social neighbors; (ii) when the individuals in different social groups such as children vs. adults or the vaccinated vs. unprotected have different distancing preferences; (iii) when leadership plays a role

in decision making, with a certain number of leaders making decisions while the rest of the population just follow. The simulation results show how the distancing game is played out in each of these scenarios, reveal the conflicting yet cooperative nature of social distancing, and shed lights on a self-organizing, bottom-up perspective of distancing practices.

MS02-B-1: Leveraging mobility data to model drug overdose mortality in the United States during COVID-19 Pandemic
Folashade Agusto, University of Kansas
Abstract: Drug overdose fatalities have become a significant health issue in many countries, with the United States experiencing a particularly alarming rise over the past two decades. In this study, we examine the geographical patterns of drug overdose deaths at the county level across the United States by utilizing five newly defined spatial weights, developed using mobility data from Google and Facebook. Google Mobility Data, derived from users' location services, provides insights into how populations move between various categories of places, while Facebook Mobility Data, collected through its Data for Good program, tracks population movements between geographic areas. These spatial weights are based on the correlation of mobility data between two spatial units and a threshold distance decay between them. We analyze the spatial distribution of drug overdose deaths using datasets from County Health Rankings and Roadmaps, as well as the Centers for Disease Control and Prevention, focusing on the COVID-19 era spanning 2020, 2021, and 2022. By incorporating spatial covariate information into the new spatial weight definitions, these methods more accurately represent the relationships between spatial units and enhance the performance of spatial analysis techniques. Three of the methods effectively captured nearly all high-incident counties and accurately identified hot and cold spot clusters over the years. In contrast, the other two methods failed to identify many counties with high cases, classifying them as insignificant.

MS02-B-2: Modeling the Impact of Climate Change on Intra- and Inter-Species Interactions Among Rodent Species
Majid Bani-Yaghoub, University of Missouri-Kansas City
Abstract: Numerous studies have documented the effects of climate change on interacting species. This includes habitat fragmentation, increased competition, and extinction or shifts in geographic range. In the present study, we use 1973-2003 data sets of five different rodent species in Kansas and historical weather data to assess the effects of climate change on the interaction within and between the species. By applying the Lotka-Volterra models to the data, we find that the nature of these interactions varies according to both seasonal shifts and long-term climatic changes. This study highlights the application of mathematical models to elucidate how rodents respond to climate change.

MS02-B-3: Characterizing single-cell transcriptomic signatures with persistent homology and molecular cartography
Erik Amezquita, University of Missouri
Abstract: The central dogma of molecular biology follows a simple path: DNA is transcribed into RNA transcripts in the cell nucleus, and these transcripts are then translated into proteins in the cell cytosol. However, protein production is not solely impacted by the level of expression of genes, but by many other regulatory processes that can be specific to the gene type and even specific to the cell spatial location. Different cells of different shapes and sizes present different RNA transcript distribution for different genes. To mathematically model and

analyze this highly variable distributions, we turn to Topological Data Analysis (TDA) for a robust and comprehensive pipeline.

Here, through the use of single-cell sequencing and molecular cartography technologies, we first produce detailed maps of the spatial location of individual transcripts for different genes, cell types, and organs of the soybean root and nodule. We then use persistent homology to characterize the distribution of these transcripts for each cell. Comparing these topological shape signatures reveals a new perspective on the role of the nuclear and cytoplasmic localization of transcripts as a central mechanism to control protein translation and the biology of plant cells. This work reveals the influence of the compartmentalization of transcripts as another regulatory mechanism of protein translation and a new understanding of the central dogma of molecular biology. **MS02-B-4: A Time Scale Approach for Analyzing Pathogenesis of ATL Development associated with HTLV-1 Infection**

Neslihan Nesliye Pelen, Missouri University of Science and Technology

Abstract: Mathematical modeling of the dynamics of Human T-cell lymphotropic virus type I (HTLV-1) infection and the development of adult T-cell leukemia (ATL) cells is investigated by a time-scale approach. The proposed models, constructed by nonlinear systems of first-order difference equations and h-difference equations, characterize the relationship among uninfected, latently infected, actively infected CD4+ cells, and ATL cells, where discrete logistic curves describe the growth of leukemia cells. The stability results are established based on the basic reproduction number R_0. When $R_0 < 1$, infected T-cells always die out and two disease-free equilibria exist depending on the proliferation rate and the death rate of leukemia cells. When $R_0 > 1$, HTLV-1 infection becomes chronic and spreads, and a unique endemic equilibrium exists. The stability results of disease-free and endemic equilibrium points are obtained when $R_0 < 1$ and $R_0 > 1$, respectively. Furthermore, the sensitivity analysis discovers the key parameters of the models related to Ro. Estimated parameters are applied based on the experimental observation. The numerical analysis also shows the equilibrium level of ATL cell proliferation is higher when the HTLV-I infection of T-cells is chronic than when it is acute. Moreover, our mathematical modeling by a time scale approach yields a new parameter to an HTLV-1 infection model which determines data frequency. **MS02-C-1: Studying Infectious Diseases by Time Scale Approach**

Elvan Akin, Missouri University of Science and Technology

Abstract: In this talk, we introduce a time scale approach for understanding the dynamics of infectious diseases such as HIV (human immunodeficiency virus), swine influenza, and Tuberculosis. Depending on how data set is collected, we would fix a time scale, a closed subset of real numbers, and investigate epidemic models. During the talk, we present mathematical and numerical results.

MS02-C-2: Effects of harvesting mediated emigration on a landscape ecological model

Xiaohuan Xue, University of North Carolina at Greensboro

Abstract: We analyze the structure of positive steady states for landscape ecological models of the form:

$$\begin{cases} -\Delta u = \lambda \left[u(1-u) - h(c,u) \right]; \ \Omega \\ \frac{\partial u}{\partial \eta} + \sqrt{\lambda}\gamma g(c,u)u = 0; \ \partial\Omega \end{cases}$$

where $\lambda > 0$ is a parameter that is proportional to patch size square, $\gamma > 0$ is a parameter that quantifies the exterior matrix hostility, Ω is a bounded domain in $\mathbb{R}^N$; $N > 1$ with smooth boundary $\partial\Omega$ or $\Omega = (0,1)$, $\frac{\partial u}{\partial \eta}$

is the outward normal derivative of u. Here, $h(c,s)$ represents harvesting and we consider the following forms:

- $h_1(c,s) = c; c > 0$
- $h_2(c,s) = cs; c > 0$
- $h_3(c,s) = \frac{cs^2}{m+s^2}; c > 0, m > 0$

For the emigration patterns g, we consider:

- $g_1(c,s) = 1 + \mu c;\ \mu \geq 0$
- $g_2(c,s) = 1 + \beta s + \mu c;\ \mu \geq 0, \beta > 0$
- $g_3(c,s) = \frac{1}{1+\beta s} + \mu c;\ \mu \geq 0, \beta > 0.$

We note that g_1, g_2, g_3 represent density-independent emigration (DIE), positive density-dependent emigration (+DDE), and negative density-dependent emigration (-DDE) respectively. Our motivation is to compare the structure of the positive solutions when $\mu = 0$ (when the harvesting does not affect the emigration) to the case when $\mu > 0$ (when the harvesting influences the emigration). We establish several existence, non-existence, and multiplicity results via the method of sub and super solutions. When $n = 1$, namely when $\Omega = (0,1)$, we obtain more detailed information about the bifurcation diagrams and their evolution as μ varies via a quadrature method and Mathematica computations. We also discuss the biological implications of our results.

MS02-C-3: A Discrete-Time Model for TYC strategy

Don Kumudu Mallawa Arachchi, Iowa State University

Abstract: TBD

MS02-C-4: A bifurcation diagram for a reaction-diffusion equation with nonlinear boundary conditions

Nalin Fonseka, University of Central Missouri

Abstract: We analyze positive solutions to the steady state reaction-diffusion equation:

$$\begin{cases} -\Delta u = \lambda f(u);\ \Omega \\ \frac{\partial u}{\partial \eta} + \gamma\sqrt{\lambda} g(u) u = 0;\ \partial\Omega \end{cases}$$

where $\lambda > 0$, $\gamma > 0$, Ω is a bounded domain in $\mathbb{R}^N$; $N > 1$ with smooth boundary $\partial\Omega$ or $\Omega = (0,1)$, $\frac{\partial u}{\partial \eta}$ is the outward normal derivative of u, $g \in C([0,\infty),(0,1])$ is a non-increasing function such that $g(0) = 1$ and $\lim_{s\to\infty} g(s) = g_\infty > 0$, $f \in C^2([0,r_0])$ with $f(0) = 0, f'(0) = 1$, $0 < r_0 < \infty$ such that $f(r_0) = 0$ and $f(s)(s - r_0) \leq 0$ for $s \in [0,\infty)$. We note that the parameter λ influences both the equation and the boundary condition. Under additional hypotheses, we establish the existence, nonexistence, and multiplicity results for certain ranges of λ via the method of sub-super-solutions, in particular, we establish that the bifurcation curve is at least Σ-shaped. Further, when Ω is a ball, for the example (that arises in ecology) where $f(s) = s - \frac{s^2}{K} - \frac{Ms^2}{1+s^2}$, $g(s) = 1 - ms$ for $0 \leq s \leq \frac{1}{2m}$ and $g(s) = \frac{1}{2}$ for $s > \frac{1}{2m}$ with K, M, and m are positive parameters, we prove that the bifurcation diagram for positive solutions is at least Σ-shaped for certain ranges of the parameters. When $\Omega = (0,1)$, via a quadrature method and Mathematica computations we obtain exact bifurcation diagrams for positive solutions of this example.

MS03-A-1: Harmonic-measure distribution functions in various geometries

Christopher Green, Wichita State University

Abstract: Consider releasing a Brownian particle from a basepoint zo in a planar domain $\Omega \cup C$. What is the chance, denoted $h(r)$, that the particle's first exit from Ω occurs within a fixed distance $r > 0$ of $z0$? The function $h : [0,\infty) \to [0,1]$ is called the harmonic-measure distribution function, or h-function, of Ω with respect to zo. It can also be formulated in terms of a Dirichlet problem on Ω with suitable boundary values. For simply connected domains Ω, the theory of h-functions is now quite well-developed, and in particular the h-function can often be explicitly computed, making

use of the Riemann mapping theorem. However, until recently, for multiply connected domains the theory of h-functions has been almost entirely out of reach. In this talk, it will be shown how to construct explicit formulae for h-functions of symmetric multiply connected slit domains whose boundaries consist of an even number of colinear slits, and how these formulae can be generalized to compute h-functions for multiply connected slit domains on a spherical surface.

MS03-A-2: Numerical experiments with potential flow and vortices in multiply connected domains in the plane

Thomas K DeLillo, Wichita State University

Abstract: We will give an overview of recent numerical experiments computing plane potential flow and vortices in multiply connected domains with circular boundaries in the complex plane. The velocity potentials determining the motion of both the interacting vortices and the circular cylinders are represented by Laurent series.

MS03-A-3: Numerical computation of Stephenson's g-functions in multiply connected domains

Mohamed Nasser, Wichita State University

Abstract: There has been much recent attention on h-functions, so named since they describe the distribution of harmonic measure of a given multiply connected domain with respect to some basepoint. In this talk, we focus on a closely related function to the h-function, known as the g-function, which originally stemmed from questions posed by Stephenson in [1]. Given a planar domain and some basepoint in this domain, computing the associated Stephenson's g-function requires considering various domain regimes. We use a well-established boundary integral equation method to solve the relevant Dirichlet boundary value problems.

[1] D.A. Brannan & W.K. Hayman, Research problems in complex analysis, *Bull. London Math. Soc.* 21 (1989) 1-35.

MS03-A-4: TBD

Vijay Matheswaran, Wichita State University

Abstract: A Hybrid Potential Flow (HPF) model for flow around a circular cylinder in the subcritical Reynolds number range ($300 \leq Re \leq 3 \times 10^5$) is presented using a combination of elementary flow solutions and empirical data. By joining this developed near-body solution with von Karman's model for the vortex wake, a complete solution for flow around a circular cylinder is calculated. Results for oscillatory forces, including the transverse lift force, due to vortex shedding as well as shedding frequencies are then calculated and presented. These numerical results are then compared to experimental observations on a free-surface water table and validated.

MS04-A-1: Utilizing Bayesian Inference to Understand the Evolution of MRSA Infection and Transmission in Urban Anchor Hospital Settings

Kiel Daniel Corkran, University of Missouri-Kansas City

Abstract: Methicillin-resistant Staphylococcus aureus (MRSA) is a type of staph bacteria that can cause healthcare-associated infections (HAIs) in hospitals, and nursing homes. Given the 2019-2023 electronic health records from the University Health system, the main objective of our study was to estimate HAI MRSA transmission rates in their two urban anchor hospitals. To achieve this goal, we applied the delayed rejection adaptive metropolis (DRAM) algorithm to an ODE model of MSRA transmission. DRAM calculated the posterior probability of assumed values for our unknown parameters and then compared it to an optimal set of values for these parameters, including transmission rates. Two main results of our study

are (1) the detection of an MRSA transmission pattern where inpatient units had the highest mean values and (2) an MRSA transmission pattern during the COVID-19 pandemic. Consequently, the reproduction numbers were significantly higher for those two cases.

MS04-A-2: Evolution Dynamics of COVID-19 Variants: Transmission, Virulence, and Vaccination Impacting the Pathogen Fitness.

Barsha Saha, University of Missouri-Kansas City

Abstract: In this study, we investigate the evolutionary dynamics of SARS-CoV-2 variants by developing a deterministic model to explore how changes in transmission rates, virulence and vaccination may shape virus evolution. We test four hypotheses: whether virulence declines over time, whether increased transmissibility correlates with higher virulence, whether vaccination increase more virulence effect of the disease and the existence of a transmission-virulence trade-off. Considering seven epidemic waves in the United States from early of 2020 to mid of 2023, we observed that the evolution of COVID-19 variants does not always appear according to traditional hypotheses. Instead, our analysis highlights the critical role of vaccination in altering the evolutionary pressures on the virus, potentially leading to unexpected changes in both transmission and virulence. Our research will offer new insights into the ongoing evolution of the virus and informing future public health strategies.

MS04-A-3: Dynamics of Math Anxiety and Minimal Efforts Required to Eradicate it

Sara Sony, Northwest Missouri State University

Abstract: Dynamics of Math Anxiety and Minimal Efforts Required to Eradicate it This paper aims to develop a mathematical modeling framework to describe dynamics of math anxiety among college students. Borrowing from the epidemiological models, we built a compartmental model, which includes susceptible (S), anxious (A), treated (T), and untreated (U) individuals. In addition to model analysis, we validated the model using the survey data of college students taking Calculus II and III during the summer. The model has acceptable goodness of fit most compartments. The model solutions exhibit different periodic behaviors in the S and A compartments as well as S, A and T compartments. We also calculated the basic reproduction number (R0) associated with the parameterized model, where the minimal eradication efforts are given be (1-1/R0). In conclusion, mathematical models can be employed to analyze dynamics of math anxiety and determine minimum resources required to treat the students with anxiety and reaching an anxiety free population of students.

