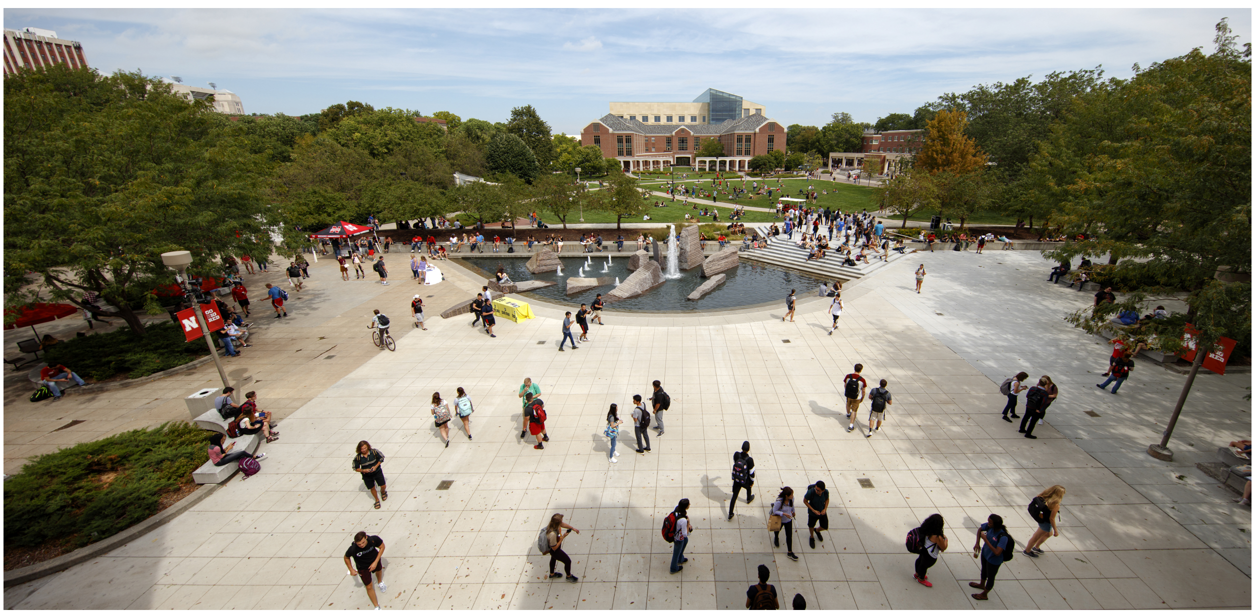
Society for Industrial and Applied Mathematics

CONFERENCE PROGRAM

8th SIAM Annual Meeting of Central States Section



University of Nebraska-Lincoln
October 7-8, 2023

Table of Contents

1 SIAM Central States Section

Welcome to the 8th annual meeting of the SIAM Central States Section at University of Nebraska - Lincoln.

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 8th SIAM-CSS annual meeting will be held at University of Nebraska - Lincoln on October 7-8, 2023.

Local Organizing Committee

- **George Avalos**, University of Nebraska - Lincoln
- **Huijing Du**, University of Nebraska - Lincoln
- **Dylan McKnight**, University of Nebraska - Lincoln
- **Sara McKnight**, University of Nebraska - Lincoln
- **Lindsay Augustyn**, University of Nebraska - Lincoln
- **Michael Bergland-Riese**, University of Nebraska - Lincoln

SIAM CSS Leadership (2022-2024)

- **President:** Weizhang Huang, University of Kansas
- **Vice President:** Nathan Albin, Kansas State University
- **Secretary:** Xukai Yan, Oklahoma Sate University
- **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)

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)**
- **Department of Mathematics**, University of Nebraska - Lincoln
- **Center for Science, Mathematics, and Computer Education**, University of Nebraska - Lincoln
- **College of Arts and Sciences**, University of Nebraska - Lincoln

2 Schedule at a glance

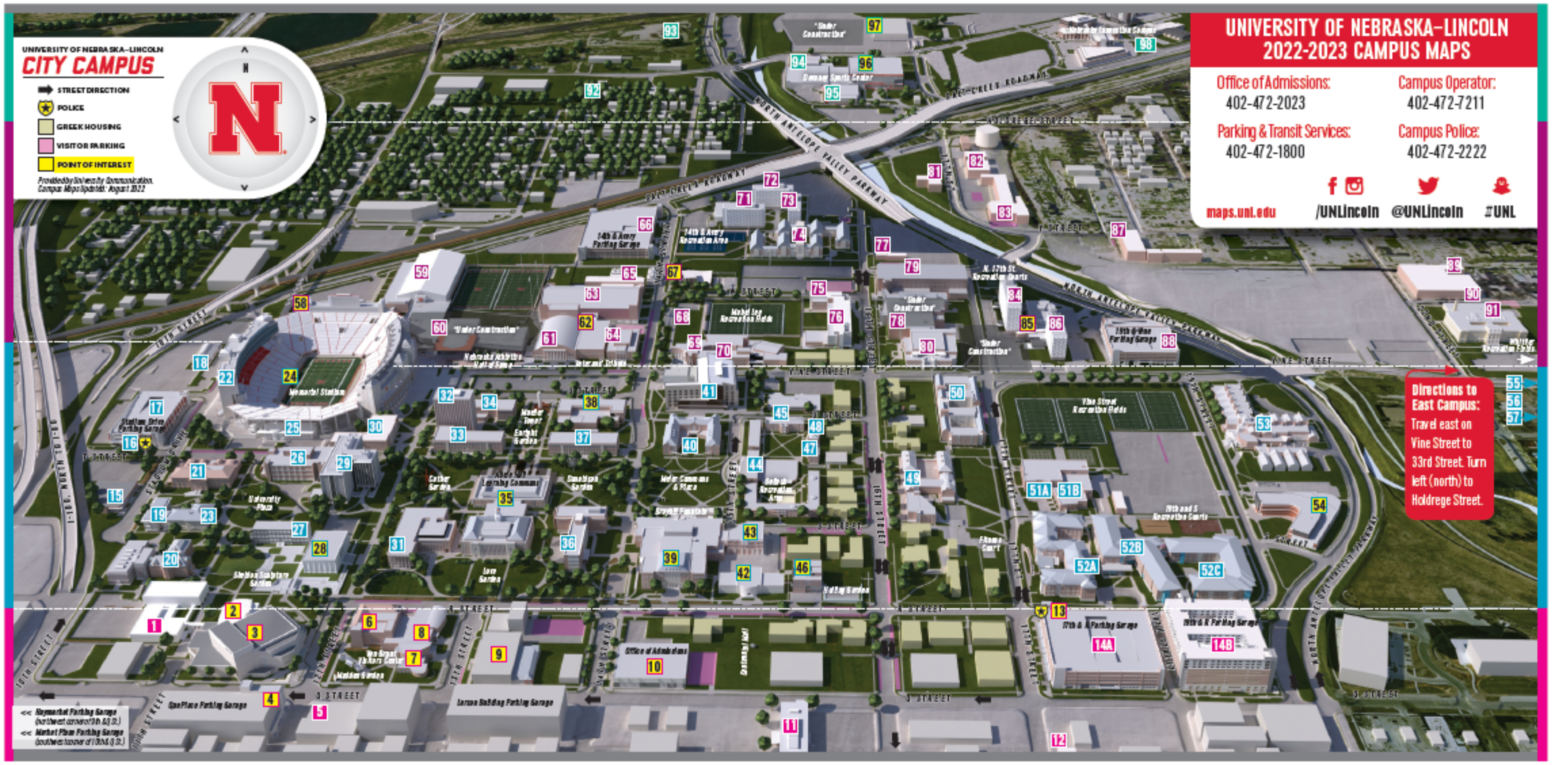
Saturday, October 7

Time	Event	Location
8:00am-9:00am	Registration Table Opens	Outside of Avery 115
9:00am-9:10am	Opening Remarks	Swanson Auditorium (Nebraska Union)
9:10am-10:10am	Plenary Talk 1: Sunčica Čanič University of California-Berkeley	Swanson Auditorium (Nebraska Union)
10:10am-10:50am	Coffee Break	Outside of Avery 115
10:50am-12:10pm	Mini-Symposium Session I	Avery
12:10pm-2:00pm	Lunch	
2:00pm-3:00pm	Plenary Lecture 2: Lorena Bociu North Carolina State University	Swanson Auditorium (Nebraska Union)
3:10pm-4:30pm	Mini-Symposium Session II	Avery and Burnett
4:30pm-5:00pm	Coffee Break	Outside of Avery 115
5:00pm-6:20pm	Mini-Symposium Session III	Avery and Burnett
6:45pm-9:00pm	Banquet Dinner	Centennial Room (Nebraska Union)

Sunday, October 8

8:30am-9:00am	Registration Table Opens	Outside of Avery 115
9:00am-10:00am	Plenary Lecture 3: Chun Liu Illinois Institute of Technology	Swanson Auditorium (Nebraska Union)
10:00am-10:40am	Coffee Break	Outside of Avery 115
10:30am-11:50am	Mini-Symposium Session IV and Contributed Talks	Avery and Burnett