MS04-A-4: Modeling the Spread of Respiratory Infections in Universities and Colleges Using UWB RTLS Real-Time Movement Data

Ravi Chandra Thota, University of Missouri-Kansas City

Abstract: There is a significant gap about how the movements of individuals, especially in academic settings, affect the dynamics of infectious disease spread. Earlier studies have mostly concentrated on outdoor movement patterns. This study models the airborne transmission of respiratory infections such as COVID-19, influenza, and chickenpox among college students. To achieve this goal, we collected and analyzed movement data from Ultra-Wideband (UWB) Real-Time Location Systems (RTLS) as detailed below. The University of Missouri-Kansas City (UMKC) campus hosted four major indoor social events during which high-resolution movement data was collected. We evaluated the frequency, intensity, and length of interac-

tions between people using this data to conduct thorough contact analytics. We then estimated the likelihood of infection for various airborne diseases as a function of contact distance for calculating individual transmission rates. This study offers a framework for computing the risk of airborne diseases and offers insightful information about the dynamics of disease transmission in indoor academic settings. In addition to being relevant to COVID-19, the findings can also be tailored to other infectious diseases, such as influenza and chickenpox, which are of great public health concern.

MS04-B-1: Delayed Reaction-Diffusion Modeling of Hes1- mRNA Oscillations and Dispersal

Mohammed Alanazi, University of Missouri-Kansas City

Abstract: This is joint work with Dr. Bani-Yagoub and Dr. Bi-Botti Youan. Hes1 (Hairy and Enhancer of Split 1) is a gene essential for embryonic development and cellular differentiation. The interaction between Hes1 and its mRNA is pivotal in regulating cell fate determination during development. This research presents the initial steps toward approximating periodic solutions in a model that describes the dynamics of Hes1-mRNA interactions. Through linearization, we identified a critical bifurcation point, leading to a loss of linear stability and the emergence of periodic solutions, as confirmed by numerical simulations. Additionally, we propose a delayed Reaction-Diffusion model of the Hes1-mRNA system. We investigated the model's asymptotic behavior. Without delay, our findings indicate that this model does not produce stable periodic solutions. The presence of delay will generate periodic solutions in the spatial domain. Out results have been verified with the numerical simulations of the proposed model.

MS04-B-2: Numerical Explorations of a Reaction-Diffusion Model of Vascular Tumor Growth: Bifurcation, Relapse and Cure

Priscilla Owusu Sekyere, University of Missouri-Kansas City

Abstract: This is joint work with Dr. Bani-Yagoub and Dr. Bi-Botti Youan. The model proposed by Pinho et al. has gained much attention in studying the effect of anti-angiogenic therapy. In the present work, we extend the model in two important respects. First, the growth behaviors of cancer, as well as normal and endothelial cells, can be better modeled using the extended logistic growth model proposed by Peleg et al. Secondly, numerous studies indicate that cancer cells can spread in the body through metastasis. Also, endothelial cells travel during the process of angiogenesis. Hence, we extended Pinho's model into a Reaction-Diffusion (RD) model. In the absence of diffusion, the model indicates the presence of several bifurcations. For instance, when the growth of endothelial cells has a long lag time (i.e., when $a3 > 1$), the system predicts cancer-free status for the patient. Otherwise, there is a narrow region where the cancer persists, and the therapy becomes ineffective. Furthermore, the numerical simulations of the RD model represent conditions under which cancer relapse can occur for 5 years or less. In conclusion, the RD model provides more in-depth dynamics compared to the original model proposed by Pinho.

MS04-B-3: Machine Learning Approaches for Predicting Hospital- and Community-Acquired Urinary Tract Infections: A Comparative Analysis

Arash Arjmand, University of Missouri-Kansas City

Abstract: Urinary Tract infections (UTIs) are a significant healthcare concern, with distinct characteristics for Community-Acquired (CAI) and hospital-acquired (HAI) infections. This study compares the per-

formance of several machine learning models, including Classification and Regression Trees (CRT), Neural Networks (NN), Logistic Regression (LR), Random Forest (RF), and XGBoost, to predict and differentiate between CAI and HAI UTIs using 2019-2023 UTI data from two major medical centers located in Kansas City. By incorporating demographic, socioeconomic, and hospital-related predictors, the models enhance UTI prediction. The issue of class imbalances has been addressed with the Synthetic Minority Oversampling Technique (SMOTE) to ensure the robustness of cross-validation. Our findings offer insights into infectious disease dynamics within hospitals and support targeted infection control strategies.

MS04-B-4: Predicting Infectious Disease Vulnerability in Long-Term Care Facilities using Social Determinants of Health
Julia Pluta, University of Missouri-Kansas City
Abstract: Residents of long-term care facilities such as nursing homes represent a population uniquely vulnerable to infectious disease. The COVID-19 pandemic hit many long-term care facilities hard, but it did not hit every facility at the same rate or intensity. This study sought to determine the role that Social Determinants of Health played in determining the vulnerability of individual facilities to respiratory diseases such as COVID-19. Using a series of machine learning models including decision trees, this study demonstrates that factors used to calculate the deprivation index -the most thorough quantitative measure of social determinants of health - were highly predictive of COVID-19 resiliency and vulnerability in long-term care facilities during the initial outbreak and, when combined with prior COVID infections continued to be predictive of infection risks during later phases of the 2020-2023 pandemic. At the same time, traditional methods of rating long-term care facilities, such as CMS's Five-Star Quality Ratings, were of little predictive value for disease vulnerability. The results of this study show that allocating more of public health budgets to address deficiencies in social determinants of health should be an effective way to reduce vulnerability to future respiratory disease outbreaks.

MS04-B-5: Infectious Disease Dynamics in Theme Parks: Challenges and Strategies
Md Afsar Ali, Tuskegee University
Abstract: Vaccination coverage for infectious diseases like COVID-19, influenza, measles, and norovirus, ebbs and flows. This requires the introduction of public health measures in public spaces, including theme parks. For daily operations, theme parks must provide public health mitigation plans. Questions on the implementation of public health mitigation strategies such as park cleaning, protocols of disease testing, and enforcement of social distancing and the wearing of personal protective equipment (PPE) in the park can be considered. We have developed a multi-patch mathematical model of infectious disease transmission in a theme park that considers direct human-human and indirect environment-human transmission of the virus. The model thus tracks the changing infection landscape of all visitors, workers, and environmental reservoirs in a theme park setting. Model results show that theme-park public health mitigation must include mechanisms that reduce virus contamination of the environment to ensure that workers and visitors are protected from COVID-19, influenza, measles, and norovirus transmission in the park. Thus, cleaning rates and mitigation of human-environment contact increase in importance. Our findings have important practical implications in terms of public health as policy- and decision-makers are equipped with a mathematical tool that can guide theme park authorities in developing public health mitigation strategies for safe theme park management.

MS05-A-1: A supervised learning scheme for computing Hamilton-Jacobi equation via density coupling

Shu Liu, UCLA

Abstract: We propose a supervised learning scheme for the first-order Hamilton–Jacobi PDEs in high dimensions. The scheme is designed using the geometric structure of Wasserstein Hamiltonian flows via a density coupling strategy. It is equivalently posed as a regression problem using the Bregman divergence, which provides the loss function in learning while the data is generated through the associated Hamiltonian system. The proposed scheme can be used to describe the behaviors of Hamilton–Jacobi PDEs beyond the singularity formations on the support of coupling density. Several numerical examples with different Hamiltonians are provided to support our findings.

MS05-A-2: An Interpretable and Efficient Method for Collaborative Multi-Agent Path-Planning

Christian Parkinson, Michigan State University

Abstract: We present control theoretic model for collaborative multi-agent path-planning. While many such models rely on deep learning architectures or mean field approximations, ours involves a simple dynamic programming and Hamilton-Jacobi (HJ) based approach. This formulation accounts for car-obstacle and car-car collision avoidance. We design a grid-free numerical method based on a Hopf-Lax type variational formula to solve the HJ equation, and demonstrate the efficacy of our model in path-planning problems involving several Dubins type vehicles.

MS05-A-3: Guarantees on State-Augmented Differential Games for Fast and Conservative High-Dimensional, Nonlinear Prediction and Control

William Sharpless, University of California, San Diego

Abstract: In this talk, we will demonstrate an approach for safely modeling or controlling a high-dimensional, nonlinear system in the presence of an antagonistic opponent or disturbance. Namely, we will present a Hamilton–Jacobi-based method using the Hopf formula, ""antagonistic error"" and state augmented (SA) linearizations. SA systems are well-known for their ability to outperform standard linear methods in capturing nonlinear dynamics by "lifting" the system to a high-dimensional space, approximating the Koopman operator. We show through a series of inequalities that it possible to define a differential game in a SA space whose projected solutions are conservative. It follows that predictions and the optimal controller of this special SA linear game with error are valid in the true system despite any bounded lifting error or disturbance. We demonstrate this in the simple slow-manifold system for clarity and in the Van der Pol system to observe the use of different lifting functions.

MS05-A-4: Overview on constraints mean field games and new perspectives

Rossana Capuani, University of Arizona

Abstract: In this talk I will give an overview of mean field games with state constraints. Interest in these types of problems has been growing rapidly in recent years. The main motivation is that state constraints appear very natural in several applications (e.g., pediatric dynamics and macroeconomic models). Unfortunately, the state constraints introduce several difficulties in the definition of the equilibrium and the solution of the problem, which cannot be defined in terms of the solution of a PDE system as in the absence of constraints. Therefore, we attack the problem by considering a relaxed version of it, for which the existence of equilibria can be proved by set-valued fixed-point arguments. By analyzing the regularity and sensitivity with respect to space variables of the relaxed solution, we will show that it satisfies the Mean Field Games system in an appropriate pointwise sense.

MS05-B-1: Convexifying State-Constrained Optimal Control Problems via Hopf-Lax Theory

Donggun Lee, North Carolina State University

Abstract: Optimal control problems are fundamental in control theory, with Hamilton-Jacobi equations providing a core solution method. However, their computational complexity can limit practical applications. Hopf-Lax theory offers an analytic solution to Hamilton-Jacobi equations through Hopf-Lax formulae, enabling effective management of high-dimensional control challenges. Although Hopf-Lax formulae themselves are optimization problems, this raises the question of their advantages compared to directly solving the original control problems. This talk answers that question by demonstrating how Hopf-Lax formulae can convexify the original control problems, thereby enhancing computational efficiency and convergence. Additionally, we will introduce a novel extension of Hopf-Lax theory incorporating viscosity theory to address state constraints—an area not extensively explored in previous research—thus providing new avenues for more efficient solutions to state-constrained optimal control problems.

MS05-B-2: An invitation to high-dimensional non-potential mean-field games

Levon Nurbekyan, Emory University

Abstract: Mean field games (MFG) theory is a framework for modeling large populations of non-cooperative agents that play differential games. MFG is an active research area with applications in crowd dynamics, swarm control, economics, generative AI, and more. Hence, computational methods for high-dimensional MFG problems are crucial for developing efficient application algorithms. Most existing computational methods address only potential MFG – a subclass of problems that admit a variational formulation. In this talk, I will present a novel monotone inclusion formulation for non-potential MFG that can serve as a foundation for developing deep learning based algorithms for general high-dimensional problems.

MS05-B-3: Pedestrian models with congestion effects

Pedro Aceves Sanchez, The University of Arizona

Abstract: We study the validity of the dissipative Aw-Rascle system as a macroscopic model for pedestrian dynamics. The model uses a congestion term (a singular diffusion term) to enforce capacity constraints in the crowd density while inducing a steering behavior. Furthermore, we introduce a semi-implicit, structure-preserving, and asymptotic-preserving numerical scheme that can handle the numerical solution of the model efficiently. We perform the first numerical simulations of the dissipative Aw-Rascle system in one and two dimensions. We demonstrate the efficiency of the scheme in solving an array of numerical experiments, and we validate the model, ultimately showing that it correctly captures the fundamental diagram of pedestrian flow.

MS05-B-3: Pedestrian models with congestion effects

Karthik Elamvazhuthi Los Alamos National Laboratory

Abstract: In this talk, I will present recent work on a novel particle method for a general class of mean field control problems, with source and terminal constraints. Specific examples of the problems we consider include the dynamic formulation of the p-Wasserstein metric, optimal transport around an obstacle, and measure transport subject to acceleration controls. Unlike existing numerical approaches, our par-

ticle method is meshfree and does not require global knowledge of an underlying cost function or of the terminal constraint. A key feature of our approach is a novel way of enforcing the terminal constraint via a soft, nonlocal approximation, inspired by recent work on blob methods for diffusion equations. We prove convergence of our particle approximation to solutions of the continuum mean-field control problem in the sense of Gamma-convergence.

MS05-C-1: Title: Bayesian sampler for inverse problems of a stochastic process by leveraging Hamilton–Jacobi PDEs and score-based generative models

Tingwei Meng, UCLA

Abstract: The interplay between stochastic processes and optimal control has been extensively explored in the literature. With the recent surge in the use of diffusion models, stochastic processes have increasingly been applied to sample generation. This paper builds on the log transform, known as the Cole-Hopf transform in Brownian motion contexts, and extends it within a more abstract framework that includes a linear operator. Within this framework, we found that the well-known relationship between the Cole-Hopf transform and optimal transport is a particular instance where the linear operator acts as the infinitesimal generator of a stochastic process. We also introduce a novel scenario where the linear operator is the adjoint of the generator, linking to Bayesian inference under specific initial and terminal conditions. Leveraging this theoretical foundation, we develop a new algorithm, named the HJ-sampler, for Bayesian inference for the inverse problem of a stochastic differential equation with given terminal observations. The HJ-sampler involves two stages: solving viscous Hamilton-Jacobi (HJ) partial differential equations (PDEs) and sampling from the associated stochastic optimal control problem. Our proposed algorithm naturally allows for flexibility in selecting the numerical solver for viscous HJ PDEs. We introduce two variants of the solver: the Riccati-HJ-sampler, based on the Riccati method, and the SGM-HJ-sampler, which utilizes diffusion models. Numerical examples demonstrate the effectiveness of our proposed methods. This is a joint work with Zongren Zou, Jerome Darbon, and George Karniadakis.

MS05-C-2: Equations on the Wasserstein space and applications

Benjamin Seeger, University of North Carolina at Chapel Hill

Abstract: The purpose of this talk is to give an overview of recent work involving differential equations posed on spaces of probability measures and their use in analyzing controlled multi-agent systems. The study of such systems has seen increased interest in recent years, due to their ubiquity in applications coming from macroeconomics, social behavior, and telecommunications. When the number of agents becomes large, the model can be formally replaced by one involving a mean-field description of the population, analogously to similar models in statistical physics. Justifying this continuum limit is often nontrivial and is sensitive to the type of stochastic noise influencing the population, i.e. idiosyncratic or systemic. We will describe settings for which the convergence to mean field stochastic control problems can be resolved through the analysis of a certain Hamilton-Jacobi-Bellman equation posed on Wasserstein spaces. In particular, we develop new stability and regularity results for the equations. These allow for new convergence results for more general problems, for example, zero-sum stochastic differential games of mean-field type. We conclude with a discussion of some further problems for which the techniques for equations on Wasserstein space may be amenable.

MS05-C-3: Optimal Path Planning on Manifolds

Edward Duy Huynh, University of Texas at Austin

Abstract: We consider the problem of optimal path planning on a manifold which is the image of a smooth function $z = M(x, y)$. Optimal path-planning is of crucial importance for motion planning, image processing, and statistical data analysis. In this work, we consider a particle lying on the graph of M that seeks to navigate from some initial point to another point on the manifold. The problem may be modeled as an optimal control problem and can be solved using the associated Hamilton-Jacobi-Bellman equation. We develop a novel model and then we design a new algorithm that finds the solution efficiently based on the generalized Hopf-Lax formula. This model allows for time and spatially varying speeds and to our knowledge is the first use of modeling path planning on evolving manifolds.

MS05-C-4: How Level Set Methods Are Key to Safety-Critical Vehicle Systems

Matthew Kirchner, Auburn University

Abstract: This talk presents recent results and future challenges in developing numerical solutions to certain classes of the Hamilton-Jacobi (HJ) equations as they relate to computing reachable sets of dynamic systems and optimal vehicle trajectories. Many interesting problems can be used in this solution framework including multiple vehicle coordination, environment exploration and information collection, and collaborative pursuit-evasion. This talk will pay special attention to safety critical applications such as reactive collision avoidance and autonomous emergency landing of aircraft. Specific HJ equations form a theoretical basis that precisely characterize both safe and unsafe operating conditions, necessitating the rapid computation of these solutions for safety critical operations, where a vehicle must react to unforeseen events in the environment. HJ equations have had limitations in the past for computing usable solutions due to poor scaling with respect to system dimension. This was because of the fact that a spatial grid had to be constructed densely in each dimension. Creating equivalent formulations that no longer require spatial grids is the goal of the research and leads to methods that can be executed in real-time on embedded hardware. Additionally, I will discuss ongoing efforts to expand and generalize these methods to cover a larger field of applications.

MS05-D-1: Utilizing machine learning and game theory to find optimal policies for large number of agents

Gökçe Dayanikli, University of Illinois at Urbana-Champaign

Abstract: In many real-life policy making applications, the principal (i.e., governor or regulator) would like to find optimal policies for a large population of interacting agents who optimize their own objectives in a game theoretical framework. With the motivation of finding optimal policies for large populations, we start by introducing continuous time Stackelberg mean field game problem between a principal and a large number of agents. In Stackelberg mean field games, the mean field of agents play a noncooperative game and choose their controls to optimize their individual objectives by interacting with the principal and other agents in the society through the population distribution. The principal can influence the resulting mean field game Nash equilibrium through incentives (i.e., policies) to optimize her own objective. This creates a bi-level problem where at the lower level, the equilibrium of the population given the policies of the principal needs to be found and at the upper level, policy optimization of the principal should be executed given the reactions of agents. In order to solve these com-

plex problems efficiently, we propose rewriting the bi-level Stackelberg mean field game problem as a single-level problem and introduce a numerical approach that utilizes machine learning to solve it. Finally, we discuss experiment results on different applications such as regulating systemic risk among banks and finding an optimal contract between an employer and a large number of employees.

MS05-D-2: Mean-Field Control Barrier Functions: A Framework for Real-Time Swarm Control

Samy Wu Fung, Colorado School of Mines

Abstract: Control Barrier Functions (CBFs) are an effective methodology to ensure safety and performative efficacy in real-time control applications such as power systems, resource allocation, autonomous vehicles, robotics, etc. This approach ensures safety independently of the high-level tasks that may have been pre-planned off-line. For example, CBFs can be used to guarantee that a self-driving car will remain in its lane. However, when the number of agents is large, computation of CBFs can suffer from the curse of dimensionality in the multi-agent setting. In this work, we present Mean-field Control Barrier Functions (MF-CBFs), which extends the CBF framework to the mean-field (or swarm control) setting. The core idea is to model swarms as probability measures in the state space and build corresponding control barrier functions. Similar to traditional CBFs, we derive safety constraints on the (distributed) controls but now relying on the differential calculus in the space of probability measures. Our numerical experiments show the effectiveness of MF-CBFs applied to swarm tracking and avoidance.

MS05-D-3: Hamilton-Jacobi Reachability Analysis for Hybrid Systems with Controlled and Forced Transitions

Javier Borquez, University of Southern California

Abstract: Hybrid dynamical systems with nonlinear dynamics are one of the most general modeling tools for representing robotic systems, especially contact-rich systems. However, providing guarantees regarding the safety or performance of nonlinear hybrid systems remains a challenging problem because it requires simultaneous reasoning about continuous state evolution and discrete mode switching. In this work, we address this problem by extending classical Hamilton-Jacobi (HJ) reachability analysis, a formal verification method for continuous-time nonlinear dynamical systems, to hybrid dynamical systems. We characterize the reachable sets for hybrid systems through a generalized value function defined over discrete and continuous states of the hybrid system. We also provide a numerical algorithm to compute this value function and obtain the reachable set. Our framework can compute reachable sets for hybrid systems consisting of multiple discrete modes, each with its own set of nonlinear continuous dynamics, discrete transitions that can be directly commanded or forced by a discrete control input, while still accounting for control bounds and adversarial disturbances in the state evolution. Along with the reachable set, the proposed framework also provides an optimal continuous and discrete controller to ensure system safety. We demonstrate our framework in several simulation case studies, as well as on a real-world testbed to solve the optimal mode planning problem for a quadruped with multiple gaits.

MS06-A-1: A uniform framework for fluid dynamics in porous media

Seulip Lee, Tufts University

Abstract: This talk presents a uniform framework for computational fluid dynamics in porous media based on finite ele-

ment velocity and pressure spaces with minimal degrees of freedom. The velocity space consists of linear Lagrange polynomials enriched by a discontinuous, piecewise linear, and mean-zero vector function per element, while piecewise constant functions approximate the pressure. Since the fluid model in porous media can be seen as a combination of the Stokes and Darcy equations, different conformities of finite element spaces are required depending on viscous parameters, making it challenging to develop a robust numerical solver uniformly performing for all viscous parameters. Therefore, we propose a pressure-robust method by utilizing a velocity reconstruction operator and replacing the velocity functions with a reconstructed velocity. The robust method leads to error estimates independent of a pressure term and shows uniform performance for all viscous parameters, preserving minimal degrees of freedom. We prove well-posedness and error estimates for the robust method while comparing it with a standard method requiring an impractical mesh condition. We finally confirm theoretical results through numerical experiments with two- and three-dimensional examples and compare the methods' performance to support the need for our robust method.

MS06-A-2: Two-scale Neural Networks for Multiscale Problems

Qiao Zhuang, University of Missouri-Kansas City

Abstract: In this talk, we introduce a two-scale neural network method based on physics-informed neural networks (PINNs) to address multiscale problems involving small parameters. We directly incorporate the small parameters into the architecture of neural networks, which enables the proposed method to solve PDEs with small parameters in a simple fashion, without adding Fourier features or other computationally taxing searches of truncation parameters. Various numerical examples demonstrate reasonable accuracy in capturing features of large derivatives in the solutions caused by small parameters. "

MS06-A-3: Parametric reduced order modeling for nonlocal PDEs

Yumeng Wang, Missouri University of Science and Technology

Abstract: Many applications involve parametric nonlocal PDEs that need to be solved repeatedly for different parameter values. However, solving these PDEs even for a single parameter set can be challenging due to significant computational and storage costs. To address these challenges, we propose a convolutional neural network-based reduced-order modeling approach. Our method can predict solutions accurately for new parameters and significantly reduce computational costs. Extensive numerical experiments will be provided to demonstrate the performance of our method.

MS06-A-4: The interplay between deep learning and model reduction

Min Wang, University of Houston

Abstract: The integration of Reduced Order Modeling (ROM) and Deep Learning (DL) presents a promising avenue for enhancing computational efficiency and predictive accuracy. ROM techniques reduce complex systems into low-dimensional representations, preserving essential dynamics, while DL methodologies excel at learning intricate patterns from raw data. By combining ROM with DL, we aim to develop approaches that inherit merits from both disciplines. On one hand, we explore leveraging ROM as a preprocessing step to train DNNs with limited labeled data, addressing data scarcity. On the other hand, we intend to utilize DL to expedite ROM construction and learn ROMs directly from observational data. In this talk, we will elaborate on specific efforts made along this line.

MS06-B-1: Stopping Criteria for the Conjugate Gradient Algorithm in High-Order Finite Element Methods

Yichen Guo, Virginia Tech

Abstract: We consider stopping criteria that balance algebraic and discretization errors for the conjugate gradient algorithm applied to high-order finite element discretizations of Poisson problems. Firstly, we introduce a new stopping criterion that suggests stopping when the norm of the linear system residual is less than a small fraction of an error indicator derived directly from the residual. This indicator shares the same mesh size and polynomial degree scaling as the norm of the residual, resulting in a robust criterion regardless of the mesh size, the polynomial degree, and the shape regularity of the mesh. Secondly, for solving Poisson problems with highly variable piecewise constant coefficients, we introduce a subdomain-based criterion that recommends stopping when the norm of the linear system residual restricted to each subdomain is smaller than the corresponding indicator also restricted to that subdomain. Reliability and efficiency theorems for the first criterion are established. Numerical experiments, including tests with highly variable piecewise constant coefficients and a GPU-accelerated three-dimensional elliptic solver, demonstrate that the proposed criteria efficiently avoid both premature termination and over-solving.

MS06-B-2: Learning macroscopic parameters in nonlinear nonlocal upscaling

Maria Vasilyeva, Texas A&M University - Corpus Christi

Abstract: We present the nonlinear upscaling method for problems in fractured porous media and heterogeneous high-contrast structures. The macroscale variables of the coarse-scale model are accurately defined using the multicontinuum approach. The calculations of the upscaled parameters in the multicontinua approach are based on the solution of the local problem in the oversampled domain with a fine-scale resolution of microscale features. Then, the generated set is used to train the neural networks for fast and accurate prediction of the macroscale characteristics of the nonlinear problems. We present numerical results for several high-contrast structures and fractured porous media applications. Our numerical results show that the proposed approach can provide good accuracy with fast calculations.

MS06-B-3: A Model-Based Approach for Continuous-Time Policy Evaluation with Unknown Lévy Process Dynamics

Qihao Ye, University of California, San Diego

Abstract: This research presents a framework for evaluating policies in a continuous-time setting, where the dynamics are unknown and represented by Lévy processes. The approach involves two main steps. The first step addresses an inverse problem, where the model parameters in the fractional Fokker-Planck equation are recovered using a newly-developed fast solver. The second step involves solving a forward problem, specifically an elliptic integro-differential equation, to obtain policy evaluation. We have developed algorithms that demonstrate enhanced performance compared to existing techniques tailored for Brownian motion. Furthermore, we provide a theoretical guarantee regarding the error in policy evaluation given the model error. Experimental results, particularly for heavy-tailed data will be presented. This research provides a first step to continuous-time model-based reinforcement learning, particularly in scenarios characterized by irregular, heavy-tailed dynamics.

MS06-C-1: Data Driven Modeling of Stochastic Systems

Yuan Chen, Ohio State University

Abstract: We present a numerical framework for learning unknown stochastic dynamical systems using measurement data. Termed stochastic flow map learning (sFML), the new framework seeks to approximate the unknown flow map of the underlying system. Technically, it is realized by (conditional) generative models, such as Generative Adversarial networks (GANs), Autoencoders and Normalizing Flows. Once a sFML model is trained, it serves as a stochastic evolution model that is a weak approximation, in term of distribution, of the unknown stochastic system. It allows us to analyze the long-term system behavior under different initial conditions. A comprehensive set of numerical examples are presented to demonstrate the flexibility and effectiveness of the proposed sFML method for various types of stochastic systems. It is capable of handling systems driven by both Gaussian and non-Gaussian noises, even for jump processes, such as systems generated by Gillespie's stochastic simulations.

MS06-C-2: Cloud Effects on Sea-Ice-Floe Data Assimilation in Idealized Models

Changhong Mou, Purdue University

Abstract: Sea ice covers approximately 7% of the oceans year-round, significantly influencing and being influenced by both atmospheric and oceanic dynamics and thermodynamics, thus understanding and modeling sea ice in marginal ice zones is crucial for predicting the future climate in the Arctic. This paper introduces an idealized coupled atmosphere-ocean-ice model to investigate the effects of clouds on sea ice. This model describes the ice floes using the Discrete Element Method (DEM) to simulate the individual movements of ice floes in Lagrangian coordinates. The floes' movements are driven by both atmospheric and oceanic components, with the atmospheric component including precipitation to simulate water transfer between the sea ice and atmosphere. Moreover, the paper exploits data-driven approaches to construct reduced order stochastic models that facilitate the nonlinear data assimilation (DA) for the sea ice, atmosphere and ocean with limited observations. The DA succeeds in recovering the trajectories of ice floes, even in cases where observations typically have large uncertainties due to the presence of clouds. Furthermore, it also accurately estimates the upper atmosphere and recovers the unobserved upper atmosphere and underlying ocean fields. These advancements contribute to a more comprehensive understanding of Arctic climate dynamics.

MS06-C-3: The Runge-Kutta discontinuous Galerkin method with stage-dependent polynomial spaces for hyperbolic conservation laws

Qifan Chen, Ohio State University

Abstract: We present a novel class of high-order Runge-Kutta (RK) discontinuous Galerkin (DG) schemes for hyperbolic conservation laws. The new method extends beyond the traditional method of lines framework and utilizes stage-dependent polynomial spaces for the spatial discretization operators. To be more specific, two different DG operators, associated with P^k and P^{k-1} piecewise polynomial spaces, are used at different RK stages. The resulting method is referred to as the sdRKDG method and features fewer floating-point operations and may achieve larger time step sizes. We have also conducted von Neumann analysis for the stability and error of the sdRKDG schemes for the linear advection equation in one dimension. Numerical tests are provided to demonstrate the performance of the new method.

MS07-A-1: A Neural Networks Approach to Learning Threshold Dynamics

Luca Capogna, Smith College

Abstract: We implement a novel neural net-

works architecture to learn Threshold Dynamics of an evolving system from a few photograms of the evolution. The architecture is modeled on the well-known Bence-Merriman-Osher algorithm.

MS07-A-2: On the Relation between Graph Ricci Curvature and Community Structure
Sathyanarayanan Rengaswami, Army Research Lab
Abstract: The connection between curvature and topology is a very well-studied theme in the subject of differential geometry. By suitably defining curvature on networks, the study of this theme has been extended into the domain of network analysis as well. In particular, this has led to curvature-based community detection algorithms. In this paper, we reveal the relation between community structure of a network and the curvature of its edges. In particular, we give apriori bounds on the curvature of intercommunity edges of a graph.

MS07-A-3: Unfolding Complex Interconnected Dynamics: An Interpretable Approach to Prediction Using ε-Approximate Koopman Eigenfunctions
Heman Shakeri, University of Virginia
Abstract: TBD.

MS07-A-4: Comparison of Dirichlet and Newtonian Sobolev spaces
Ilmari Kangasniemi, University of Cincinnati
Abstract: Suppose that (X, d, μ) is an unbounded complete metric measure space with $\mu(X) = \infty$. We consider the following question: for which X does every measurable function $f : X \to \mathbb{R}$ with an upper gradient in $L^p(X)$ have some constant $c \in \mathbb{R}$ such that $f - c \in L^p(X)$? For globally doubling X, we show that this property does not hold in the overwhelming majority of cases. For hyperbolic spaces, the question becomes more involved: there are numerous conditions which rule out this property, yet the standard hyperbolic space $\mathbb{H}^n$ does satisfy it for $1 \leq p \leq n-1$.

MS07-A-5: Modulus for bases of matroids
Huy Truong, Kansas State University
Abstract: In this work, we explore the application of modulus in matroid theory, specifically, the modulus of the family of bases of matroids. This study not only recovers various concepts in matroid theory, including the strength, fractional arboricity, and principal partitions, but also offers new insights. In the process, we introduce the concept of a Beurling set. Additionally, our study revisits and provides an alternative approach to two of Edmonds's theorems related to the base packing and base covering problems. This is our stepping stone for establishing Fulkerson modulus duality for the family of bases. Finally, we provide a relationship between the base modulus of matroids and their dual matroids, and a complete understanding of the base p-modulus across all values of p.