3 Campus Map



A–J

- 84 Abel Hall (ARH)
- 85 **Abel-Sandoz Welcome Center** (ARH)
- 35 **Adele Hall Learning Commons** (LLN) (LLS)
- 10 **Admissions Office** (ALEX)
- 10 Alexander Bldg. (ALEX)
- 11 Andersen Hall (ANDN)
- 37 Andrews Hall (ANDR)
- 20 Architecture Hall (ARCH) (ARCW)
- 30 Avery Hall (AVH)
- 53 Beadle Center (BEAD)
- 19 Behlen Laboratory (BEL)
- 48 Benton Hall (BENH)
- 34 Bessey Hall (BESY)
- 53 Bioscience Greenhouses (BIOG)
- 77 Boat House - Campus Rec. (BOAT)
- 23 Brace Laboratory (BL)
- 33 Burnett Hall (BURN)
- 83 Business Services Complex (BSC)
- 62 **Campus Recreation Center** (CREC)
- 36 Canfield Administration Bldg. (ADMN) (ADMS)
- 68 Carolyn Pope Edwards Hall (CPEH)
- 51A Cather Dining Complex (WCDC)
- 61 Coliseum (COL)
- 41 College of Business (HLH)
- 54 College of Nursing (HCCN)
- 63 Cook Pavilion (COOK)
- 50 The Courtyards (CORT)
- 96 **Devaney Sports Center** (DEV)
- 52C Eastside Suites (ESST)
- 87 Facilities Management & Planning (FMP)
- 89 Facilities Management Shops (FMS)
- 47 Fairfield Hall (FAIR)
- 94 Francis Allen Training Complex
- 43 **Gaughan Multicultural Center** (GAUN)
- 4 **Great Plains Art Museum** (HEWP)
- 29 Hamilton Hall (HAH)
- 72 Harper Hall (HRH)
- 59 Hawks Championship Center (HCC)
- 41 Hawks Hall (HLH)
- 95 Hendricks Training Complex
- 70 Henzlik Hall (HENZ)
- 49 Heppner Hall (HEPP)
- 22 Herman Student Life Complex
- 4 Hewit Place (HEWP)
- 6 **Howell Theatre** (TEMP)
- 56 Husker Hall (HUSK)
- 97 **Ice Box** (ICBX)
- 92 ITS Annex (J6B) | Recycling and Refuse Building (RRB)
- 9 **Johnny Carson Center for Emerging Media Arts** (CEMA)
- 6 **Johnny Carson School of Theatre & Film** (TEMP)
- 3 **Johnny Carson Theater** (LIED - west side)
- 76 Jorgensen Hall (JH)

K–Q

- 40 Kauffman Academic Residential Center (KAUF)
- 89 Key Services (FMS)
- 2 **Kimball Recital Hall** (KRH)
- 52A Knoll Residential Center (KNOL)
- 82 Landscape & Facilities Implement Bldg. (LIB | FIB)
- 81 Landscape Services Offices (WAT)
- 3 **Lied Center for Performing Arts** (LIED)
- 31 Louise Pound Hall (LPH)
- 49 Love Hall (LOVH)
- 35 **Love Library** (LLN) (LLS)
- 26 Manter Hall (MANT)
- 8 **Mary Riepma Ross Media Arts Center** (RVB)
- 24 **Memorial Stadium**
- 64 Military & Naval Science Bldg., Pershing (M&N)
- 38 **Morrill Hall** (MORR)
- 18 Nebraska Champions Club (NECH)
- 79 Nebraska Hall (NH)
- 98 Nebraska Innovation Campus (NIC)
- 42 **Nebraska State Historical Society**
- 39 **Nebraska Union** (NU)
- 49 Neihardt Residence Center
- 32 Oldfather Hall (OLDH)
- 58 **Osborne Athletic Complex** (MSTD)
- 80 Othmer Hall (OTHM)
- 67 **Outdoor Adventures Center** (OAC)
- 16 Parking & Transit Services (SDPG)
- 91 Prem S. Paul Research Center at Whittier (WHIT)
- 49 Piper Hall (PIPH)

R–Z

- 49 Raymond Hall (RAYH)
- 21 Richards Hall (RH)
- 86 Sandoz Hall (SZRH)
- 25 Schorr Center (SHOR)
- 73 Schramm Hall (SCRH)
- 78 Scott Engineering Center (SEC) *under construction*
- 45 Seaton Hall (SEH)
- 44 Selleck Quadrangle (SELK)
- 28 **Sheldon Museum of Art** (SHEL)
- 71 Smith Hall (SMRH)
- 38 **State Museum of Natural History** (MORR)
- 60 Student Athletic Facility *under construction*
- 69 Teachers College Hall (TEAC)
- 6 **Temple Building** (TEMP)
- 93 Transportation Services (TRAN)
- 55 U Street Apartments (UST)
- 5 University Communication (UCOMM)
- 54 **University Health Center** (HCCN)
- 12 University of Neb. Federal Credit Union (UNLCU)
- 51B University Housing Offices
- 52B University Suites (UNST)
- 90 UNL Children's Center (CHC)
- 83 **UNL Print, Copy & Passport Services** (BSC)
- 13 **UNL Police Dept. - 300 N 17th St** (17PG)
- 65 Utility Plant (CCUP)
- 7 **Van Brunt Visitors Center** (RVB)
- 74 Village, The (VILL)
- 57 Vine Street Apartments (2222, 2244)
- 75 Voelte-Keegan Nanoscience Research Center (JH)
- 81 Watson Bldg. (WAT)
- 1 Westbrook Music Bldg. (WMB)
- 46 **Wick Alumni Center** (WICK)
- 27 Woods Art Bldg. (WAB)
- 15 501 Bldg. (501)

PARKING GARAGES

- 14A/B 17/18th & R Parking Garages (17PG, 18PG)
- 66 14th & Avery Parking Garage (14PG)
- 88 19th & Vine Parking Garage (19PG)
- 17 Stadium Drive Parking Garage (SDPG)

Haymarket Park Stadium Complex (HAYB)
West on O Street to Sunvalley Blvd.–turn right (north) to Line Drive Circle–turn right (east).

Pinnacle Bank Arena – West on Q Street to N 8th Street–turn right (north) to R Street–turn left (west).

4 Plenary Lectures

Sunčica Čanić

Professor Čanić is in the Department of Mathematics at the University of California, Berkeley. She previously held the Cullen Distinguished Professor of Mathematics and was Director of the Center for Mathematical Biosciences at the University of Houston. She is a well-known research authority in the field of partial differential equations and its applications in biomedical research, having authored over 100 publications on this topic.
Among the many accolades which Professor Čanić has garnered: she was honored for her research by the National Science Foundation as Distinguished MPS Lecturer in 2007; she received the US Congressional Recognition for Top Women in Technology in 2006; she is the recipient of the Esther Farfel Award in 2018, the highest award offered at the University of Houston. Moreover, she is the only woman to hold a prestigious Cullen Distinguished Professorship position at the University of Houston. In addition, Professor Čanić was elected SIAM Fellow in 2014, and AMS Fellow in 2020.

Title: A MATHEMATICAL APPROACH TO THE DESIGN OF A BIOARTIFICIAL PANCREAS

Saturday, October 7st, 9:10am-10:10am, Swanson Auditorium (Nebraska Union)

Abstract: This talk will address the design of an implantable bioartificial pancreas without the need for immunosuppressant therapy. The design is based on transplanting the healthy (donor) pancreatic cells into a poroelastic medium (alginate hydrogel, or agarose gel) and encapsulating the cell-containing medium between two nanopore semi-permeable membranes. The nanopore membranes are manufactured to block the immune cells from attacking the organ, while allowing passage of nutrients and oxygen to keep the transplanted cells viable as long as possible. The key challenge is maintaining the survival of transplanted pancreatic cells for an extended period of time by providing sufficient oxygen supply. This challenge is addressed via our nonlinear, multi-scale, multi-physics mathematical and computational models. At the macro scale we designed a nonlinear fluid-poroelastic structure interaction model to study the flow of blood in the bioartificial pancreas, coupled to a nonlinear advection-reaction-diffusion model to study oxygen supply to the cells. At the micro-scale, we use particle-based simulations (Smoothed Particle Hydrodynamics) in conjunction with Encoder-Decoder Convolution Neural Networks to capture the fine micro-structure (architecture) of hydrogels and how the architecture influences the macro-scale parameters, such as the spatially dependent permeability tensor. These models inspired the design of a second-generation bioartificial pancreas. They also initiated the development of new mathematical analysis approaches to study multi-layered poroelastic media interacting with incompressible, viscous fluids. I will talk about both. In particular, a new mathematical well-posedness result for a nonlinearly coupled model will be shown. Parts of this work are joint with biomedical engineer S. Roy (UCSF), and mathematicians Y. Wang (Texas Tech), J. Webster (University of Maryland Baltimore County), L. Bociu (North Carolina State University), and B. Muha (University of Zagreb, Croatia).

Lorena Bociu

Professor Bociu, in the Department of Mathematics at North Carolina State University, works in analysis, optimization, and control of partial differential equations (PDEs). She has research expertise in the qualitative and quantitative analysis of solutions to systems of PDEs, as well as its applications in real world problems in fields such as nonlinear structural acoustics, fluid-structure interactions, and fluid-solid mixtures.

Professor Bociu has been the recipient of many honors and awards, including an NSF CAREER Award in 2016 and Presidential Early Career Award in Sciences and Engineering (PECASE) in 2019. Moreover, she has been a North Carolina State University Faculty Scholar since 2016.

Professor Bociu serves as Chair of the AWM SIAM Committee, and Chair of the Working Group 7.2 (Computational Techniques in Distributed Systems) as part of The International Federation for Information Processing (IFIP), Technical Committee 7. She is also a member of the SIAM Committee for the JMM (chair in 2022), AWM Meetings Committee, and JMM Program Committee.

Title: Multiscale Interface Coupling of PDEs and ODEs for Tissue Perfusion

Saturday, October 7th, 2:00pm-3:00pm, Swanson Auditoritum (Nebraska Union)

Abstract: In biomechanics, local phenomena, such as tissue perfusion, are strictly related to the global features of the whole blood circulation. We propose a heterogeneous model where a local, accurate, 3D description of tissue perfusion by means of poroelastic equations is coupled with a systemic 0D lumped model of the remainder of the circulation. This represents a multiscale strategy, which couples an initial boundary value problem to be used in a specific tissue region with an initial value problem in the rest of the circulatory system. We discuss wellposedness analysis for this multiscale model, as well as solution methods focused on a detailed comparison between functional iterations and an energy-based operator splitting method and how they handle the interface conditions.

Chun Liu

Professor Liu is currently the Chair of the Department of Applied Mathematics at the Illinois Institute of Technology. His research includes partial differential equations and calculus of variations, and their applications in complex fluids. Professor Liu has published over 180 publications. Many of his research projects have been partially supported by grants from the NSF, the Department of Energy, and various international research foundations. Professor Liu has been the recipient of several awards, including Householder Lecturer at Oak Ridge National Laboratory in 2019.

Moreover, Professor Liu has also long served as Editor for the SIAM Journal on Mathematical Analysis, Communications in Mathematical Sciences, Interfaces and Free Boundaries, Kinetic and Related Models, Analysis and Application, Journal of Mathematical Study, and Computational and Mathematical Biophysics (CMB).

Title: Energetic Variational Approaches in Biological Active Materials

Sunday, October 8th, 9:00am-10:00am, Swanson Auditorium (Nebraska Union)

Abstract: A thermodynamic theory will be presented for active fluids whose dynamics involves converting chemical energy into various type of mechanical energy. The framework is the extension of the classical energetic variational approaches for mechanical systems. This approach can be applied to a wide range of evolutions modeled by chemical reaction kenetics and mechanical processes. Here we will focus on applications such as micellar polymer solutions and muscle contractions.

This is a joint project with many collaborators, in particular, Bob Eisenberg, Yiwei Wang and Tengfei Zhang.

5 Mini-Symposium and Contributed Talk Sessions

MS01. Advances in Computational Modeling of Infectious Diseases (ACMID)

Organizers: *Majid Bani-Yaghoub*, University of Missouri-Kansas City; *Md Yusuf Uddin*, University of Missouri-Kansas City

Session A: Saturday, October 7, 10:50am-12:10pm, Avery Hall 106

- **MS01-A-1** (10:50am) Estimating the Individual Reproduction Numbers for Staff and Residents of Nursing Homes Linked By a Shared Staff. *Kiel Daniel Corkran*, University of Missouri-Kansas City
- **MS01-A-2** (11:10am) Prioritizing interventions for preventing COVID-19 outbreaks in military basic training. *Alex Perkins*, University of Notre Dame
- **MS01-A-3** (11:30am) TBD. *Rana Parshad*, Iowa State University
- **MS01-A-4** (11:50am) TBD. *XiuFeng Wan*, University of Missouri

Session B: Saturday, October 7, 3:10pm-4:30pm, Avery Hall 106

- **MS01-B-1** (3:10pm) Multiscale modeling of epidermal-dermal interactions during skin wound healing. *Huijing Du*, University of Nebraska-Lincoln
- **MS01-B-2** (3:30pm) Using Patient Flow Data to Model Infectious Disease Transmission in Emergency Departments. *Sarawat Murtaza Sara*, University of Missouri-Kansas City
- **MS01-B-3** *Md Yusuf Sarwar Uddin*, University of Missouri-Kansas City
- **MS01-B-4** (4:10pm) Leveraging Machine Learning Models to Identify Possible Outcomes of Discrete and Continuous Dynamical Systems. *Majid Bani-Yaghoub*, University of Missouri-Kansas City

Session C: Saturday, October 7, 5:00 pm - 6:20 pm, Avery Hall 106

- **MS01-C-1** (5:00 pm) Some Discrete Composite Distributions with Applications to Infectious Disease Data. *Bowen Liu*, University of Missouri-Kansas City
- **MS01-C-2** (5:20 pm) Estimating Infection Transmission Risk During Social Events Using Real-Time Indoor Location Data. *Ravi Chandra Thota*, University of Missouri-Kansas City
- **MS01-C-3** (5:40 pm) Deterministic and Stochastic Modeling Approaches for Analyzing Dynamics of Antimicrobial Resistant Organisms. *Arash Arjmand*, University of Missouri-Kansas City
- **MS01-C-4** (6:00 pm) Developing a Predictive Model of Infections Disease Vulnerability in Long-Term Care Facilities Using Machine Learning. *Julia Pluta*, University of Missouri-Kansas City

MS02. The Interplay of Data, Machine Learning, and Numerical Analysis

Organizers: *Shuhao Cao*, University of Missouri-Kansas City *Dinh-Liem Nguyen*, Kansas State University

Session A: Saturday, October 7, 10:50am-12:10pm, Avery Hall 108

- **MS02-A-1** (10:50am) Transmission Dynamics of Mpox outbreak from May 1, 2022– May 31, 2023: Data-driven modeling for Global and Regional Scales. *Haridas Kumar Das*, Oklahoma State University
- **MS02-A-2** (11:10am) Joint control of flow-shop manufacturing system coupled with microgrid. *Jiali Zhang*, Missouri University of Science and Technology
- **MS02-A-3** (11:30am) New deep learning enhanced indicator function for imaging photonic crystals with super-resolution. *Trung Truong*, Marshall University
- **MS02-A-4** (11:50am) Accelerating and enabling convergence of nonlinear solvers for Navier-Stokes equations by continuous data assimilation. *Xuejian Li*, Clemson University

Session B: Saturday, October 7, 5:00pm-6:20pm, Avery Hall 108

- **MS02-B-1** (5:00pm) Fixed-point pseudo-spectral methods for wave propagation problems. *Songting Luo*, Iowa State University
- **MS02-B-2** (5:20pm) Physics-informed neural networks with data enhancement for large scale partial differential equations. *Xuan Gu*, University of Arkansas
- **MS02-B-3** (5:40pm) Training data studies of the cell-average based neural network method for linear PDEs. *Tyler Kroells* Iowa State University
- **MS02-B-4** (6:00pm) Sampling Methods for Inverse Scattering Problems in Locally Perturbed Periodic Media. *Thi-Phong Nguyen*, New Jersey Institute of Technology

MS03. Recent Developments in Deterministic and Stochastic PDEs: Theoretical and Numerical Analysis

Organizers: *Pelin Guven Geredeli*, Clemson University; *Quyuan Lin*, Clemson University

Session A: Saturday, October 7, 10:50am-12:10pm, Avery Hall 109

- **MS03-A-1** (10:50am) UNIQUENESS FOR A STOCHASTIC IDEAL DYADIC MHD MODEL. *Qirui Peng*, University of Illinois at Chicago
- **MS03-A-2** (11:10am) TBD. *George Avalos*, University of Nebraska-Lincoln
- **MS03-A-3** (11:30am) Analysis of a Structural Acoustics Model with Competing Nonlinear Forces. *Yanqui Guo*, Florida International University
- **MS03-A-4** (11:50am) On ergodicity of the damped-driven stochastically forced KdV equation via a simple feedback-control mechanism. *Vincent Martinez*, CUNY Hunter College & Graduate Center

Session B: Saturday, October 7, 3:10pm-4:30pm, Avery Hall 109

- **MS03-B-1** (3:10pm) Long-time statistics of SPDEs: mixing and numerical approximation. *Cecilia Mondaini*, Drexel University
- **MS03-B-2** (3:30pm) Stabilizing phenomenon for incompressible fluids. *Weinan Wang*, University of Arizona
- **MS03-B-3** (3:50pm) Remarks on the two-dimensional magnetohydrodynamics system forced by space-time white noise. *Kazuo Yamazaki*, University of Nebraska-Lincoln
- **MS03-B-4** (4:10pm) Calming the Navier-Stokes Equations. *Matt Enlow*, University of Nebraska-Lincoln

Session C: Saturday, October 7, 5:00pm-6:00pm, Avery Hall 109

- **MS03-C-1** (5:00pm) The PE diagram. *Xin Liu*, Texas A&M University
- **MS03-C-2** (5:20pm) Recent Results on Data Assimilation for Turbulent Flows. *Adam Larios*, University of Nebraska-Lincoln
- **MS03-C-3** (5:40pm) On the Proximity Between Solutions to the Completely Integrable Focusing Nonlinear Schrödinger Equation and its Non-Integrable Generalizations. *Dionyssios Mantzavinos*, University of Kansas
- **MS03-C-4** (6:00pm) Stable singularity formation of the inviscid primitive equations. *Quyuan Lin*, Clemson University

MS04. Interactions among Analysis, Optimization and Network Science

Organizers: *Nathan Albin*, Kansas State University; *Lukas Geyer*, Montana State University; *Pietro Poggi-Corradini*, Kansas State University; *Dominique Zosso* Montana State University.