MS07-B-1: Self-improvement of fractional Hardy inequalities in metric measure spaces
Josh Kline, University of Cincinnati
Abstract: In the setting of a compact, doubling metric measure space (X, d, μ), we say that a closed set $E \subset X$ satisfies an (θ, p)-Hardy inequality for $1 < p < \infty$ and $0 < \theta < 1$ if the following holds for all Lipschitz functions u which vanish on E:

$$\int_{X \setminus E} \frac{|u(x)|^p}{\mathrm{dist}(x,E)^{\theta p}} d\mu(x) \leq C \int_X \int_X \frac{|u(x)-u(y)|^p}{d(x,y)^{\theta p} \mu(B(x, d(x,y)))} d\mu(y) d\mu(x).$$

In this talk, we discuss the relationship between such fractional Hardy inequalities on X and p-Hardy inequalities in the hyperbolic filling of X. By first showing that a p-Hardy inequality implies the validity of weighted versions for a certain class of *regularizable* weights, we then use the structure of the hyperbolic filling to show self-improvement of the (θ, p)-Hardy inequality in both exponent p and smoothness parameter θ.

MS07-B-2: Fractional Hardy inequalities

Lizaveta Ihnatsyeva, Kansas State University
Abstract: I would like to discuss a variant of the fractional Hardy inequality defined via a Gagliardo-type seminorm and the corresponding pointwise inequality. Motivated by the relation between p-Hardy integral inequality and the pointwise p-Hardy inequality, we show that a pointwise fractional Hardy inequality implies a fractional Hardy inequality. The proof consists of two main parts. The first one is to characterize the pointwise fractional Hardy inequality in terms of a fractional capacity density condition. The second part is to show the self-improvement property of the fractional capacity density. This is a joint work with Antti Vähäkangas and Kaushik Mohanta from the University of Jyväskylä.

MS07-B-3: Chromatic symmetric functions and polynomial tree invariants
Jeremy L. Martin, University of Kansas
Abstract: Stanley asked whether a tree is determined up to isomorphism by its chromatic symmetric function. We approach Stanley's problem by studying the relationship between the chromatic symmetric function and other invariants. First, we prove Crew's conjecture that the chromatic symmetric function of a tree determines its generalized degree sequence, which enumerates vertex subsets by cardinality and the numbers of internal and external edges. Second, we prove that the restriction of the generalized degree sequence to subtrees contains exactly the same information as the subtree polynomial, which enumerates subtrees by cardinality and number of leaves. Third, we construct arbitrarily large families of trees sharing the same subtree polynomial, proving and generalizing a conjecture of Eisenstat and Gordon. This is joint work with José Aliste-Prieto, Jennifer Wagner, and José Zamora.

MS07-B-4: Balancing Graphs Using Geometric Invariant Theory
Clayton Shonkwiler, Colorado State University
Abstract: Call a weighted, directed graph balanced if at each vertex the sum of weights coming into the vertex equals the sum of weights going out of the vertex. For example, if the graph represents a road network and the weights represent roadway capacities, the graph being balanced corresponds to feasibility of traffic flow through all intersections. In this talk I will describe a new way of balancing graphs based on minimizing a potential called the unbalanced energy of the graph. Although the unbalanced energy is non-convex, all of its critical points are global minima, so it is simple to minimize by gradient descent. These results were inspired by concepts from symplectic geometry and Geometric Invariant Theory, but have entirely elementary proofs. This is joint work with Tom Needham.

MS07-C-1: Factoring bi-Lipschitz mappings on large subsets
Matthew Romney, Stevens Institute of Technology
Abstract: A common problem in mathematics is to represent an arbitrary object of some type as the combination of simple, well-understood objects. An open question in geometric function theory is whether an arbitrary planar bi-Lipschitz mapping can be factored as the composite of mappings of arbitrarily small distortion. We solve a modified version of this problem in which one can ignore an exceptional set of small measure. Moreover, our result is quantitative. The main tool we use is a new multiscale approximation scheme by so-called almost affine mappings. This talk is based on joint work with G. C. David and R. Schul.

MS07-C-2: Maximal Directional Derivatives and Universal Differentiability Sets
Gareth Speight, University of Cincinnati
Abstract: Rademacher's theorem asserts that

Lipschitz functions are differentiable almost everywhere. Often it is useful to have conditions which imply differentiability at a point or inside a set of measure zero. An application of this is existence of measure zero universal differentiability sets, which contain a point of differentiability for each Lipschitz function. This talk gives an overview of what is known in Euclidean spaces and in more general metric spaces like Carnot groups and Laakso space.

MS07-C-3: A topological approach to analyzing access to resources with heterogeneous quality
Sarah Tymochko, UCLA
Abstract: Ideally, all public resources (e.g. parks, grocery stores, hospitals, etc.) should be distributed in a way that is fair and equitable to everyone. However, this is not always the case. Quantifying how much (or little) access individuals have to certain resources is a complex problem. Previous work has shown that tools from topological data analysis (TDA) can be useful in determining ""holes"" in the locations of resource locations based on geographic locations and travel times [Hickok et al., Persistent homology for resource coverage: a case study of access to polling sites, 2024]. Some resources may necessitate incorporation a notion of quality. As a case study, we look at public parks, which are heterogeneous in many ways. Having access to a park that is hundreds of acres with basketball courts, baseball diamonds, and an aquarium is inherently different than having access to a small patch of grass with an overgrown tennis court. Here we present an exploration of the access to public parks in Chicago using persistent homology, a tool from TDA. Our goal is to identify not only who lacks access to parks, but also who lacks access to quality parks.

MS07-C-4: Optimal Experimental Design using Zero-suppressed Binary Decision Diagrams
Michael Higgins, Kansas State University
Abstract: TBD.

MS07-D-1: Robust Minicocyclicity
Eric Babson, UC Davis
Abstract: This is an idea I have been discussing with Volkmar Welker which arises for clique complexes of certain random graphs. The idea is that the complex may not be acyclic but the cocycles are generated by ones of small norm and this property persists (is robust) when a small number of vertices are deleted.

MS07-D-2: Some applications of neural networks to modulus on networks
Abhinav Chand, Kansas State University
Abstract: Inspired by recent applications of machine learning to mathematics, we trained graph neural networks to predict the solution of the modulus problem on graphs. We used saliency analysis to identify important features of the graph that affect the minimum feasible partition problem. We believe this could be applied to other problems in network science/graph theory to identify patterns and generate conjectures.

MS07-D-3: Conformal dimension of the Brownian graph
Hrant Hakobyan, Kansas State University
Abstract: Conformal dimension of a metric space X is the infimum of the Hausdorff dimension among all its quasisymmetric images. If conformal dimension of X is equal to its Hausdorff dimension, X is said to be minimal for conformal dimension. In this paper we show that the graph of one dimensional Brownian motion is almost surely minimal for conformal dimension. We also give other examples of sets that are minimal for conformal dimension. These include Bedford-McMullen self-affine carpets with uniform fibers as well as graphs of continuous functions of Hausdorff dimension d, for every d

in [1,2]. The main technique in the Fuglede's modulus of families of measures.

MS07-D-4: Perfect matchings in the random bipartite geometric graph

Xavier Pérez-Giménez, University of Nebraska - Lincoln

Abstract: We consider the standard random bipartite geometric graph process in which n red vertices and n blue vertices are placed at random on the unit d-dimensional cube and edges are added sequentially, between vertices of different colors, in increasing order of edge-length. A natural question is to ask whether the first edge in the process that results in the minimum degree being at least one coincides, with high probability, with the first edge that creates a perfect matching. While this was already known to be false when $d = 2$, as the thresholds are not even of the same order, we are able to positively answer it for d at least 3. (This is joint work with Abigail Raz.)

MS07-D-5: Large deviations of Dyson Brownian motion on the circle and multiradial SLE_{0+}

Vivian Healey, Texas State University

Abstract: Schramm-Loewner evolution (SLE) is a model of a random curve that appears in the scaling limit of many discrete models in statistical physics. Multiradial SLE, the multiple curve version of this process in the disk, is constructed by using a form of Dyson Brownian motion as the "driving function" for the process. For all variants of SLE, how rough the curves are depends on a single parameter κ. We will discuss recent work with O. Abuzaid and E. Peltola investigating the asymptotic behavior of multiradial SLE as $\kappa \to 0$. We show that this process satisfies a finite-time large deviation principle (LDP) in the Hausdorff metric with non-negative rate function, the multiradial Loewner energy. We also characterize the large-time behavior of curves with finite energy and zero energy (whose driving functions correspond to the trigonometric Calogero-Moser system). An essential step is the finite time LDP for Dyson Brownian motion on the circle.

MS08-A-1: Data assimilation and UQ in coupled geosphysical models

Elaine Spiller, Marquette University

Abstract: TBD.

MS08-A-2: TBD

Adam Larios, University of Nebraska - Lincoln

Abstract: TBD.

MS08-A-3: Data Assimilation for the Nonlinear Richards Equation

Amanda Rowley, University of Nebraska-Lincoln

Abstract: Continuous data assimilation (or AOT data assimilation), which was introduced by Azouani, Olsen, and Titi in 2014, is a computationally-efficient algorithm that has been shown analytically and computationally to recover the true solution for a wide variety of regimes exponentially fast in time, in addition to being robust with respect to noisy data, stochastic forcing, and errors in parameters. In this talk, we will apply continuous data assimilation to the Richards equation, a nonlinear system that models fluid flow in unsaturated soil. We will examine convergence of the AOT approach numerically and analytically, assuming unknown initial data and sparse-in-time-and-space observations.

MS08-A-4: Data Assimilation On Adaptive Meshes for a Coupled Kuramoto-Sivashinsky System

Jeremiah Buenger, University of Kansas

Abstract: Adaptive spatial meshing has proven invaluable for the accurate, efficient solution of time dependent partial differential equations. In a data assimilation context, the use of adaptive spatial meshes addresses several factors that are present that place increased demands on meshing. These include the relative importance and location of observations and the use of ensemble solutions. To increase the efficiency of adaptive meshes for data assimilation, robust look ahead meshes are developed that fix the same adaptive mesh for each ensemble member and over the entire time interval of the forecasts that also incorporate the observations at the next analysis time. This increases the efficiency and allows for increased vectorization of the ensemble forecasts while minimizing interpolation of solutions between different meshes. The techniques to determine these robust meshes are based upon combining metric tensors or mesh density functions that are employed to define non-uniform meshes. We illustrate the robust ensemble look ahead meshes using traveling wave solutions of a bistable reaction-diffusion equation. Finally, numerical experiments with different observation scenarios are presented for a coupled system of two 1D Kuramoto-Sivashinsky equations.

MS08-B-1: Approximations of the implicit particle filters

Xuemin Tu, University of Kansas

Abstract: The implicit particle filters (IPFs) focus the particles on the high probability regions to mitigate the particle degeneracy for high dimensional applications. In this talk, we discuss some strategies to approximate the IPFs with a bank of nonlinear Kalman filters. These approximations reduce the computation of the IPFs but still keep their efficiency. Some numerical results for the Lorenz 96 will be given..

MS08-B-2: A Hybrid Tangent Linear Model in The Generic JEDI Data Assimilation System

Christian Sampson, UCAR/JCSDA

Abstract: TBD.

MS08-B-3: From Nudging to Synchronization: The Infinite Nudging Limit

Collin Victor, Texas A&M University

Abstract: In this talk, I explore the relationship between two filtering algorithms for continuous data assimilation: the synchronization filter and the nudging filter, in the context of the 2D incompressible Navier-Stokes equations. I show that as the nudging parameter becomes very large, the nudging filter converges to the synchronization filter. I will present numerical experiments that support these theoretical findings, both in the deterministic case and when observations are polluted by stochastic noise. To address the challenges posed by observational noise, I propose a simple adaptive strategy for selecting the nudging parameter, which demonstrates improved performance over constant parameter approaches.

MS08-B-4: Decomposition of Likelihoods and Projection Techniques for Multi-Scale Data Assimilation

Erik Van Vleck, University of Kansas

Abstract: Data assimilation (DA) combines physical models and observational data to improve predictive capabilities and quantify uncertainties in future states of the physical model. Challenges for DA include highly nonlinear behavior in models and data, high dimensionality, and quantifying non-Gaussian uncertainties. In this talk we focus on projection-based decomposition of both the physical model solutions and observational data to reduce effective dimensionality. We highlight recent progress in the application of Particle Filters (PFs) to model non-Gaussian uncertainties employing reduced dimensional surrogate physical and data models. The first technique is based upon the use of POD type projections obtained from short forecasts and the second is based on the decomposition of Gaussian likelihoods using a block matrix generalized inverse result to obtain a combined PF/ensemble Kalman Filter. Numerical results show the effectiveness of the techniques

when applied to inhomogeneous Lorenz'96 type models.

MS09-A-1: Oscillation-free numerical schemes for Biot's model and their iterative coupling solution

James H Adler, Tufts University

Abstract: Single-phase flow problems on deformable porous media are modeled by means of the so-called Biot's model. Several challenges appear in the numerical solution of this model. On the one hand, it is important to choose appropriate discretization schemes that avoid the appearance of spurious oscillations in the pressure approximation when low permeabilities and/or small time steps are considered. On the other hand, the efficient solution of the large-sparse systems of equations arising after discretization also is challenging. In this work, for different finite-element discretizations of Biot's model, we propose a new stabilized scheme that provides numerical solutions that are free of non-physical oscillations, and that, at the same time, allows us to iterate the fluid and mechanic problems in a convergent way to obtain the solution of the whole coupled system. We present numerical results illustrating the robust behavior of both the stabilization and iterative solver with respect to the physical and discretization parameters of the model.

MS09-A-2: Decoupled Finite Element Method for a novel phase field model of two-phase ferrofluid flows

Youxin Yuan, Missouri University of Science and Technology

Abstract: Ferrofluid is a type of liquid attracted to the poles of a magnet and usually does not retain magnetization in the absence of an externally applied magnetic field. In this presentation, we will discuss a decoupled finite element method and numerical validations for a novel two-dimensional ferrohydrodynamics model consisting of the Navier-Stokes equation, Cahn-Hilliard equation, and magnetic field equation.

MS09-A-3: Shape Optimization with Unfitted Finite Element Methods

Shawn W. Walker, Louisiana State University

Abstract: We present a formulation of a PDE-constrained shape optimization problem that uses an unfitted finite element method (FEM). The geometry is represented (and optimized) using a level set approach and we consider objective functionals that are defined over bulk domains. For a discrete objective functional (i.e. one defined in the unfitted FEM framework), we derive the exact Frechet, shape derivative in terms of perturbing the level set function directly. In other words, no domain velocity is needed. We also show that the derivative is (essentially) the same as the shape derivative at the continuous level, so is rather easy to compute. In other words, one gains the benefits of both the optimize-then-discretize and discretize-then-optimize approaches. We illustrate the method on a simple model (geometric) problem with known exact solution, as well as shape optimization of structural designs. We also give some discussion on future work.

MS09-A-4: Dynamically regularized Lagrange multiplier schemes with energy dissipation for the incompressible Navier-Stokes equations

Kha Doan, Auburn University

Abstract: In this work, we present efficient numerical schemes based on the Lagrange multiplier approach for the Navier-Stokes equations. By introducing a dynamic equation (involving the kinetic energy, the Lagrange multiplier, and a regularization parameter), we form a new system that incorporates the energy evolution process but is still equivalent to the original equations. Such nonlinear system is then discretized in time based on the backward differentiation

formulas, resulting in a dynamically regularized Lagrange multiplier (DRLM) method. First- and second-order DRLM schemes are derived and shown to be unconditionally energy stable with respect to the original variables. The proposed schemes require only the solutions of two linear Stokes systems and a scalar quadratic equation at each time step. Moreover, with the introduction of the regularization parameter, the Lagrange multiplier can be uniquely determined from the quadratic equation, even with large time step sizes, without affecting the accuracy and stability of the numerical solutions. Extension of the DRLM method to the Cahn-Hilliard-Navier-Stokes system will also be discussed.