Session A: Saturday, October 7, 10:50am-12:10pm, Avery Hall 110

- **MS04-A-1** (10:50am) Triangle percolation on the grid. *Tyrrell McAllister*, University of Wyoming
- **MS04-A-2** (11:10am) On quasiregular values. *K. Ilmari Kangasniemi*, University of Cincinati
- **MS04-A-3** (11:30am) Convergence of the Probabilistic Interpretation of Modulus. *Joan Lind*, University of Tennessee
- **MS04-A-4** (11:50am) Homogeneous graph reinforcement. *Huy Truong*, Kansas State University

Session B: Saturday, October 7, 3:10pm-4:30pm, Avery Hall 110

- **MS04-B-1** (3:10pm) Uniformization of metric surfaces. *Matthew Romney*, Stevens Institute of Technology
- **MS04-B-2** (3:30pm) An Intrinsic Approach to Scalar-Curvature Estimation for Point Clouds, Networks, and Finite Metric Spaces. *Abigail Hickok*, Columbia University
- **MS04-B-3** (3:50pm) From the discrete to the continuum. *Pietro Poggi-Corradini*, Kansas State University
- **MS04-B-4** (4:10pm) Modulus of edge covers and stars. *Adriana M. Ortiz Aquino*, Kansas State University

Session C: Saturday, October 7, 5:00pm-6:20pm, Avery Hall 110

- **MS04-C-1** (5:00pm) ON REGULARITY OF SETS OF FINITE FRACTIONAL PERIMETER IN METRIC MEASURE SPACES. *Josh Kline*, University of Cincinnati
- **MS04-C-2** (5:20pm) Whitney Extension in the Heisenberg Group and Beyond. *Gareth Speight*, University of Cincinnati
- **MS04-C-3** (5:40pm) Spectral Gaps and Cubical Complexes. *Eric Babson*, University of California at Davis
- **MS04-C-4** (6:00pm) Gravitational Lensing and Dynamics of Rational Maps. *Lukas Geyer*, Montana State University

MS05. Evolutionary Partial Differential Equations of Deterministic and Stochastic Type

Organizers: *George Avalos*, University of Nebraska-Lincoln; *Kazuo Yamazaki*, University of Nebraska-Lincoln

Session A: Saturday, October 7, 10:50am-12:10pm, Avery Hall 111

- **MS05-A-1** (10:50am) Grounded ice sheets melting as an obstacle problem. *Paolo Piersanti*, Indiana University
- **MS05-A-2** (11:10am) Fractional Voigt Regularization of the 3D Navier Stokes Equations. *Isabel Safarik*, University of Nebraska-Lincoln
- **MS05-A-3** (11:30am) Luenberger Compensator Theory for Heat-Structure Interaction via Boundary/Interface Feedback Controls. *Xiang Wan*, Loyola University Chicago
- **MS05-A-4** (11:50am) Local Nonuniqueness for Stochastic Transport Equations with Deterministic Drift. *Andre Schenke*, Courant Institute of Mathematical Sciences at New York University (NYU)

Session B: Saturday, October 7, 3:10pm-4:30pm, Avery Hall 111

- **MS05-B-1** (3:10pm) Controllability of a Cochlea Model. *Scott Hansen*, Iowa State University
- **MS05-B-2** (3:30pm) Synchronization of stochastic models in complex networks. *Hakima Bessaih*, Florida International University
- **MS05-B-3** (3:50pm) Several Robust Model Reductions for the Boundary Feedback Stabilization of Fully Magnetic Piezoelectric Smart Beams. *Ahmet Kaan Aydin*, University of Maryland, Baltimore County
- **MS05-B-4** (4:10pm) A New Practical Framework for the Stability Analysis of Perturbed Saddle-point Problems and Applications. *Qingguo Hong*, Missouri University of Science and Technology

Session C: Saturday, October 7, 5:00pm-6:20pm, Avery Hall 111

- **MS05-C-1** (5:00pm) Babuska-Brezzi formulation for semigroup wellposedness of a coupled composite structure-fluid interaction PDE system. *Pelin Guven Geredeli*, Clemson University
- **MS05-C-2** (5:20pm) NON-UNIQUE STATIONARY SOLUTIONS OF FORCED SQG. *Qirui Peng*, University of Illinois at Chicago
- **MS05-C-3** (5:40pm) New a priori interior trace estimates on the 3D incompressible Navier-Stokes equation. *Jincheng Yang*, University of Chicago
- **MS05-C-4** (6:00pm) Semigroup Well-Posedness and Finite Element Approximation for a Biot Model. *Sara McKnight*, University of Nebraska-Lincoln

MS06: Advances in Numerical Methods for Partial Differential Equations and Applications

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

Session A: Saturday, October 7, 10:50am-12:10pm, Avery Hall 112

- **MS06-A-1** (10:50am) Stability and time-step constraints of implicit-explicit Runge–Kutta methods for the linearized Korteweg–de Vries equation. *Zheng Sun*, The University of Alabama
- **MS06-A-2** (11:10am) An immersed finite element method and error analysis for elastodynamic interface problems. *Xu Zhang*, Oklahoma State University
- **MS06-A-3** (11:30am) A high order geometry conforming immersed finite element for elliptic interface problems. *Haroun Meghaichi*, Virginia Tech

- **MS06-A-4** (11:50am) Optimal Error Estimates of Ultra-weak Discontinuous Galerkin Methods with Generalized Numerical Fluxes for Multi-dimensional Convection-Diffusion and Biharmonic Equations. *Yuan Chen*, Ohio State University

Session B: Saturday, October 7, 3:10pm-4:30pm, Avery Hall 112

- **MS06-B-1** (3:10pm) High-order IPDG Method for Anisotropic Diffusion Equations. *Lin Mu*, University of Georgia
- **MS06-B-2** (3:30pm) Hybridizable discontinuous Galerkin methods for coupled systems of porous/-poroelastic media and free flow equations. *Jeonghun Lee*, Baylor University
- **MS06-B-3** (3:50pm) A Positivity-preserving and Robust Fast Solver for Time-fractional Convection-subdiffusion Problems. *Jiangguo (James) Lin*, Colorado State University
- **MS06-B-4** (4:10pm) A fully decoupled iterative method with 3D anisotropic immersed finite elements of non-homogeneous flux jump for Kaufman-type discharge problems. *Xiaoming He*, Missouri University of Science and Technology

MS07. Bio-Control of Invasive Species by Studying Pest Dynamics and Additional Food Strategy

Organizers: *Rana Parshad*, Iowa State University; *Aniket Banerjee*, Iowa State University

Session A: Saturday, October 7, 10:50am-12:10pm, Avery Hall 118

- **MS07-A-1** (10:50am) TBD. *Rana Parshad*, Iowa State University
- **MS07-A-2** (11:10am) Understanding the Chemostat and reversing Competitive Exclusion. *Thomas Griffin*, Iowa State University
- **MS07-A-3** (11:30am) A patch driven additional food model. *Urvashi Verma*, Iowa State University
- **MS07-A-4** (11:50am) Sex-biased predation and predator intraspecific competition effects in a mating system. *Eric Takyi*, Ursinus College

Session B: Saturday, October 7, 3:10pm-4:30pm, Avery 118

- **MS07-B-1** (3:10pm) A discrete Model for the Trojan Y Chromosome Strategy. *Don “Kumudu" Mallawa Arachchi*, Iowa State University
- **MS07-B-2** (3:30pm) Dynamical Analysis of a Lotka-Volterra Competition Model with both Allee and Fear Effect. *Vaibhava Srivastava*, Iowa State University
- **MS07-B-3** (3:50pm) Towards holistic modeling of invasive species, zoonotic diseases, and climate change. *Majid Bani-Yaghoub*, University of Missouri-Kansas City
- **MS07-B-4** (4:10pm) The changing dynamics of Virulent and Avirulent Aphids: Effect of plant suitability and soybean field flooding. *Aniket Banerjee*, Iowa State University

MS08. Nonlinear Evolution Equations and Related Topics

Organizer: *Xiang Wan*, Loyola University Chicago

Session A: Saturday, October 7, 10:50am-12:10pm, Avery Hall 115

- **MS08-A-1** (10:50am) Robust Model Reductions for the Strongly-Coupled PDEs of Piezoelectric Multi-layer Beams. *Ahmet Ozkan Ozer*, Western Kentucky University
- **MS08-A-2** (11:10am) Uniform Stability in a Vectorial Full Von Karman Thermoelastic System with Solenoidal Dissipation and Free Boundary Conditions. *Catherine Lebiedzik*, Wayne State University
- **MS08-A-3** (11:30am) Multi-Scale Interface Coupling between Deformable Porous Media and Lumped Hydraulic Circuits. *Sarah Strikwerda*, University of Pennsylvania
- **MS08-A-4** (11:50am) Existence and stability of forced oscillation of a type of parabolic equations. *Taige Wang*, University of Cincinnati

Session B: Saturday, October 7, 3:10pm-4:30pm, Avery Hall 115

- **MS08-B-1** (3:10pm) Global Attractors for Suspension Bridge Models Under Unstable Flow of Gas. *Madhumita Roy*, The University of Memphis
- **MS08-B-2** (3:30pm) The relativistic Euler equations for an ideal gas with a physical vacuum boundary. *Brian Luczak*, Vanderbilt University
- **MS08-B-3** (3:50pm) Fluid–Plate Interaction with Kelvin-Voigt Damping and Bending Moment at the Interface: Well-posedness, Spectral Analysis, Uniform Stability. *Rasika Mahawattege*, University of Maryland, Baltimore County
- **MS08-B-4** (4:10pm) A regularity criterion for the 3-D Navier-Stokes equations based on finitely many observations. *Abhishek Balakrishna*, University of Southern California

Session C: Saturday, October 7, 5:00pm-6:20pm, Avery Hall 115

- **MS08-C-1** (5:00pm) Existence of solutions past collisions for viscoelastic solids. *Giovanni Gravina*, Arizona State University
- **MS08-C-2** (5:20pm) Time Dependent Finite Elements for a Fluid-Structure System. *Dylan McKnight*, University of Nebraska-Lincoln
- **MS08-C-3** (5:40pm) A brief introduction to the controllability of quantum systems:Lie algebras, representations and the role of symmetries. *Domenico D'Alessandro*, Iowa State University
- **MS08-C-4** (6:00pm) Stability analysis on HDG method for elliptic equation. *Yukun Yue*, University of Wisconsin-Madison

MS09. Novel Numerical Algorithms Developed by Female Researchers

Organizer: *James Liu*, Iowa State University

Session A: Sunday, October 8, 10:40am-12:00pm, Avery Hall 115

- **MS09-A-1** (10:40am) Full weak Galerkin FEMs for linear and nonlinear poroelasticity problems. *Zhuoran Wang*, University of Kansas
- **MS09-A-2** (11:00am) Weak Galerkin Methods. *Chunmei Wang*, University of Florida
- **MS09-A-3** (11:20am) Front Tracking Method for the Numerical Simulations of Turbulent Mixing. *Tulin Kaman*, University of Arkansas
- **MS09-A-4** (11:40am) Pressure robust numerical scheme for incompressible flow. *Lin Mu*, University of Georgia

MS10. Recent Advances in Analysis and Learning of Differential Equations and Operators

Organizers: *Ming Zhong*, Illinois Institute of Technology; *Trevor Leslie*, Illinois Institute of Technology

Session A: Saturday, October 7, 10:50am-12:10pm, Avery Hall 119

- **MS10-A-1** (10:50am) Parameter estimation in nonlinear PDEs. *Vincent Martinez*, CUNY Hunter College & Graduate Center
- **MS10-A-2** (11:10am) Learning Parameters and Forcing Terms in Turbulent Flows Using Analytic Techniques. *Elizabeth Carlson*, California Institute of Technology
- **MS10-A-3** (11:30am) Operator learning and nonlinear dimension reduction by deep neural networks. *Wenjing Liao*, Georgia Institute of Technology
- **MS10-A-4** (11:50am) Learning a zero of the score operator: a new transport method for Bayesian inference and sampling. *Nisha Chandramoorthy*, Georgia Institute of Technology

Session B: Saturday, October 7, 3:10pm-4:30pm, Avery Hall 119

- **MS10-B-1** (3:10pm) DATA-DRIVEN OPTIMAL CONTROL WITH NEURAL NETWORK MODELING OF GRADIENT FLOWS. *Hailiang Liu*, Iowa State University
- **MS10-B-2** (3:30pm) Neural differential equations for medical image prediction and segmentation. *Hangjie Ji*, North Carolina State University
- **MS10-B-3** (3:50pm) A nonlocal gradient for black-box optimization with applications to data-driven discovery and design. *Hoang Tran*, Oak Ridge National Laboratory
- **MS10-B-4** (4:10pm) Geometric Surface Characterization and Learning. *Yingying Wu*, University of Houston

MS11. Recent Advances in CFD for Wind Engineering

Organizers: *Irina Afanasyeva*, University of Arkansas; *Tulin Kaman*, University of Arkansas

Session A: Saturday, October 7, 5:00pm - 6:20 pm, Burnett Hall 115

- **MS11-A-1** (5:00pm) Wind farm modeling and optimization. *Stefano Leonardi*, The University of Texas at Dallas
- **MS11-A-2** (5:20pm) Accurately predicting aerodynamic loads from synoptic and non-synoptic winds using CFD simulations. *Faiaz Khaled*, University of Illinois, Urbana Champaign
- **MS11-A-3** (5:40pm) Computation of Building Corner Peak Pressure Using CFD. *Panneer Selvam*, University of Arkansas
- **MS11-A-4** (6:00pm) Examining the Effects of Synthetically Generated Inlet Turbulence on Wind Loads using Large Eddy Simulation (LES). *Irina Afanasyeva*, University of Arkansas

MS12. Recent Advances in Discontinuous Galerkin Methods in Computational Fluid Dynamics

Organizer: *Ziyao Xu*, University of Notre Dame;

Session A: Saturday, October 7, 5:00pm-6:20pm, Avery Hall 112

- **MS12-A-1** (5:00pm) High-order bound-preserving discontinuous Galerkin methods for multicomponent chemically reacting flows. *Yang Yang*, Michigan Technological University
- **MS12-A-2** (5:20pm) A high-order well-balanced discontinuous Galerkin method for hyperbolic balance laws with non-hydrostatic equilibria. *Ziyao Xu*, University of Notre Dame
- **MS12-A-3** (5:40pm) The Runge–Kutta discontinuous Galerkin method with compact stencils for hyperbolic conservation laws. *Zheng Sun*, The University of Alabama
- **MS12-A-4** (6:00pm) Well-balanced positivity-preserving high-order discontinuous Galerkin methods for Euler equations with gravitation. *Fangyao Zhu*, Michigan Technological University

MS13. Recent Advances in Efficient and Robust Numerical Techniques for Partial Differential Equations and Their Applications

Organizers: *Seulip Lee*, University of Georgia; *Lin Mu* University of Georgia,

Session A: Saturday, October 7, 3:10pm-4:30pm, Burnett Hall 107

- **MS13-A-1** (3:10pm) C0 interior penalty methods for an elliptic distributed optimal control problem with general tracking and pointwise state constraints. *SeongHee Jeong*, Florida State University
- **MS13-A-2** (3:30pm) A fourth order finite difference method for solving elliptic interface problems with the FFT acceleration. *Shan Zhao*, University of Alabama
- **MS13-A-3** (3:50pm) Reduced Mixed Finite Element Method. *Rajan Bahadur Adhikari*, Oklahoma State University
- **MS13-A-4** (4:10pm) Best approximation results and essential boundary conditions for novel types of weak adversarial network discretizations for PDEs. *Cuiyu He*, University of Georgia

Session B: Saturday, October 7, 5:00pm-6:20pm, Burnett Hall 107

- **MS13-B-1** (5:00pm) Adaptive least-squares finite element methods: guaranteed upper bounds and Convergence in L_2 norm of the dual variables. *JaEun Ku*, Oklahoma State University
- **MS13-B-2** (5:20pm) A uniform and pressure-robust enriched Galerkin method for the Brinkman equations. *Seulip Lee*, University of Georgia
- **MS13-B-3** (5:40pm) Regularized Reduced Order Modeling for Turbulent Flow. *Jorge Reyes*, Virginia Tech
- **MS13-B-4** (6:00pm) Radial basis function methods for integral fractional Laplacian using arbitrary radial functions. *Qiao Zhuang*, Worcester Polytechnic Institute

MS14. Recent Advances in Mathematical and Numerical Analysis of PDEs and Applications

Organizers: *Hailiang Liu*, Iowa State University; *Songting Luo*, Iowa State University

Session A: Saturday, October 7, 10:50am-12:10pm, Burnett Hall 115

- **MS14-A-1** (10:50am) An efficient and provable sequential quadratic programming method for American and swing option pricing. *Weizhang Huang*, University of Kansas
- **MS14-A-2** (11:10am) Recent results in inverse gravimetry and inverse conductivity problems. *Tianshi Lu*, Wichita State University
- **MS14-A-3** (11:30am) A direct parallel-in-time quasi-boundary value method for inverse space-dependent source problems. *Yi Jiang*, Southern Illinois University Edwardsville
- **MS14-A-4** (11:50am) A dynamic mass transport method for Poisson-Nernst-Planck equations. *Hailiang Liu*, Iowa State University

Session B: Saturday, October 1, 3:10pm-4:30pm, Burnett Hall 115

- **MS14-B-1** (3:10pm) Learning Free Space Green's Function For Elliptic Partial Differential Equations. *Shuwang Li*, Illinois Institute of Technology
- **MS14-B-2** (3:30pm) Discontinuous Galerkin methods for network patterning phase-field models. *Yuan Liu*, Wichita State University
- **MS14-B-3** (3:50pm) Adaptive gradient methods with energy and momentum. *Xuping Tian*, Iowa State University
- **MS14-B-4** (4:10pm) Maximum-Taylor discontinuous Galerkin (MTDG) schemes for solving linear hyperbolic systems. *James Rossmanith*, Iowa State University

MS15. Recent Developments in Applied Inverse Problems and Imaging

Organizers: *Din-Liem Nguyen*, Kansas State University; *Thi-Phong Nguyen*, New Jersey Institute of Technology; *Trung Truong*, Marshal University