MS09-B-1: Addressing Numerical Challenges in Frictional Contact Simulation for Finite-Deformation Solid Mechanics

Zachary Atkins, University of Colorado Boulder

Abstract: The numerical simulation of contact phenomena in implicit, finite-deformation solid mechanics codes presents significant challenges due to the introduction of nonlinear and non-smooth operators. These complexities necessitate specialized linear and nonlinear solvers to be performant at scale. In this context, our finite element package, Ratel, distinguishes itself by employing high-order matrix-free methods, contrasting with the prevailing industry standard of low-order solvers applied to sparse assembled Jacobian matrices. Ratel capitalizes on the robust solver infrastructure provided by the Portable Extensible Toolkit for Scientific Computing (PETSc) and integrates the flexible matrix-free library libCEED, enabling highly scalable performance across both CPU and GPU architectures. Ratel supports level-set based frictional contact, which can be enforced by either Nitsche's method or a penalty method. This talk will elucidate approaches to several numerical challenges associated with these contact formulations, particularly for high-order and matrix-free methods. These challenges include the computation of material stresses on contact surfaces, the solution of the asymmetric, indefinite, and/or poorly conditioned Jacobian matrices, and the numerical instability and slow nonlinear solver convergence behavior due to non-smooth friction models.

MS09-B-2: Finite Element Exterior Calculus for Hamiltonian PDEs

Ari Stern, Washington University in St. Louis

Abstract: We consider the application of finite element exterior calculus (FEEC) methods to a class of canonical Hamiltonian PDE systems involving differential forms. Solutions to these systems satisfy a local multisymplectic conservation law, which generalizes the more familiar symplectic conservation law for Hamiltonian systems of ODEs, and which is connected with physically-important reciprocity phenomena, such as Lorentz reciprocity in electromagnetics. We characterize hybrid FEEC methods whose numerical traces satisfy a version of the multisymplectic conservation law, and we apply this characterization to several specific classes of FEEC methods, including conforming Arnold–Falk–Winther-type methods and various hybridizable discontinuous Galerkin (HDG) methods. Interestingly, the HDG-type and other nonconforming methods are shown, in general, to be multisymplectic in a stronger sense than the conforming FEEC methods. This substantially generalizes previous work of McLachlan and Stern [Found. Comput. Math., 20 (2020), pp. 35–69] on the more restricted class of canonical Hamiltonian PDEs in the de Donder–Weyl grad-div form. Joint work with Enrico Zampa.

MS09-B-3: A practical error indicator for TraceFEM discretizations of material interfaces

Vladimir Yushutin, University of Tennessee, Knoxville
Abstract: Abstract: Trace finite element method features approximations of interfaces and material fields on them using an unfitted, shape-regular bulk mesh in the embedding space. For equations posed on a surface, we propose a residual-based error indicator that avoids the integration of 'jumps' along implicit intersections of the surface with faces of background cells by replacing it with the integration over faces themselves. For the prototypical Laplace–Beltrami problem, we provide a posteriori error estimates, establishing the reliability of the error indicator for the Q_1 and Q_2 elements assuming that either the normal-gradient volume or gradient-jump face stabilization is involved in the stabilized TraceFEM. In numerical experiments on low- regularity test cases, we assess efficiency of the error indicator within the adaptive TraceFEM framework thus demonstrating its robustness.

MS09-C-1: Solving Navier-Stokes Equations with Stationary and Moving Interfaces on Unfitted Meshes

Xu Zhang, Oklahoma State University
Abstract: We present a high-order immersed finite element (IFE) method for solving the two-phase Navier-Stokes equations on interface-unfitted meshes. We have developed an immersed P2-P1 Taylor-Hood finite element space for spatial discretization. The method incorporates an enhanced partially penalized IFE approach, applying penalization to both interface edges and the interface itself. For temporal discretization, we employ the theta-scheme and backward difference differentiation formulas. Thanks to the isomorphism of the IFE spaces with the standard finite element spaces, the new method allows for efficient updates of global matrices, significantly reducing overall computational costs. Extensive numerical experiments demonstrate that the proposed method achieves optimal-order convergence for both velocity and pressure in both stationary and moving interface scenarios.

MS09-C-2: Continuous data assimilation and long-time accuracy in a FEM for the Cahn-Hillard equation

Amanda E. Diegel, Mississippi State University
Abstract: We propose a numerical approximation method for the Cahn-Hilliard equation that incorporates continuous data assimilation in order to achieve long-time accuracy and stability for arbitrarily inaccurate initial conditions provided enough data measurements are incorporated into the simulation. We conclude with a demonstration of the effectiveness of our method via several numerical experiments.

MS09-C-3: An HDG/DG method for fractured porous media

Jeonghun Lee, Baylor University
Abstract: In this work we consider an HDG/DG coupled method for porous media with fractures. The fractures are conductive, so exchange of fluids between fractures and their surrounding materials is given as interface conditions. We consider a discretization using HDG (LDG-H) methods for pore matrix domain and IPDG methods for the fracture domain. Existence/uniqueness of solutions and error estimates will be discussed.

MS09-D-1: Thermodynamically consistent hydrodynamic phase-field computational modeling for fluid-structure interaction with moving contact lines

Jia Zhao, Binghamton University (SUNY)
Abstract: In this talk, we will present a novel computational modeling approach to investigate the fluid-structure interactions with moving contact lines. By embracing the generalized Onsager principle, a coupled hydrodynamics and phase field system is introduced that can describe the fluid-structure

interactions with moving contact lines in a thermodynamically consistent manner. The resulting partial differential equation (PDE) model consists of the Navier-Stokes equation and a nonlinear Allen-Cahn type equation. Volume conservation is enforced through an additional penalty term. A fully-discrete structure-preserving numerical scheme is proposed by combining several techniques to solve this coupled PDE system effectively and accurately.

MS09-D-2: TBD
Yiming Ren, The University of Alabama
Abstract: The geometric multigrid method is the only effective fast Poisson solver for elliptic equations with variable coefficients, because the commonly used fast Fourier transform (FFT) Poisson solver is inapplicable to non-constant coefficients problems. Several second order multigrid methods have been successfully developed in the literature for solving elliptic interface problems with complex interfaces and discontinuous solutions. Nevertheless, the generalization of the underlying second order interface treatments to fourth order is significantly nontrivial, especially when such treatments are required in different levels of multigrids. In this work, a fourth order multigrid method will be introduced in the framework of the augmented matched interface and boundary (AMIB) method for elliptic interface problems with variable coefficients in two and three dimensions. Based on a Cartesian mesh, the standard fourth-order finite differences are employed to approximate the first and second derivatives involved in the Laplacian with variable coefficients. Near the interface, a fourth-order ray-casting matched interface and boundary (MIB) scheme is generalized to variable coefficient problems to enforce interface jump conditions in the finite difference discretization. The augmented formulation of the AMIB allows us to decouple the interface treatments from the inversion of the Laplacian discretization matrix, so that one essentially solves an elliptic subproblem without interfaces. A fourth order geometric multigrid method is introduced to solve this subproblem with a Dirichlet boundary condition, where fourth order one-sided finite difference approximations are considered near the boundary in all grid levels. The proposed multigrid method significantly enhances the computational efficiency in solving variable coefficient problems, while achieves a fourth-order accuracy in accommodating complex interfaces and discontinuous solutions.

MS09-D-3: An optimization-based coupling of reduced order models with efficient reduced adjoint basis generation approach
Paul Kuberry, Sandia National Laboratories
Abstract: Partitioned coupling techniques invoking use of a ROM in one or more subdomains allows for increased efficiency, but also presents a challenge with respect to generating a reduced basis for the adjoint systems involved in optimization-based coupling (OBC). We explore optimization-based coupling of ROMs and full order models, applying it to coupled advection-diffusion equations and present a novel snapshot collection technique. We present numerical studies demonstrating the accuracy of the approach along with an investigation related to selecting a reduced order basis for the adjoint systems.

MS10-A-1: 3D Generative Adversarial Networks for Precision Synthesis of Pancreatic Cancer Tumor Images
Huijing Du, University of Nebraska-Lincoln
Abstract: Pancreatic ductal adenocarcinoma (PDAC) has the highest fatality rate among solid malignancies, emphasizing the need for early detection. Advances in medical imaging and deep learning, particularly convolutional neural networks (CNNs), offer

potential solutions, but progress is limited by a lack of clinical data. This study introduces 3DGAUnet, a model using generative adversarial networks (GANs) to generate realistic 3D CT images of PDAC, maintaining contextual information between slices for improved accuracy. The model integrates a 3D U-Net architecture to enhance learning of PDAC tumor and tissue characteristics, showing promise in overcoming data scarcity and improving PDAC detection.

MS10-A-2:A Deep Learning Model for Predicting Biophysical Properties Using Topological and Electrostatic Features

Md Abu Talha, Southern Methodist University

Abstract: In this project, we introduce a deep-learning neural network (DNN) based biophysics model to predict protein properties using multi-scale and uniform topological and electrostatic features derived from protein structural information and molecular mechanics force fields. The topological features are generated using element-specific persistent homology (ESPH), while the electrostatic features are efficiently computed with a Cartesian treecode. These features maintain uniformity across proteins of varying sizes, enabling the use of a widely available protein structure database for training the network. Furthermore, the multi-scale nature of these features allows users to balance between resolution and computational cost. Our machine learning simulations, conducted on over 20,000 protein structures, demonstrate the effectiveness and accuracy of these features in representing protein structures and force fields for predicting their biophysical properties, such as electrostatic solvation energy. Tests conducted using only topological or electrostatic features, as well as a combination of both, reveal that optimal performance is achieved when both feature types are utilized. This model shows significant potential as a versatile tool for predicting bio- physical properties and functions of a wide range of biomolecules, using data from both theoretical computations and experimental observations.

MS10-A-3: Integrating differential operators and deep learning in biology application

Jiahui Chen, University of Arkansas

Abstract: This talk will discuss differential operators and deep learing in biology applications and focus on the recent developments. The multiscale analysis of graph neural networks and the de Rham-Hodge theory provide a unified paradigm for the evolving manifolds constructed from filtration, which induces a family of evolutionary complexes. While the present evolutionary de Rham-Hodge method can be easily applied to close manifolds, the emphasis is given to more challenging compact manifolds with 2-manifold boundaries, which require appropriate analysis and treatment of boundary conditions on differential forms to maintain proper topological properties. Meanwhile, we will discuss the multiscale graph neural network in the modeling of biomolecules.

MS10-A-4: A priori error analysis and greedy training algorithms for neural networks solving PDEs

Qingguo Hong, Missouri University of Science and Technology

Abstract: We provide an a priori error analysis for methods solving PDEs using neural networks. We show that the resulting constrained optimization problem can be efficiently solved using greedy algorithms, which replaces stochastic gradient descent. Following this, we show that the error arising from discretizing the energy integrals is bounded both in the deterministic case, i.e. when using numerical quadrature, and also in the stochastic case, i.e. when sampling points to approximate the integrals. This innovative greedy algorithm is tested on several benchmark examples to confirm its efficiency and robustness.

MS11-A-1: Efficient Energy-Stable Numerical Schemes for Cahn-Hilliard Equations with Dynamic Boundary Conditions

Xinyu Liu, Ohio State University

Abstract: This talk introduces a unified framework for developing efficient, energy-stable numerical schemes for the Cahn-Hilliard equation with Allen-Cahn and Cahn-Hilliard type dynamic boundary conditions. We present a novel second-order, linear scheme based on the multiple scalar auxiliary variable (MSAV) approach, which is unconditionally energy stable and mass-conserving. We address the challenge of efficiently solving the resulting linear system that couples bulk and boundary unknowns, proposing algorithms that effectively decouple these unknowns. For different domain types, we employ specialized methods: a Fourier-Legendre spectral method for domains with one non-periodic direction, and a matrix diagonalization approach for fully non-periodic rectangular domains. Numerical experiments validate the scheme's accuracy and stability, demonstrating its effectiveness in simulating various phenomena like coarsening, droplet evolution, and spinodal decomposition. The results highlight the distinct impacts of different boundary conditions on phase separation dynamics, particularly at domain boundaries.

MS11-A-2: Advances in Front Tracking Simulations of the Richtmyer-Meshkov Instability

Ryan Holley, University of Arkansas

Abstract: Turbulent mixing due to hydrodynamic instabilities occurs in a broad spectrum of engineering, astrophysical and geophysical applications. Theory, experiment, and numerical simulation help us to understand the dynamics of interface instabilities between two fluids. We present an increasingly accurate and robust front tracking method for the numerical simulations of shock induced turbulent mixing known as Richtmyer-Meshkov Instability (RMI). Front tracking is an adaptive computational method, where the interface instability is explicitly represented as lower dimensional manifolds moving through a rectangular grid. All the cell-center states (density, velocity and pressure) are updated using higher order weighted essentially non-oscillatory (WENO) scheme. The strength of this method is shown through validation studies where our simulations are compared with the single-mode shock-tube experiments of Collins and Jacobs 2002.

MS11-A-3: Constraint Optimization-based High-order Accurate Bound-preserving Limiter for time-dependent PDEs

Chen Liu, University of Arkansas

Abstract: For time-dependent partial differential equations, the numerical schemes can be rendered bound-preserving without losing conservation and accuracy, by a postprocessing procedure of solving a constrained minimization at each time step. Such constrained optimization can be formulated as a non-smooth convex minimization problem, which can be efficiently solved by the Douglas-Rachford method if using the optimal algorithm parameters. By analyzing the asymptotic linear convergence rate of the generalized Douglas-Rachford splitting method, optimal algorithm parameters can be approximately expressed as a simple function of the numerical solutions. Significant practical advantages of our approach include high accuracy, efficiency, and ease of implementation. Numerical tests suggest that our postprocessing approach of the discrete solution is well-suited for large-scale simulations.

MS11-A-4: High-order exponential time differencing multi-resolution alternative fi-

nite difference WENO methods for nonlinear degenerate parabolic equations
Ziyao Xu, University of Notre Dame
Abstract: In this work, we focus on the finite difference approximation of nonlinear degenerate parabolic equations, a special class of parabolic equations where the viscous term vanishes in certain regions. This vanishing gives rise to additional challenges in capturing sharp fronts, beyond the restrictive CFL conditions commonly encountered with explicit time discretization in parabolic equations. To resolve the sharp front, we adopt the high-order multi-resolution alternative finite difference WENO (A-WENO) methods for the spatial discretization. To alleviate the time step restriction from the nonlinear stiff diffusion terms, we employ the exponential time differencing Runge-Kutta (ETD-RK) methods, a class of efficient and accurate exponential integrators, for the time discretization. However, for highly nonlinear spatial discretizations such as high-order WENO schemes, it is a challenging problem how to efficiently form the linear stiff part in applying the exponential integrators, since direct computation of a Jacobian matrix for high-order WENO discretizations of the nonlinear diffusion terms is very complicated and expensive. Here we propose a novel and effective approach of replacing the exact Jacobian of high-order multi-resolution A-WENO scheme with that of the corresponding high-order linear scheme in the ETD-RK time marching, based on the fact that in smooth regions the nonlinear weights closely approximate the optimal linear weights, while in non-smooth regions the stiff diffusion degenerates. The algorithm is described in detail, and numerous numerical experiments are conducted to demonstrate the effectiveness of such a treatment and the good performance of our method. The stiffness of the nonlinear parabolic partial differential equations (PDEs) is resolved well, and large time-step size computations are achieved.