Session A: Saturday, October 7, 3:10pm-4:30pm, Avery Hall 108

- **MS15-A-1** (3:10pm) Sampling type method combined with deep learning for inverse scattering with one incident wave. *Thu Thi Anh Le*, Kansas State University
- **MS15-A-2** (3:30pm) On nonscattering media and their connections in inverse problems. *Jingni Xiao*, Drexel University
- **MS15-A-3** (3:50pm) Inverse scattering for higher waves. *Paul Sacks*, Iowa State University
- **MS15-A-4** (4:10pm) Fast imaging of point-like electromagnetic sources using single-frequency data. *Dinh-Liem Nguyen*, Kansas State University

Session B: Saturday, October 7, 5:00pm-6:20pm, Avery Hall 118

- **MS15-B-1** (5:00pm) A Spectral Target Signature for Thin Surfaces with Higher Order Jump Conditions. *Heejin Lee*, Purdue University
- **MS15-B-2** (5:20pm) Coupling physics-deep learning inversion. *Lu Zhang*, Rice University
- **MS15-B-3** (5:40pm) A variational quasi-reversibility model for a time-reversed nonlinear parabolic problem. *Anh Khoa Vo*, Florida A&M University
- **MS15-B-4** (6:00pm) A new sampling indicator function for stable imaging of periodic scattering media. *Trung Truong*, Marshall University

Session C: Sunday, October 8, 10:40am-12:00pm, Avery Hall 118

- **MS15-C-1** (10:40am) Conditional sampling via block-triangular transport maps. *Ricardo Baptista*, Caltech
- **MS15-C-2** (11:00am) Noise-robust Deep Direct Sampling via Transformers. *Shuhao Cao*, University of Missouri-Kansas City
- **MS15-C-3** (11:20am) On a new interior transmission eigenvalue problem in locally perturbed periodic media. *Thi-Phong Nguyen*, New Jersey Institute of Technology

MS16. Recent Developments in Nonlocal and Fractional Differential Problems

Organizers: *Weizhang Huang*, University of Kansas; *Yanzhi Zhang*, Missouri University of Science and Technology

Session A: Saturday, October 7, 5:00pm-6:20pm, Avery Hall 119

- **MS16-A-1** (5:00pm) Regularity of solutions to boundary nonlocal equations. *Pablo Raúl Stinga*, Iowa State University
- **MS16-A-2** (5:20pm) Monotone meshfree methods for linear elliptic equations in non-divergence form via nonlocal relaxation. *Qihao Ye*, University of California, San Diego
- **MS16-A-3** (5:40pm) Extension equation for fractional power of operator defined on Banach spaces. *Animesh Biswas*, University of Nebraska-Lincoln
- **MS16-A-4** (6:00pm) A novel and simple spectral method for nonlocal PDEs with the fractional Laplacian. *Shiping Zhou*, Missouri University of Science and Technology

Session B: Sunday, October 8, 10:40am-12pm, Avery Hall 112

- **MS16-B-1** (10:40am) Analytical and applied aspects for nonlocal frameworks and operators. *Petronela Radu*, University of Nebraska-Lincoln
- **MS16-B-2** (11:00am) A grid-overlay finite difference method for the fractional Laplacian on arbitrary bounded domains. *Weizhang Huang*, University of Kansas
- **MS16-B-3** (11:20am) Fourier Multipliers for Linear Peridynamic Operators. *Nathan Albin*, Kansas State University
- **MS16-B-4** (11:40am) Solving A Non-local Fokker-Planck Equation by Deep Learning. *Xiaofan Li*, Illinois Institute of Technology

MS17. Theoretical and Applied Aspects of Nonlocal Models

Organizers: *Animesh Biswas*, University of Nebraska-Lincoln; *Javier Cueto Garcia*, University of Nebraska-Lincoln; *Scott Hootman-Ng*, University of Nebraska-Lincoln

Session A: Saturday, October 7, 10:50am-12:10pm, Burnett Hall 107

- **MS17-A-1** (10:50am) Mathematical studies of nonlocal half-ball vector operators and their applications to peridynamics correspondence material models. *Xiaochuan Tian*, University of California, San Diego
- **MS17-A-2** (11:10am) Analysis and Discretization of Optimal Control Problems in Peridynamics. *Joshua Siktar*, University of Tennessee-Knoxville
- **MS17-A-3** (11:30am) Asymptotically compatible schemes for saddle point problems and applications to nonlocal models. *Zhaolong Han*, University of California, San Diego

- **MS17-A-4** (11:50am) Nonlocal Boundary Value Problems with Local Boundary Conditions. *James Scott*, Columbia University

Session B: Sunday, October 8, 10:40am-12pm, Avery Hall 119

- **MS17-B-1** (10:40am) The extension problem characterization for higher fractional power operators in Banach spaces. *Pablo Raúl Stinga*, Iowa State University
- **MS17-B-2** (11:00am) A Spectral Method for Fractional Wave Equations in Heterogeneous Media. *Yanzhi Zhang*, Missouri University of Science and Technology
- **MS17-B-3** (11:20am) Analytical Solutions for Peridynamic Models for Transient Diffusion and Elastodynamics. *Florin Bobaru*, University of Nebraska-Lincoln
- **MS17-B-4** (11:40am) Results on Nonlocal Volume Constraint Problems with Finite Horizon. *Scott Hootman-Ng*, University of Nebraska-Lincoln

MS18. Applied and Computational Complex Analysis

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

Session A: Sunday, October 8, 10:40am-12:00pm, Burnett Hall 107

- **MS18-A-1** (10:40am) Harmonic measure distribution functions in various geometries. *Christopher Green*, Wichita State University
- **MS18-A-2** (11:00am) Fast computation of analytic capacity. *Mohamed Nasser*, Wichita State University
- **MS18-A-3** (11:20am) Vortex shedding from bluff bodies: A conformal mapping approach. *Vijay Matheswaran*, Wichita State University
- **MS18-A-4** (11:40am) Computation of plane potential flow in multiply connected domains. *Thomas K DeLillo*, Wichita State University

SC. SIAM CSS Student Chapter Research Presentations

Organizers: *Tulin Kaman*, University of Arkansas; *James Rossmanith*, Iowa State University

Session A: Saturday, October 7, 10:50am-12:10pm, Avery Hall 13

- **SC-A-1** (10:50am) Asymptotic-Preserving Scheme for the Kinetic Boltzmann-BGK Equation. *Preeti Sar*, Iowa State University
- **SC-A-2** (11:10am) Functional equivariance and modified vector fields. *Sanah Suri*, Washington University in St. Louis
- **SC-A-3** (11:30am) Decoupled Finite Element Method for a phase field model of two-phase ferrofluid flows. *Youxin Yuan*, Missouri University of Science and Technology
- **SC-A-4** (11:50am) Spacetime Discontinuous Galerkin Methods for the Vlasov-Maxwell System. *Yifan Hu*, Iowa State University

Session B: Saturday, October 7, 3:10pm-4:30pm, Avery Hall 13

- **SC-B-1** (3:10pm) Role of Network Geometry and Human Mobility in the Metapopulation Model. *Haridas Das*, Oklahoma State University
- **SC-B-2** (3:30pm) Simulation of turbulent mixing due to Richtmyer-Meshkov Instability using high order Weighted Essentially Non-Oscillatory Scheme. *Ryan Holley*, University of Arkansas
- **SC-B-3** (3:50pm) Block-structured, adaptive mesh refinement in the front-tracking method for numerical simulation of fluid instabilities. *James Burton*, University of Arkansas
- **SC-B-4** (4:10pm) Performance analysis of U-Net over the different number of initial channels. *Nailah Rawnaq, Pritom Roy*, University of Arkansas

CT1. Contributed Talks-1

Session A: Sunday, October 8, 10:40am-12:00pm, Avery Hall 106

- **CT1-A-1** (10:40am) Learning Collective Behaviors from Observation. *Ming Zhong*, Illinois Institute of Technology
- **CT1-A-2** (11:00am) Monolithic and local time-stepping decoupled algorithms for transport problems in fractured porous media. *Toan Huynh*, Auburn University
- **CT1-A-3** (11:20am) Low regularity integrators for the conservative Allen-Cahn equation with maximum bound principle. *Cao Kha Doan*, Auburn University
- **CT1-A-4** (11:40am) Learning Temporal Evolution of Parametrized PDEs with Convolutional Neural Networks. *Yumeng Wang*, Missouri University of Science and Technology

CT2. Contributed Talks-2

Session A: Sunday, October 8, 10:40am-12:00pm, Avery Hall 108

- **CT2-A-1** (10:40am) The Exponential Stabilization of a Heat and Piezoelectric Beam Interaction with Static and Dynamic Feedback Controllers. *Sk Md Ibrahim Khalilullah*, Western Kentucky University
- **CT2-A-2** (11:00am) Applying LES-C Turbulence Models for Turbulent Fluid-Fluid Interaction Problems. *Kyle James Schwiebert*, Michigan Technological University
- **CT2-A-3** (11:20am) TBD. *Md Afsar Ali*, Kansas Wesleyan University