MS11-B-1: Cell-average-based Neural Network Method for time-dependent Problems
Jue Yan, Iowa State University
Abstract: In this talk, we introduce the newly developed cell-average-based neural network (CANN). The method is based on the integral or weak formulation of the partial differential equation and is motivated by finite volume schemes. A "stencil" concept is introduced, and the network structure is designed to align with the conventional one-step method. The well-trained network parameters are identified as the scheme coefficients of an explicit one-step method. Unlike conventional numerical methods, the CANN method is found to be relieved from small time step CFL restrictions. A large time step can be applied to evolve the solution forward in time explicitly. The CANN method exhibits several unusual and remarkable properties. The method allows for sharp evolution of contact discontinuity and shocks with almost zero numerical diffusion. The method can be generalized to solve out-of-distribution initial value problems accurately.

MS11-B-2: Local-variation based ENO type polynomial reconstruction for high order finite volume methods
Yuan Liu, Wichita State University
Abstract: In this talk, we present a novel ENO type polynomial reconstruction for high order finite volume methods solving hyperbolic conservation laws. Adaptive stencil choosing process was adopted in the traditional ENO method based on calculation and comparison of local divided differences of cell average values for high order finite volume methods. The computed divided differences measure the relative smoothness of each candidate stencil. One can then decide which is the smoothest stencil to choose for polynomial reconstruc-

tion. The new stencil selection strategy proposed here will rely on an approximate measurement of local variation computed from the local cell average values and the corresponding reconstructed polynomial values at interfaces. Numerical results are presented to demonstrate the non-oscillatory effect of the new stencil selection strategy.

MS11-B-3: The Runge-Kutta discontinuous Galerkin method with compact stencils for hyperbolic conservation laws

Zheng Sun, The University of Alabama

Abstract: In this talk, we present a new type of Runge-Kutta (RK) discontinuous Galerkin (DG) method for solving hyperbolic conservation laws. Compared with the original RKDG method, the new method features improved compactness and allows simple boundary treatment. The key idea is to hybridize two different spatial operators in an explicit RK scheme, utilizing local projected derivatives for inner RK stages and the usual DG spatial discretization for the final stage only. Limiters are applied only at the final stage for the control of spurious oscillations. We also explore the connections between our method and Lax–Wendroff DG schemes and ADER-DG schemes. Numerical examples are given to confirm that the new RKDG method is as accurate as the original RKDG method, while being more compact, for problems including two-dimensional Euler equations for compressible gas dynamics.

MS11-B-4: HRIDG schemes and their application to kinetic Vlasov systems

James Rossmanith, Iowa State University

Abstract: Plasma, often called the fourth state of matter after solids, liquids, and gases, is a collection of electrically charged and neutral particles interacting through various short-, medium-, and long-range forces. In the collisionless approximation, which is relevant in many applications, including space-weather and laser wakefield accelerators, the plasma can be modeled by a kinetic Vlasov system. In this work, we develop a novel discontinuous Galerkin (DG) finite element method, which we call the hierarchical regionally implicit DG (HRIDG) scheme; the terms hierarchical and regionally implicit refer to specific design principles in how we time-advance the numerical solution. We demonstrate that the HRIDG scheme is more efficient for various transport problems than standard explicit DG approaches, including kinetic Vlasov systems. We test the resulting methods on standard single and multi-species Vlasov-Poisson problems, including the Landau damping, two-stream instability, and ion-acoustic shock problems. This is joint work with Yifan Hu (Iowa State University).

MS12-A-1: An Adaptive Safeguarded Newton-Anderson Algorithm for Solving Nonlinear Problems Near Singular Points.

Matt Dallas, University of Dallas

Abstract: We present an adaptive safeguarding scheme with a tunable parameter that one can use in tandem with Anderson acceleration to improve the performance of Newton's method when solving problems at or near singular points. The key features of this scheme are that it converges locally for singular problems, and it can detect nonsingular problems automatically, in which case the Newton-Anderson iterates are scaled towards a standard Newton step. The result is a flexible algorithm that performs well for singular and nonsingular problems, and can recover convergence from both standard Newton and Newton-Anderson with the right parameter choice. Efficiently computing accurate solutions for singular problems is of continued interest due to their prevalence in parameter-dependent models, where any bifurcation point is necessarily a singular point. We demonstrate our methods on two such models from the theory of

incompressible flow systems: flow in a channel and Rayleigh Bénard convection.

MS12-A-2: Numerical Analysis of a Stabilized Hyperbolic Equation Inspired from Models of Bio-Polymerization

Jorge Reyes, Virginia Tech

Abstract: This talk focuses on a stabilization method for first order hyperbolic differential equations applied to DNA transcription modeling. It is known that the usual unstabilized finite element method contains spurious oscillations for non-smooth solutions. To stabilize the finite element method we consider adding to the first order hyperbolic differential system a stabilization term in space as well as time filtering. Numerical analysis of the stabilized finite element algorithms and computations describing a few biological settings will be presented.

MS12-A-3: A Second-order Correction Method for Loosely Coupled Discretizations Applied to Parabolic-parabolic Interface Problems.

Sijing Liu, Worcester Polytechnic Institute

Abstract: We consider a parabolic-parabolic interface problem and construct a loosely coupled prediction-correction scheme based on the Robin-Robin splitting method analyzed in [J. Numer. Math., 31(1):59–77, 2023]. We show that the errors of the correction step converge at $O(\delta t^2)$, under suitable convergence rate assumptions on the discrete time derivative of the prediction step, where δt stands for the time-step length. Numerical results are shown to support our analysis and the assumptions.

MS12-A-4: On the stability and convergence of finite element solutions to the Gay Lussac incompressible natural convection model, Nevada National Security Site

Sean Breckling, Nevada National Security Site

Abstract: Herein we present a finite element study of the simplified Gay-Lussac equations; an incompressible natural convection model that provides a more flexible framework for balancing density fluctuations between buoyancy and convective forces. Such models are available when temperature fluctuations are beyond what is considered acceptable under the more-common Boussinesq model. Herein we provide a stability and convergence analyses, and discuss the benefits of this approach compared to traditional low-Mach number compressible models.

MS12-B-1: Computing of Eigenpairs of the Magnetic Schrodinger Operator.

Li Zhu, Portland State University

Abstract: The Magnetic Schrödinger operator,

$$H(A, V) = (-i\nabla - A) \cdot (-i\nabla - A) + V,$$

is used to model the motion of a charged particle in an electromagnetic field. We study the eigenvalue problem associated with $H(A, V)$ and leverage the property of gauge invariance to select a ""canonical"" magnetic potential from the equivalence class. This choice enhances computational efficiency and accuracy. We will present various numerical simulation results using the finite element method to demonstrate these improvements."

MS12-B-2: On The Sharpness Of A Korn's Inequality For Piecewise H^1 Space And Its Applications.

Qingguo Hong, Missouri University of Science and Technology

Abstract: In this talk, we investigate the sharpness of a Korn's inequality for piecewise H^1 space and its applications. We first revisit a Korn's inequality for the piecewise H^1 space based on general polygonal or polyhedral decompositions of the domain. We express the Korn's inequality with minimal jump terms. Then we prove that such minimal jump conditions are sharp for achiev- ing the Korn's inequality. The sharpness of the Korn's inequality and explicitly

given minimal conditions can be used to test whether any given finite element spaces satisfy Korn's inequality, immediately as well as to build or modify nonconforming finite elements for Korn's inequality to hold.

MS12-B-3: Regularized Reduced Order Models for Turbulent Flows and Parameter Scalings.

Ping-Hsuan Tsai, Virginia Tech

Abstract: Regularized reduced order models (Reg-ROMs) are stabilization strategies that leverage spatial filtering to alleviate the spurious numerical oscillations generally displayed by the classical Galerkin ROM (G-ROM) in under-resolved numerical simulations of turbulent flows. In this talk, we present three Reg-ROMs, that is, the Leray ROM (L-ROM), the evolve-filter-relax ROM (EFR-ROM), and a new Reg-ROM, the time-relaxation ROM (TR-ROM). We first show the promise of the Reg-ROMs in several flow problems. Next, with the turbulent channel flows, we demonstrate that the TR-ROM is the most accurate model among the three to capture the Reynolds shear stress and turbulence spectrum. In addition, we demonstrate the Reg-ROM's predictive capabilities through the sensitivity study of the optimal parameters. Lastly, we prove and illustrate numerical parameter scalings for the TR-ROM.

MS12-B-4: Continuous Data Assimilation and Long-time Accuracy of a FEM for the Barotropic Vorticity Equation.

Amanda E. Diegel, Mississippi State Univeristy

Abstract: We consider continuous data assimilation applied to a finite element spatial discretization and backward difference temporal discretization of the barotropic vorticity model of geophysical flow. We prove that with sufficient measurement data and properly chosen nudging parameter (guided by our analysis), the proposed algorithm achieves optimal long-time accuracy for any initial condition. While our analysis requires nudging of both the streamfunction and vorticity, our numerical tests indicate that nudging only the streamfunction can be sufficient."

MS12-C-1: High-order Interface Tracking Methods for Simulating Mean Curcature Flows in Two Dimensions.

Linjie Ying, University of Nevada, Las Vegas

Abstract: Based on the MARS (mapping and adjusting regular semi-analytic sets) framework for interface tracking [Zhang and Fogelson, SIAM J. Numer. Anal. 54 (2016): 530] [Q. Zhang, SIAM J. Sci. Comput. 40 (2018): A3755-A3788] [Zhang and Li, Math. Comput. 89 (2020): 2333], we propose MARS-MCF2D, a novel numerical method called the method, for simulating mean curvature flows in two dimensions. We represent the interface by cubic or quintic splines and add/remove interface markers at each time step to maintain a roughly uniform distribution of chordal lengths. We approximate spatial derivative with finite difference formulas and solve the resulting nonlinear system of ordinary differential equations (ODEs) by explicit, semi-implicit, and implicit Runge–Kutta methods. As such, the semi-implicit and implicit MARS-MCF2D methods are unconditionally stable. We analyze our method under the MARS framework to show that the order of accuracy of MARS-MCF2D can be 2, 4, or 6. Results of numerical experiments confirm the analysis, show the effectiveness of MARS-MCF2D in maintaining the regularity of interface markers, and demonstrate its superior accuracy over other existing methods. The utility of MARS-MCF2D is also illustrated by solving problems of image segmentation. The MARS strategy of adding and removing interface markers may also be useful for simulating other geometric flows.

MS12-C-2: Stabilized numerical simulations for the transport equation in a fluid.

Seulip Lee, Tufts University
Abstract: This talk presents stabilized numerical simulations for the transport equation in a fluid while applying polygonal discretization. A convection-dominated problem explains convective and molecular transport along a given fluid velocity with a small diffusive effect, where classical numerical methods may yield spurious oscillations on numerical solutions and fail to provide accurate simulations. The edge-averaged finite element (EAFE) scheme is a stable discretization for the convection-dominated problem, and its stability is mathematically verified by the discrete maximum principle (DMP). We aim to generalize the edge-averaged stabilization to a polygonal discretization called the virtual element method. Hence, the edge-averaged virtual element (EAVE) methods produce stable and accurate numerical simulations on polygonal meshes and have less computational complexity than other stabilized schemes on polygons. We also show numerical experiments with numerical solutions with sharp boundary layers.

MS12-C-3: Stabilized SAV ensemble algorithms for parameterized flow problems.
Nan Jiang, University of Florida
Abstract: Computing a flow system a number of times with different samples of flow parameters is a common practice in many uncertainty quantification (UQ) applications, which can be prohibitively expensive for complex nonlinear flow problems. This talk will present stabilized, scalar auxiliary variable (SAV) ensemble algorithms for fast computation of the Navier-Stokes flow ensembles. The algorithms are based on the ensemble timestepping idea which makes use of a quantity called ensemble mean to construct a common coefficient matrix for all realizations at the same time step after spatial discretization, in which case efficient block solvers, e.g., block GMRES, can be used to significantly reduce both storage and computational time. The adoption of the SAV approach that treats the nonlinear term explicitly results in a constant shared coefficient matrix among all realizations at different time steps, which further cuts down the computational cost, yielding a highly efficient ensemble algorithm for simulating nonlinear flow ensembles with provable long time stability without any timestep conditions. We also use a linear stabilization to increase the accuracy of the SAV algorithms. Numerical experiments will be presented to show the efficiency of the ensemble algorithms and the effectiveness of the stabilization for increasing accuracy and stability.

MS12-C-4: A Stochastic Precipitating Quasi-Geostrophic Model.
Changhong Mou, Purdue University
Abstract: Efficient and effective modeling of complex systems, incorporating cloud physics and precipitation, is essential for accurate climate modeling and forecasting. However, simulating these systems is computationally demanding since microphysics has crucial contributions to the dynamics of moisture and precipitation. In this paper, appropriate stochastic models are developed for the phase-transition dynamics of water, focusing on the precipitating quasi-geostrophic (PQG) model as a prototype. By treating the moisture, phase transitions, and latent heat release as integral components of the system, the PQG model constitutes a set of partial differential equations (PDEs) that involve Heaviside nonlinearities due to phase changes of water. Despite systematically characterizing the precipitation physics, expensive iterative algorithms are needed to find a PDE inversion at each numerical integration time step. As a crucial step toward building an effective stochastic model, a computationally efficient Markov jump process is designed to randomly simulate transitions between saturated and unsaturated states that avoids using the expensive

iterative solver. The transition rates, which are deterministic, are derived from the physical fields, guaranteeing physical and statistical consistency with nature. Furthermore, to maintain the consistent spatial pattern of precipitation, the stochastic model incorporates an adaptive parameterization that automatically adjusts the transitions based on spatial information. Numerical tests show the stochastic model retains critical properties of the original PQG system while significantly reducing computational demands. It accurately captures observed precipitation patterns, including the spatial distribution and temporal variability of rainfall, alongside reproducing essential dynamic features such as potential vorticity fields and zonal mean flows.

MS13-A-1: Finite element methods for thermo-poroelasticity with Brinkman flows
Jeonghun Lee, Baylor University
Abstract: Thermo-poroelasticity equations are popular in modelling of geothermal energy extraction. In this work we consider finite element discretizations of a coupled thermo-poroelasticity model with Brinkman flows in porous media. We will discuss stable finite element discretizations and error analysis of the problem.

MS13-A-2: BDDC algorithms for the Brinkman problems with HDG discretization
Xuemin Tu, University of Kansas
Abstract: TBD

MS13-A-3: Convergence analysis of GMRES with inexact block triangular preconditioning for saddle point systems with application to weak Galerkin finite element approximation of Stokes flow
Weizhang Huang, University of Kansas
Abstract: A study is presented for the convergence of the generalized minimal residual method (GMRES) for nondiagonalizable saddle point systems resulting from inexact block triangular Schur complement preconditioning. It is shown that the convergence of GMRES for the preconditioned system is primarily determined by the Schur complement and its approximation. As an example of application of this theoretical finding, the weak Galerkin finite element approximation of Stokes flow problems is studied. For this approximation, the resulting saddle point system is singular and inconsistent. A commonly used regularization strategy that specifies the value of the pressure at a specific location is employed. The nonsingularity of the regularized system is proved rigorously and bounds are obtained for the eigenvalues of the preconditioned system and for the residual of GMRES. These bounds show that the convergence factor of GMRES is almost independent of the viscosity parameter and mesh size while the number of GMRES iterations required to reach a prescribed level of residual depends on the parameters only logarithmically. Numerical results in two and three dimensions are presented to verify the theoretical findings.