CT3. Contributed Talks-3

Session A: Sunday, October 8, 10:40am-12:00pm, Avery Hall 109

- **CT3-A-1** (10:40am) Semi Discrete Models of Radiation Therapy. *Abigail D'Ovidio Long*, University of Nebraska-Lincoln
- **CT3-A-2** (11:00am) On the kinetic description of the objective molecular dynamics. *Kunlun Qi*, University of Minnesota-Twin Cities
- **CT3-A-3** (11:20am) Swarm-Based Gradient Method for Non-Convex Optimization. *Jingcheng Lu*, University of Minnesota
- **CT3-A-4** (11:40am) Piecewise Smooth Solutions to Scalar Balance Laws with Singular Source Terms. *Evangelia Ftaka*, North Carolina State University

CT4. Contributed Talks-4

Session A: Sunday, October 8, 10:40am-12:00pm, Avery Hall 111

- **CT4-A-1** (10:40am) Boundary Output Feedback Stabilization for a Magnetizable Piezoelectric Beam Model with non-collocated Controllers and Observers. *Uthman Rasaq Adeniran*, Western Kentucky University
- **CT4-A-2** (11:00am) An Agent-Based modeling approach to Investigate Pandemic Preparedness of Nursing Homes. *Kiel Daniel Corkran*, University of Missouri-Kansas City
- **CT4-A-3** (11:20am) Mathematical analysis of singularities in the diffusion model under the submanifold assumption. *Yubin Lu*, Illinois Institute of Technology
- **CT4-A-4** (11:40am) 3D Generative Adversarial Network to Achieve Realistic Synthesis of Pancreatic Cancer CT Image Data. *Yu Shi*, University of Nebraska-Lincoln

P. Poster Presentations

Session A: Saturday, October 7, 5:00pm-6:20pm, Avery Hall 13

- **P-A-1** The effect of "fear" on two species competition. *Vaibhava Srivastava*, Iowa State University
- **P-A-2** A Study on the Local Deep Galerkin Method (LDGM) applied to 2D - Cahn-Hilliard Equation (2D-CH). *Caden Fischer*, South Dakota State University
- **P-A-3** A Study on the Local Deep Galerkin Method (LDGM) applied to 2D - Cahn-Hilliard Equation (2D-CH). *Jung-Han Kimm*, South Dakota State University
- **P-A-4** Chebyshev Radon transform methods for solving multidimensional linear hyperbolic systems. *Joanna Held*, Iowa State University

6 Abstracts of Mini-Symposium and Contributed Talks

MS01-A-1: Estimating the Individual Reproduction Numbers for Staff and Residents of Nursing Homes Linked By a Shared Staff

Kiel Daniel Corkran, University of Missouri-Kansas City

Abstract: The Individual Reproduction Number (IRN) can be defined as the average number of people infected by a particular person over the course of his or her infection. Estimating the IRN can help the epidemiologists and decision makers understand the severity of infection in local communities. Research shows that one out of every six cumulative Covid deaths in the U.S is a Nursing home resident. It is also known that many nursing home staff work in multiple nursing homes and they can unintentionally spread COVID-19 between the nursing homes. In the study we used the GAMA simulation platform to build an agent-based model of COVID-19 spread within and between nursing homes. Using the model simulations we calculated the IRN of staff and residents. We found that increasing from no shared staff to 5% shared staff will result in a significant increase in the IRN of both residents and staff. We also found that 10% to 15% will result in presence of superspreaders of COVID-19 with IRN up to 24 (i.e., a staff member can transmit COVID-19 infection to 24 staff and residents). Further increases in the percent shared staff 30% to 50% did not increase the IRN suggesting that the system has reached to an endemic state. This study highlights the practical use of GAMA agent-based modeling to better understand the dynamics of infectious diseases.

MS01-A-2: Prioritizing interventions for preventing COVID-19 outbreaks in military basic training

Alex Perkins, University of Notre Dame

Abstract: Like other congregate living settings, military basic training has been subject to outbreaks of COVID-19. We sought to identify improved strategies for preventing outbreaks in this setting using an agent-based model of a hypothetical cohort of trainees on a U.S. Army post. Our analysis revealed unique aspects of basic training that require customized approaches to outbreak prevention, which draws attention to the possibility that customized approaches may be necessary in other settings, too. In particular, we showed that introductions by trainers and support staff may be a major vulnerability, given that those individuals remain at risk of community exposure throughout the training period. We also found that increased testing of trainees upon arrival could actually increase the risk of outbreaks, given the potential for false-positive test results to lead to susceptible individuals becoming infected in group isolation and seeding outbreaks in training units upon release. Until an effective transmission-blocking vaccine is adopted at high coverage by individuals involved with basic training, need will persist for non-pharmaceutical interventions to prevent outbreaks in military basic training. Ongoing uncertainties about virus variants and breakthrough infections necessitate continued vigilance in this setting, even as vaccination coverage increases.

MS01-A-3: TBD

Rana Parshad

Abstract: TBD

MS01-A-4: TBD

XiuFeng Wan

Abstract: TBD

MS01-B-1: Multiscale modeling of epidermal-dermal interactions during skin wound healing

Huijing Du, University of Nebraska-Lincoln

Abstract: Following injury, skin activates a complex wound healing program. While cellular and signaling mechanisms of wound repair have been extensively studied, the principles of

epidermal-dermal interactions and their effects on wound healing outcomes are only partially understood. We developed a multiscale, hybrid mathematical model of skin wound healing. The model takes into consideration interactions between epidermis and dermis across the basement membrane. Simulations revealed that epidermal-dermal interactions are critical for proper extracellular matrix deposition in the dermis, suggesting the important role of signaling across dermal-epidermal interface and the effect of fibrin clot density and wound geometry on scar formation.

MS01-B-2: Using Patient Flow Data to Model Infectious Disease Transmission in Emergency Departments

Sarawat Murtaza Sara, University of Missouri-Kansas City

Abstract: Improving patient flow in emergency departments (EDs) can reduce the undesired outcome and the likelihood of infectious disease transmission within the hospital. We constructed a detailed simulation model of patient flow and disease transmission using Anylogic software. The model includes various parameters such as arrival type, severity of illness, duration of stay in the waiting room, and patient movements between different units. We calibrated the model using data from University Health Truman Medical Center (UHTMC). The calibrated model estimates the number of patients at each location of an ED, including the triage, waiting room, and minor procedure rooms. Moreover, we used infection data and the associated probability distributions to simulate hospital-acquired COVID-19 and influenza in the ED waiting room. By utilizing our model, hospital administrators and infection control teams can implement targeted strategies to reduce the incidence of disease transmission and enhance patient safety, ultimately leading to improved healthcare outcomes.

MS01-B-3: TBD

Md Yusuf Sarwar Uddin, University of Missouri-Kansas City

Abstract: TBD

MS01-B-4: Leveraging Machine Learning Models to Identify Possible Outcomes of Discrete and Continuous Dynamical Systems

Majid Bani-Yaghoub, University of Missouri-Kansas City

Abstract: Discrete and Continuous Dynamics Systems (DCDS) have been historically used to understand and predict a wide range of physical and biological phenomena. Linear stability analysis is a standard tool to predict the local behaviors of DCDS solutions. Bifurcation analysis is also used to further explore possible local and global behaviors of DCDS solutions. Identifying all possible outcomes can be extremely challenging for DCDS with more than two equations. A typical example is the Lotka–Volterra model of n interacting species. In the present work, we explore the possibility of using Machine Learning Models (MLM), such as neural networks and decision tree models, to predict the outcomes of DCDS. Our numerical results indicate that MLM can have overall accuracies greater than 95% for binary outcomes such as stable versus unstable or periodic versus monotonic. This can be useful for analyzing high-dimensional and/or computationally expensive DCDS. However, predictive accuracies for three or more outcomes are substantially less. Another shortcoming of MLM is to identify the corresponding threshold quantities leading to those outcomes. A combination of mathematical techniques, numerical simulations, and machine learning algorithms may enable us to identify nontrivial outcomes of DCDS as a function of the parameter values.

MS01-C-1: Some Discrete Composite Distributions with Applications to Infectious Disease Data

Bowen Liu, University of Missouri-Kansas City

Abstract: It was observed that the numbers of cases and deaths for infectious diseases were associated with heavy-tailed power law distributions such as the Pareto distribution. While

Pareto distribution was widely used to model the cases and deaths of infectious diseases, a major limitation of Pareto distribution is that it can only fit a given data set beyond a certain threshold. Thus, it does not have the ability to model the whole data set. Thus, we proposed multiple discrete composite distributions with Pareto tails to fit the real infectious disease data. The analysis results suggested that the discrete composite distributions could demonstrate competitive performances compared to commonly used discrete distributions.

MS01-C-2: Estimating Infection Transmission Risk During Social Events Using Real-Time Indoor Location Data

Ravi Chandra Thota, University of Missouri-Kansas City

Abstract: An indoor positioning system (IPS) is a network of devices used to locate people or objects inside a building. However, due to variability in signal strength, a significant portion of data could be lost. In this study, we present an innovative approach to estimate the likelihood of exposure to an infectious disease (e.g., COVID-19 or Influenza) during a social event using partial IPS data of participants. We collected the data using ultra-broadband (UWB) tracking technology, which allowed us to track participants locations in real time. However, due to data loss issues, some of the data were collected incompletely. To overcome this limitation, we used trajectory interpolation techniques and assumed reasonable movement patterns to reconstruct the missing data points, allowing us to construct perfect trajectories. Using reconstructed trajectories, we tracked and visualized the interactions between the participants. By comparing these interactions with the CDC's social distancing guidelines for maintaining 6-foot distance between individuals, we assessed the potential risk of infection. We recorded and analyzed fine-grained location data for 12 individuals from an information session in a campus outreach event. We observed that these tagged participants displayed a variety of movement patterns revealing distinct trajectories and frequencies of interactions. Our study demonstrates how to combine epidemiological factors with cutting-edge tracking technology to improve our capacity to proactively address high risk movements leading to transmission of infectious diseases.