MS13-A-4: Learning domain-agnostic Green's function for variable coefficient elliptic PDEs
Pawan Singh Negi (advised by Shuwang Li), Illinois Institute of Technology
Abstract: Many physical phenomena, including multiphase flows, can be modeled using variable-coefficient elliptic partial differential equations (PDEs). The Green's function, also known as the fundamental solution, is essential for expressing solutions to these problems through boundary or interface jump conditions. However, when the coefficients of the PDE defined in the domain are non-constant, the Green's function is typically unknown, presenting a significant challenge to understand and compute the solution. In this talk, we introduce a novel approach to learn the domain-agnostic Green's function for variable-coefficient el-

liptic PDEs, in particular formulated as interface problems. We employ a radial basis function-based neural network to evaluate the Green's function, scaled by the coefficients of the PDEs. Our method also incorporates an innovative correction technique to mitigate substantial errors caused by singularities at boundaries. To validate our approach, we apply it to learn the Green's functions for the Laplace and Helmholtz equations. Additionally, we demonstrate the accuracy and reliability of the learned Green's functions for variable-coefficient PDEs by solving boundary value and interface problems, underscoring the effectiveness of our method.

MS13-B-1: Efficient uncertainty quantification for scientific machine learning via Ensemble Kalman Inversion
Xueyu Zhu, University of Iowa
Abstract: Uncertainty quantification (UQ) for Physics Informed Neural Networks (B-PINNs) have gained significant attention for PDE-based inverse problems. Existing UQ approaches are either computationally expensive for high-dimensional posterior inference or provide unsatisfactory uncertainty estimates. In this paper, we present a new efficient inference algorithm for B-PINNs that uses Ensemble Kalman Inversion (EKI). We find that our proposed method can achieve inference results with informative uncertainty estimates comparable to Hamiltonian Monte Carlo (HMC)-based B-PINNs with a much reduced computational cost. Besides, we shall also discuss the extension of the proposed method to operator learning, such as DeepONets.

MS13-B-2: A grid-overlay finite difference (GoFD) method for the fractional Laplacian on arbitrary bounded domains
Jinye Shen, Southwestern University of Finance and Economics
Abstract: In this talk, we introduce a grid-overlay finite difference method (GoFD) which is proposed for the numerical solution of homogeneous and inhomogeneous Dirichlet boundary value problems of the fractional Laplacian on arbitrary bounded domains and shown to have advantages of both finite difference and finite element methods, including its efficient implementation through the fast Fourier transform and ability to work for complex domains and with mesh adaptation. Moreover, we also present a meshfree GoFD for homogenous Dirichlet boundary value problems of the fractional Laplacian on arbitrary bounded domains.

MS13-B-3: Asymptotic methods for some fractional partial differential equations
Songting Luo, Iowa State University
Abstract: The main difficulty for solving the wave equation is dispersion errors, which is commonly known as pollution effect. We will present high-order method for solving the wave equation numerically, aiming to balance efficiency and accuracy, where high-order implicit time integration and Fourier pesudospectral approximations will be used. At each time, a modified Helmholtz equation needs to be solved, for which we will use an iterative functional evaluation method. Numerical experiments will be presented to demonstrate the method.

MS13-B-4: Asymptotic methods for some fractional partial differential equations
Young Ju Lee, Texas State University
Abstract: TBD

MS13-C-1: Pressure-robust WG solvers for Stokes flow based on a lifting operator
Zhuoran Wang, University of Kansas
Abstract: This talk presents novel finite element solvers for Stokes flow problems that are pressure-robust through the use of a lifting operator. Weak Galerkin (WG) finite element schemes are developed for the Stokes flow on quadrilateral and hexahedral

meshes, utilizing local Arbogast-Correa or Arbogast-Tao spaces for discrete weak gradients. With the lifting operator, the velocity error is independent of pressure and the pressure error is independent of viscosity. The robustness of the solver is supported theoretically and numerically. This is a joint work with Dr. Jiangguo Liu and Dr. Ruishu Wang.

MS13-C-2: Novel Numerical Solvers for Transport in Porous Media with Mass Conservation and Positivity Preserving

Jiangguo 'James' Liu, Colorado State University

Abstract: This talk presents two novel numerical solvers for transport in porous media with focus on preserving physical properties such as mass conservation and solution positivity. Quadrilateral meshes are adopted due to their flexibility in accommodation of domain geometry. A weak Galerkin (WG) finite element method with linear shape functions is utilized to solve the Darcy equation. Then the mapped bilinear finite volumes on the same mesh are used to solve the time-dependent convection-diffusion equation. Positivity correction applied to both diffusive and convective fluxes is an important technique for ensuring positivity of numerical solutions. Numerical examples are tested to demonstrate robustness and physical property preserving of these numerical schemes while handling convection-dominance and anisotropy/heterogeneity of permeability and diffusion.

MS13-C-3: Efficient High-Order Methods for Wave Propagation

Ian Morgan, Iowa State University

Abstract: Numerically solving the wave equation is challenging, especially when high wave numbers are present due to dispersion errors. Conventional methods need a more refined mesh to maintain accuracy, which often leads to large linear systems that are prohibitively expensive to solve. As a result, higher-order methods are required. In our work, we utilize implicit methods like the backward differentiation formulae combined with Fourier pseudospectral spatial approximations for the wave equation, which necessitates the solution of a modified Helmholtz equation at every timestep. We then propose two solvers for the modified Helmholtz equation, one based on the well-known generalized minimal residual method, which shows promising efficiency for dealing with high wavenumbers. Additionally, we introduce an alternative strategy that translates the inverse modified Helmholtz operator into a functional, which can then be efficiently solved using Gaussian quadrature rules. These high-order methods are designed to effectively manage dispersion errors without compromising efficiency.

MS13-C-4: Front-tracking based Rayleigh-Taylor Instability simulations with adaptive mesh refinement

James Burton, University of Arkansas

Abstract: Front-tracking is a numerical method that achieves high fidelity simulations by explicitly tracking the interface between fluids as a hypersurface moving through a grid to prevent unwanted mixing, which comes at a computational cost. We can lower that cost by using adaptive mesh refinement to have high resolution only at areas of interest, and lower resolution elsewhere. To this end, the adaptive mesh refinement software AMReX is applied to the front-tracking software package FronTier. AMReX is a software framework for massively parallel, block-structured AMR applications and is maintained by Lawrence Berkely National Laboratory. FronTier is a front-tracking software package that has been developed for over 3 decades and has been used in validation and verification of turbulence mixing due to hydrodynamic instabilities. Currently the software is being

tested in 2D simulations of the Rayleigh Taylor Instability (RTI).

MS14-A-1: Reconstruction of Extended Regions in EIT with a Generalized Robin Transmission Condition

Govanni Granados, University of North Carolina at Chapel Hill

Abstract: In this talk, we will discuss an application of the Regularized Factorization Method (RegFM) to a problem coming from Electrical Impedance Tomography (EIT) with a second-order Robin condition. This method falls under the category of qualitative methods for inverse problems. Qualitative methods are used in non-destructive testing where physical measurements on the surface of an object are used to infer the interior structure. The Robin condition on this boundary asymptotically models delamination. We assume that the Dirichlet-to-Neumann (DtN) mapping is given on the exterior boundary and will be used to recover an unknown, extended region. Using Cauchy data as physical measurements, we can determine if all of the coefficients from the Robin condition are real- or complex-valued. We study these two cases separately and show how RegFM can be used to detect whether delamination has occurred and recover the damaged subregion. Numerical examples will be presented for both cases in two dimensions in the unit circle.

MS14-A-2: A direct reconstruction method for radiating sources in Maxwell's equations with single-frequency data

Thu Thi Anh Le, University of Wisconsin-Madison

Abstract: This work presents a fast and robust numerical method for reconstructing point-like sources in the time-harmonic Maxwell's equations given Cauchy data at a fixed frequency. This is an electromagnetic inverse source problem with broad applications, such as antenna synthesis and design, medical imaging, and pollution source tracing. We introduce new imaging functions and computational algorithms to determine the number of point sources, their locations, and associated moment vectors, even when these vectors have notably different magnitudes. The number of sources and locations are estimated using significant peaks of the imaging functions and the moment vectors are computed via explicitly simple formulas. The theoretical analysis and stability of the imaging functions are investigated, where the main challenge lies in analyzing the behavior of the dot products between the columns of the imaginary part of the Green's tensor and the unknown moment vectors. Additionally, we extend our method to reconstruct small-volume sources using an asymptotic expansion of their radiated electric field. We provide numerical examples in three dimensions to demonstrate the performance of our method.

MS14-A-3: A discretization invariant operator learning method for inverse problems

Ke Chen, University of Delaware

Abstract: Deep neural networks (DNNs) have been a successful model across diverse machine learning tasks, increasingly capturing the interest for their potential in scientific computing. This talk delves into efficient training for PDE operator learning for solving inverse problems based on partial differential equations (PDEs). We introduce a new DNN, the pseudo-differential auto-encoder integral network (pd-IAE net), and compare its numerical performance with baseline models on several inverse problems, including optical tomography and inverse scattering. One key feature is the discretization invariance, i.e. networks trained with a fixed data structure can be applied to heterogeneous data structures without expensive re-training.

MS14-A-4: Regularized Least Squares un-

der Nonlinear Dynamics Constraints with Applications to Optimal Control in Epidemiology

Alexandra Smirnova, Georgia State University

Abstract: In recent years, advanced regularization techniques have emerged as a powerful tool aimed at stable reconstruction of infectious disease parameters that are crucial for future projections, prevention, and control. Unlike other system parameters, i.e., incubation and recovery rates, the case reporting rate and the time-dependent effective reproduction number are directly influenced by a large number of factors making it impossible to pre-estimate these parameters in any meaningful way. In this study, we propose a novel iteratively-regularized trust-region optimization algorithm, combined with a biological model for the post-vaccination stage of an outbreak, for reconstruction of disease parameters from reported epidemic data on vaccination percentages, incidence cases, and daily deaths. The innovative regularization procedure exploits (and takes full advantage of) a unique structure of the Jacobian and Hessian approximation for the nonlinear observation operator. Reconstructed parameters are employed to solve an optimal control problem intended to contain the disease by eliminating and/or delaying new cases. The proposed inversion method is thoroughly tested with synthetic and real SARS-CoV-2 Delta variant data for different regions in the United States of America from July 9, 2021, to November 25, 2021.

MS14-B-1: Learning-to-Optimize via Implicit Networks

Samy Wu Fung, Colorado School of Mines

Abstract: Learning-to-Optimize (or L2O) is an emerging approach where machine learning is used to learn an optimization algorithm. It automates the design of an optimization method based on its performance on a set of training problems. Learning optimization algorithms in an end-to-end fashion can be challenging due to their asymptotic nature. This talk discusses a class of network architectures, called implicit networks, whose outputs are defined by a fixed point (or optimality) condition, which makes them naturally suited for L2O. We will cover how to design and train these networks efficiently.

MS14-B-2: Direct Sampling for recovering a clamped cavity from biharmonic far field data

Heejin Lee, Purdue University

Abstract: We consider the inverse shape problem of recovering an unknown clamped cavity in a thin infinite plate, modeled by the two-dimensional biharmonic wave equation in the frequency domain. Using far-field data, we perform a resolution analysis for recovering the cavity through direct sampling methods. By applying the Funk-Hecke integral identity, we demonstrate that the imaging functionals originally developed for acoustic inverse shape problems are also valid for biharmonic waves. This is the first extension of direct sampling methods to biharmonic waves using far-field data. Numerical examples will illustrate the effectiveness of these imaging functionals in detecting a clamped cavity.

MS14-B-3: Fast and stable imaging of objects in 2D acoustic waveguides using scattering data

Nhung Nguyen, Kansas State University

Abstract: This talk addresses the inverse problem of reconstructing extended objects from scattering data at a fixed frequency within a 2D acoustic waveguide. This problem has significant applications in physics and engineering, including radar, sonar, and nondestructive testing. We propose an imaging function to efficiently determine the shape of the unknown object. The method is both fast and stable, with a simple im-

plementation that avoids the need of solving an ill-posed problem. Our numerical studies demonstrate that the proposed imaging function can provide more accurate reconstructions compared to the direct sampling method and Kirchhoff migration.

MS14-B-4: A Tikhonov-based regularization method for Inverse Source Problems for Fractional Parabolic Equations
Thi Phong Nguyen, Iowa State University
Abstract: Fractional Differential Equations FDEs) can be found in many problems that replace regular ones in modeling complicated real-world applications, such as underground fluid flows, anomalous diffusion processes in viscoelastic materials or plasma, and stochastic processes. The forward and inverse problems for FDEs have been investigated actively in recent decades. As usual, inverse problems for FDEs are generally ill-posed, which increases the challenges in studying them. This talk will discuss a regularization method for inverse problems of finding a factor of the source term for fractional parabolic equations. This method guarantees the Holder-type error estimate with the optimal order. This ends with an algorithm for recovering the source and numerical illustrations. This is a joint work with Nguyen Van Duc (Vinh University)

MS14-C-1: An algorithm for computing scattering poles based on dual characterization to interior eigenvalues
Dana Zilberberg, Rutgers University
Abstract: We present an algorithm for the computation of scattering poles for an impenetrable obstacle with Dirichlet or Robin boundary conditions in acoustic scattering. This method builds upon the previous work of Cakoni et al. (2020) titled 'A duality between scattering poles and transmission eigenvalues in scattering theory' (Cakoni et al. 2020 Proc. A. 476, 20200612 (doi:10.1098/rspa.2020.0612)), where the authors developed a conceptually unified approach for characterizing the scattering poles and interior eigenvalues corresponding to a scattering problem. This approach views scattering poles as dual to interior eigenvalues by interchanging the roles of incident and scattered fields. In this framework, both sets are linked to the kernel of the relative scattering operator that maps incident fields to scattered fields. This mapping corresponds to the exterior scattering problem for the interior eigenvalues and the interior scattering problem for scattering poles. Leveraging this dual characterization and inspired by the generalized linear sampling method for computing the interior eigenvalues, we present a novel numerical algorithm for computing scattering poles without relying on an iterative scheme. Preliminary numerical examples showcase the effectiveness of this computational approach.

MS14-C-2: Inverse gravimetry by multipole expansions
Tianshi Lu, Wichita State University
Abstract: We improved the algorithm proposed by Isakov and Titi to find the location and size of the source from the gravity fields measured at a few points around the source. First we estimated the center of the source by tracing the measured gravity fields via least-squares fitting. Then we computed the monopole, dipole, and quadruple source terms at the estimated center to match the fields, also in the least-squares sense. Lastly, we solved a nonlinear equation to obtain the center, size, and orientation of the source. The nonlinear equation involved an eigenvalue solver and a quadratic or cubic equation. We validated the algorithm for two- and three- dimensional sources in the presence of noises. We also derived a priori error bounds for the reconstructed source parameters.

MS14-C-3: Numerical algorithms for non-

local imaging problems.
Jeremy Hoskins, University of Chicago
Abstract: TBD

MS14-C-4: Hybrid Learning of Spatiotemporal Neural Operators in Forward and Inverse Problems for Turbulent Flows
Shuhao Cao, University of Missouri - Kansas City
Abstract: TBD

MS15-A-1: A Generalized Direct Discontinuous Galerkin Method for a Doubly Nonlinear Diffusion Equation in Shallow Water Modeling.
Stephanie Berg, Iowa State University
Abstract: In this study, we propose a new generalized direct discontinuous Galerkin method for the doubly nonlinear diffusion equation, commonly known as the diffusive wave approximation of the shallow water equations (DSW). The new method accommodates a doubly nonlinear diffusion coefficient matrix that depends on both the solution u and its gradient ∇u, rather than just the solution itself. Stability analyses of the proposed method are provided. Numerical tests are carried out to demonstrate the optimal convergence of the proposed method.

MS15-A-2: Second Order in Time Bound-Preserving Implicit Pressure Explicit Concentration Methods for Contaminant Transportation in Porous Media
Yang Yang, Michigan Technological University
Abstract: In this talk, we apply the implicit pressure and explicit concentration (IMPEC) methods for compressible miscible displacements in porous media. The method can yield a much larger time step size compared with the fully explicit method. However, most IMPEC methods are only of first order in time. In this talk, we will discuss how to construct a second order in time IMPEC method. The basic idea is to add the correction stage after each time step. Moreover, we will also construct the bound-preserving technique to preserve the upper and lower bounds of the concentration. Numerical experiments will be given to demonstrate the good performance of the proposed method.

MS15-A-3: A high-order well-balanced discontinuous Galerkin method for hyperbolic balance laws based on the Gauss-Lobatto quadrature
Ziyao Xu, University of Notre Dame
Abstract: In this work, we develop a high-order well-balanced discontinuous Galerkin method for hyperbolic balance laws based on the Gauss-Lobatto quadrature rules. Important applications of the method include preserving the non-hydrostatic equilibria of shallow water equations with non-flat bottom topography and Euler equations in gravitational fields. The well-balanced property is achieved through two essen- tial components. First, the source term is reformulated in a flux-gradient form in the local reference equilibrium state to mimic the true flux gradient in the balance laws. Consequently, the source term integral is discretized using the same approach as the flux integral at Gauss-Lobatto quadrature points, ensuring that the source term is exactly balanced by the flux in equilibrium states. Our method differs from existing well-balanced DG methods for shallow water equations with non-hydrostatic equilibria, particularly in the aspect that it does not require the decomposition of the source term integral. The effectiveness of our method is demonstrated through ample numerical tests.

MS15-A-4: Well-balanced positivity-preserving high-order discontinuous Galerkin methods for Euler equations with gravitation
Fangyao Zhu, Michigan Technological University
Abstract: We develop high order discontinuous Galerkin (DG) methods with Lax-

Friedrich fluxes for Euler equations under gravitational fields. Such problems may yield steady-state solutions and the density and pressure are positive. There were plenty of previous works developing either well-balanced (WB) schemes to preserve the steady states or positivity-preserving (PP) schemes to get positive density and pressure. However, it is rather difficult to construct WB PP schemes with Lax-Friedrich fluxes, due to the penalty term in the flux. In fact, for general PP DG methods, the penalty coefficient must be sufficiently large, while the WB scheme requires that to be zero. This contradiction can hardly be fixed following the original design of the PP technique, where the numerical fluxes in the DG scheme are treated separately. However, if the numerical approximations are close to the steady state, the numerical fluxes are not independent, and it is possible to use the relationship to obtain a new penalty parameter which is zero at the steady state and the full scheme is PP. To be more precise, we first reformulate the source term such that it balances with the flux term when the steady state has reached. To obtain positive numerical density and pressure, we choose a special penalty coefficient in the Lax-Friedrich flux, which is zero at the steady state. The technique works for general steady-state solutions with zero velocities. Numerical experiments will be given to show the performance of the proposed methods.

CT1-A-1: Physics-preserving IMPES based multiscale methods for immiscible two-phase flow in highly heterogeneous porous media

Yiran Wang, University of Alabama

Abstract: In this talk, I will introduce a novel physics-preserving multiscale approach to tackle the challenge of immiscible two-phase flow problems. These are typically described as a coupled system comprising Darcy's law and mass conservation equations. Physics-preserving IMplicit Pressure Explicit Saturation (P-IMPES) scheme, is designed to uphold local mass conservation for both phases while remaining unbiased. Notably, when the time step is kept below a certain threshold, the P-IMPES scheme ensures bounds-preserving saturation for both phases. For velocity updates, we employ the Mixed Generalized Multiscale Finite Element Method (MGMsFEM), a highly efficient solver that operates on a coarse grid to compute unknowns. We adopt an operation splitting technique to manage the complexities of two-phase flow, utilizing an upwind strategy for explicit saturation iteration, while employing the MGMsFEM to compute velocity via a decoupled system on a coarse mesh. To validate the effectiveness and robustness of our proposed method, we conduct a series of comprehensive experiments. Additionally, we provide a rigorous analysis to establish the theoretical underpinnings of the method, which are corroborated by our numerical findings. Both simulations and analysis demonstrate that our approach strikes a favorable balance between accuracy and computational efficiency.

CT1-A-2: Semigroup well-posedness of a Biot-Stokes Interactive System

Sara McKnight, Colorado Mesa University

Abstract: The coupling of a porous medium modeled by the Biot equations and a fluid has many biological applications. There are numerous ways by which to model the fluid and to couple the porous medium with the fluid. This particular model couples the Biot equations to Stokes flow along the boundary, through the Beavers-Joseph-Saffman conditions. We address semigroup well-posedness of the system via an inf-sup approach, which along the way requires consideration of a related but uncoupled static Biot system.

CT1-A-3: Intrinsic Projection of Implicit Runge-Kutta Methods for DAEs

Nikita Kapur, The University of Iowa
Abstract: We present the new technique of Intrinsic Projection (IP) for Implicit Runge-Kutta (IRK) Methods applied to differential-algebraic equations (DAEs). IP does not require the accurate evaluation of any additional Jacobian like for standard Projected Implicit Runge-Kutta Methods and is therefore simpler to implement. IP for IRK methods is analyzed for index 2 DAEs, in particular we give results about existence and uniqueness, and some error estimates. For index 2 DAEs IP for IRK methods is shown to lead to the same order of error estimates as standard Projected Implicit Runge-Kutta Methods, but at a lower computational cost. Some preliminary results for index 3 DAEs will also be given.

CT1-A-4: Starting Approximations for SIRK Methods Applied to Index 2 DAEs

Joseph Small, University of Iowa
Abstract: Implicit Runge-Kutta (IRK) methods are often used to numerically approximate solutions of stiff differential equations and differential-algebraic equations (DAEs). While these methods have very useful properties that their explicit counterparts lack, they also come at the cost of having to solve a nonlinear system of equations at every time step. In this presentation, we look at applications of IRK methods to index 2 DAEs ($y' = f(t,y,z), 0 = g(t,y)$), henceforth referred to as specialized implicit Runge-Kutta (SIRK) methods. We are particularly interested in developing high order starting approximations for the internal stages to minimize the number of fixed-point/Newton type iterations needed to solve the nonlinear system within the desired error bounds. Starting approximations for some of these SIRK methods have been previously studied but our new formulation greatly simplifies the analysis and further-generalizes the methods for which we can apply the approximations. We expand our starting approximations and exact internal stages (in step size h) about the current time-step rather than the previous time-step by using reverse SIRK Methods. Many of these so-called reverse methods had not been considered for index 2 DAEs before this work. Reverse SIRK methods also have many convenient relationships to the original SIRK methods they stem from, such as satisfying the same simplifying assumptions. Our starting approximations are split into two parts: The y components and the z components. Both use linear combinations of the previous step's internal stages, while the starting approximations for Y_i's also include the previous and current time-steps. For methods satisfying the simplifying assumption $C(q)$, we are able to develop starting approximations of order q for Y_i's and order $\min(q, s-1)$ for Z_i's. The coefficients for these methods are found by solving a linear system dependent on the underlying IRK coefficients.

CT1-A-5: Fluid Dissipation Gevrey Class Estimates for a Problem in Fluid Structure Interaction

Dylan McKnight, Colorado Mesa University
Abstract: A result of Gevrey regularity is ascertained for a semigroup which models a fluid-structure interaction problem. In this model, the fluid evolves in a piecewise smooth or convex geometry $\mathcal{O}$. On a portion of the boundary, a fourth order plate equation is coupled with the fluid through pressure and matching velocities. The key to obtaining the conclusion of Gevrey regularity is an appropriate estimation of the resolvent of the associated C_0-semigroup operator. Moreover, a numerical scheme and example is provided which empirically demonstrates smoothing of the fluid-structure semigroup.

CT1-B-1: Starting approximations of implicit Runge-Kutta methods for ODEs and DAEs

Laurent O. Jay, University of Iowa
Abstract: We consider the application of implicit Runge-Kutta (IRK) type methods to ordinary differential equations (ODEs) and to differential-algebraic equations (DAEs). We consider starting approximations based on values from the previous step to obtain accurate values for the internal stages of the current step. We will discuss recent results on such starting approximations using a new kind of analysis based on reverse methods.

CT1-B-2: Moving Mesh SUPG Method for Time-dependent Convection-Dominated Convection-Diffusion Problems
Xianping Li, Arizona State University
Abstract: Time-dependent convection-diffusion problems is considered, particularly when the diffusivity is very small and sharp layers exist in the solutions. Nonphysical oscillations may occur in the numerical solutions when using regular mesh with standard computational methods. In this work, we develop a moving mesh SUPG (MM-SUPG) method, which integrates the streamline upwind Petrov-Galerkin (SUPG) method with the moving mesh partial differential equation (MMPDE) approach. The proposed method is designed to handle both isotropic and anisotropic diffusivity tensors. For the isotropic case, we focus on improving the stability of the numerical solution by utilizing both artificial diffusion from SUPG and mesh adaptation from MMPDE. And for the anisotropic case, we focus on the positivity of the numerical solution. We introduce a weighted diffusion tensor and develop a new metric tensor to control the mesh movement. We also develop conditions for time step size so that the numerical solution satisfies the discrete maximum principle (DMP). Numerical results demonstrate that the proposed MM-SUPG method provides results better than SUPG with fixed mesh or moving mesh without SUPG.

CT1-B-3: Regularity of Solutions for the Peridynamic Equation on Periodic Distributions
Thinh Dang, Kansas State University
Abstract: In this work, we study the asymptotic behavior of the eigenvalues of the Peridynamic operator's Fourier multipliers. Here the operator of choice is given by a radial symmetric, compactly supported integral kernel and the eigenvalues integral and hypergeometric representations were first derived in alali2022. We then use these analyses to study the corresponding Equilibrium equation and Peridynamic equations over the space of periodic distributions in any spatial dimensions. In these equations, solution spatial and temporal regularity are formulated based on the regularity of the initial data or the source/ forcing term. Furthermore, the solution to these equations are shown to converge to their local counterparts, where the systems are governed by the Navier operator of linear elasticity. We conduct two types of convergence analysis: as the spatial nonlocality vanishes or as the singularity of the integral kernel approaches a certain critical singularity that depends on the spatial dimension.

CT1-B-4: Fourier Continuation Method for Nonlocal Boundary Value Problems
Ilyas Mustapha, Kansas State University
Abstract: We present a two-dimensional Fourier continuation algorithm which extends a smooth nonperiodic function to a smooth biperiodic function over a smooth two-dimensional domain. We demonstrate the performance of this algorithm and apply it to solve nonlocal Poisson equations within a bounded domain.

CT2-A-1: Machine Learning Integrated with In Vitro Experiments for Study of Drug Release from PLGA Nanoparticles
Shuhuai Qin, Colorado State University
Abstract: We investigated delivery of en-

capsulated drug from poly lactic-co-glycolic (PLGA) micro-/nano-particles (MPs/NPs). Experimental data collected from about 50 papers are analyzed by machine learning (ML) algorithms including linear regression, principal component analysis (PCA), Gaussian process regression (GPR), and artificial neural networks (ANNs). The focus is to understand the effect of drug solubility, drug molecular weight, particle size, and pH-value of the release matrix/environment on drug release profiles. The results obtained from machine learning is then used as guidelines for designing new in vitro experiments to examine dependence of drug release profiles on those four factors. It is interesting to see that indeed the results of the new in vitro experiments are in basic agreement with the results obtained from machine learning.

CT2-A-2: TBD
Sahil Chindal, Virginia Commonwealth University
Abstract: TBD.

CT2-A-3: TBD
Bidemi O. Falodun, Missouri University of Science and Technology, Missouri
Abstract: TBD.

CT2-A-4: TBD
Asma Azizi, Kennesaw State University
Abstract: TBD.

CT2-B-1: Penalty Adversarial Network (PAN): A neural network-based method to solve PDE-constrained optimal control problems
Yukun Yue, University of Wisconsin-Madison
Abstract: In this work, we introduce a novel strategy for tackling constrained optimization problems through a modified penalty method. Conventional penalty methods convert constrained problems into unconstrained ones by incorporating constraints into the loss function via a penalty term. However, selecting an optimal penalty parameter remains challenging; an improper choice, whether excessively high or low, can significantly impede the discovery of the true solution. This challenge is particularly evident when training neural networks for constrained optimization, where tuning parameters can become an extensive and laborious task. To overcome these issues, we propose an adversarial approach that redefines the conventional penalty method by simultaneously considering two competing penalty problems—a technique we term the penalty adversarial problem. Within linear settings, our method not only ensures the fulfillment of constraints but also guarantees solvability, leading to more precise solutions compared to traditional approaches. We further reveal that our method effectively performs an automatic adjustment of penalty parameters by leveraging the relationship between the objective and loss functions, thereby obviating the need for manual parameter tuning. Additionally, we extend this adversarial framework to develop a neural network-based solution for optimal control problems governed by linear or nonlinear partial differential equations. We demonstrate the efficacy of this innovative approach through a series of numerical examples.

CT2-B-2: Maximal volume matrix cross approximation for image compression and least squares solution
Zhaiming Shen, Georgia Institute of Technology
Abstract: We study the classic matrix cross approximation based on the maximal volume submatrices. Our main results consist of an improvement of the classic estimate for matrix cross approximation and a greedy approach for finding the maximal volume submatrices. More precisely, we present a new proof of the classic estimate of the inequality with an improved constant. Also, we present a family of greedy maximal volume algorithms to improve the computational efficiency of matrix cross approximation. The

proposed algorithms are shown to have theoretical guarantees of convergence. Finally, we present two applications: image compression and the least squares approximation of continuous functions.

CT2-B-3: Shallow ReLU Neural Networks and their Representations of Piecewise Linear Functions

Sarah McCarty, Iowa State University

Abstract: The ReLU function is a simple function that is a popular choice as an activation function for neural networks. Infinite-width, shallow ReLU networks are integrals over a parameter space and are poorly understood compared to finite-width networks. We prove a conjecture that every piecewise linear infinite-width, shallow ReLU neural network is also expressible as a finite-width network. The conjecture originated with Ongie et al. (A Function Space View of Bounded Norm Infinite Width ReLU Nets: The Multivariate Case, 2019). In the proof, we will show the simple derivatives of a piecewise linear function force the measure over the parameter space to be zero almost everywhere. We then extend results of finite-width networks to infinite-width networks as corollaries.

CT2-B-4: Multifidelity Operator Learning with Learned Neural Input Basis

Jacob Hauck, Missouri University of Science and Technology

Abstract: We propose a novel operator learning architecture based on learned neural representations of bases for both input and output function distributions. Our method differs from existing order reduction methods like DeepONet and POD-NN/PCA-Net in its applicability to arbitrary input and output discretizations with a single model. This makes our method particularly suitable for multifidelity and multiresolution problems. Furthermore, unlike methods based on proper orthogonal decomposition, our method is trained end-to-end. We demonstrate the effectiveness of our method and explore phenomena related to multifidelity training and testing with numerical examples using synthetic data to learn solution operators for the 2D Poisson equation, the 1D Burgers equation, and the 2D Navier-Stokes equation.