MS01-C-3: Deterministic and Stochastic Modeling Approaches for Analyzing Dynamics of Antimicrobial Resistant Organisms

Arash Arjmand University of Missouri-Kansas City

Abstract: Antimicrobial resistance (AMR), exemplified by Salmonella infections, presents dual challenges in dairy farms, as it not only affects animal health but also poses risks of zoonotic transmission to humans including farm workers. Our study addressed concerns related to the risk of zoonotic transmission of AMR Salmonella using a hybrid modeling approach. We first employed a deterministic model to examine the effects of dairy farm workers' biosecurity compliance on the dynamics of AMR among farm animals and their environment. Through local and global sensitivity analyses, we identified crucial biosecurity measures that significantly impact resistance trajectories. Transitioning from the animal population, we also applied a stochastic modeling approach to assess the potential spillover of infections from animals and contaminated environments to farm workers. This stochastic approach aids in estimating the likelihood of zoonotic transmission. Together, the deterministic and stochastic models offer a comprehensive assessment of the risks posed by AMR on dairy farms. Our findings underscore the need for targeted interventions to safeguard both animal and human health in these settings.

MS01-C-4: Developing a Predictive Model of Infections Disease Vulnerability in Long-Term Care Facilities Using Machine Learning

Julia Pluta, University of Missouri-Kansas City

Abstract: The Center for Medicare and Medicaid

Services uses its Five-Star Quality Rating System ("FSQRS") to rate every nursing home receiving Medicare payments based on a variety of criteria. However, the overall rating system and its major components had no significant predictive value as to how serious COVID-19 outbreaks would hit a given facility. This study attempts to use the data collected by CMS to generate a predictive model for the spread of infectious disease within a nursing home population in order to create a rating system that accounts for infectious disease.

Data for the Nursing Home population was taken from the Center for Medicare and Medicaid Services' public Medicare COVID-19 Nursing Home Data reporting system. Data prior to the week of May 24, 2020 was excluded as nursing home reporting prior to that date was not mandatory. This data was combined with facility information from the Five-Star Quality Rating System to connect the body of information about each facility to COVID-19 reporting. It was also combined with census data compiled by UnitedStatesZipCodes.org to get community profile information. We then used machine learning to generate decision tree analysis for a variety of combinations of variables available in our dataset to determine which factors were significant in predicting infectious disease spread and severity in nursing homes.

Preliminary results suggest that during the early phases of the pandemic, the community's education level, income, wealth, and population density combined with the nursing staffing levels, facility population, and facility ownership to be the most predictive combination of factors to determine the likelihood a facility would be at high risk for widespread infection. Future simulations will look at the subsequent phases of the pandemic to determine how those factors combined with the pandemic's progress to be predictive of future developments.

MS02-A-1: Transmission Dynamics of Mpox outbreak from May 1, 2022– May 31, 2023: Data-driven modeling for Global and Regional Scales

Haridas Kumar Das, Oklahoma State University

Abstract: Mpox(formerly known as monkeypox) spread globally, surpassing previous outbreaks and raising severe public health concerns in 2022-2023 by spreading to many regions (112 countries) worldwide with 87875 confirmed cases as of May 31, 2023. In this study, we analyze the spatial pattern of global Mpox data and apply deep learning (1D-CNN, LSTM, bidirectional LSTM(BiLSTM), hybrid CNN-LSTM, and CNN-BiLSTM) and statistical time series models (ARIMA and exponential smoothing) to forecast the transmission of Mpox globally on the weekly (Sunday-Saturday) epidemiological data. We also implement data fitting to estimate the essential epidemiological parameters in a proposed mpox deterministic model. By comparing all models with actual mpox time series data, we find a potential for a trustworthy prediction model to minimize an epidemic's social and economic impacts on a country.

MS02-A-2: Joint control of flow-shop manufacturing system coupled with microgrid

Jiali Zhang, Missouri University of Science and Technology

Abstract: Microgrids play an integral role in modern distributed energy systems. In this paper, we integrate them with a manufacturing dynamic control model. By utilizing a Markov decision process, our goal is to derive a flow-shop work sequence and simultaneously develop a dynamic control system to minimize energy costs. Our ongoing research explores the implementation of dual approaches and prioritized allocation optimization in this problem domain.

MS02-A-3: New deep learning enhanced indicator function for imaging photonic crystals with super-resolution

Trung Truong, Marshall University

Abstract: Inverse scattering problems for periodic media arise from many real-life applications, especially non-destructive testing for

photonic crystals. Photonic crystals are an important type of material in optics. Therefore, studying them is of interest to not only mathematicians, but also physicists and engineers. The inverse problem that we consider in the presented work is severely ill-posed. Thus, a lot of numerical methods fail to give reasonable results when there is a high level of noise in the data. In this talk, we present a sampling method with a new indicator function. This method is capable of reconstructing periodic media from highly noisy data, is very simple to implement and does not require any regularization. The theoretical justification of the method is proved using an integral representation that involves the Green's function along with a series expansion of the scattered waves. This is joint work is Dinh-Liem Nguyen and Kale Stahl.

MS02-A-4: Accelerating and enabling convergence of nonlinear solvers for Navier-Stokes equations by continuous data assimilation

Xuejian Li, Clemson University

Abstract: This presentation considers improving the Picard and Newton iterative solvers for the Navier-Stokes equations in the setting where data measurements or solution observations are available. We construct adapted iterations that use continuous data assimilation (CDA) style nudging to incorporate the known solution data into the solvers. For CDA-Picard, we prove the method has an improved convergence rate compared to usual Picard, and the rate improves as more measurement data is incorporated. We also prove that CDA-Picard is contractive for larger Reynolds numbers than usual Picard, and the more measurement data that is incorporated the larger the Reynolds number can be with CDA-Picard still being contractive. For CDA-Newton, we prove that the domain of convergence, with respect to both the initial guess and the Reynolds number, increases as the amount of measurement data is increased. Additionally, for both methods we show that CDA can be implemented as direct enforcement of measurement data into the solution. Numerical results for common benchmark Navier-Stokes tests illustrate the theory.

MS02-B-1: Fixed-point pseudo-spectral methods for wave propagation problems

Songting Luo, Iowa State University

Abstract: In this talk, I will talk about some simple but efficient methods for high frequency wave propagation problems. The methods first transform the problem into a fixed-point problem that will be solved by fixed-point iterations naturally, then in the fixed point iterations pseudo-spectral approximations will be applied for approximating differential operators. The efficiency and accuracy of the methods will be demonstrated by numerical examples. This is a joint work with Qing Huo Liu (Duke Univ.).

MS02-B-2: Physics-informed neural networks with data enhancement for large scale partial differential equations

Xuan Gu, University of Arkansas

Abstract: This presentation focuses on recent advancements in efficient physics-informed neural networks (PINNs) for solving large-scale partial differential equations (PDEs) through data enhancement. One significant drawback of the original PINNs is their limited accuracy and efficiency when dealing with noisy data in forward problems. To address this limitation, we propose the integration of two data pre-processing filters, namely Sobel and Canny operators, aimed at enhancing edges for a more precise and efficient machine learning process. The comparison involves original feed-forward PINNs trained on non-treated random data and PINNs with embedded Sobel and Canny filters for elliptic and parabolic problems. Our approach employs a coupled machine learning framework that incorporates modified Sobel and Canny operators from the open-source OpenCV library, integrated with the PINNs package DeepXDE. We further assess the performance of physics-informed neural networks on three trial PDEs, namely the thermal block problem, low-speed incompress-

ible Navier-Stokes equation, and high-speed incompressible Navier-Stokes equation, under three different data conditions: stationary, non-stationary clear data patterns, and non-stationary noisy data patterns. Finally, we present a comprehensive analysis of the advantages and limitations of each data pre-process algorithm under varying conditions, thereby illustrating their efficiency and accuracy in solving large-scale PDEs.

MS02-B-3: Training data studies of the cell-average based neural network method for linear PDEs
Tyler Kroells, Iowa State University
Abstract: We present the recently developed cell-average based neural network (CANN) method. The method is motivated by finite volume scheme and is based on the integral/weak formulation of the PDEs. A simple feed-forward network is forced to learn the solution average difference between two consecutive time steps. The well-trained network parameters are identified as the scheme coefficients of an explicit one-step method. The CANN method is implemented as a regular finite volume scheme. Unlike conventional numerical methods, the CANN method are found being relieved from the explicit scheme CFL restriction (i.e. $dt = O(dx^2)$). Large time step size (i.e. $dt = 7dx$) can be applied to explicitly evolve the solution forward in time. In this talk, we present the studies of training data such that a stable and accurate CANN method can be obtained for first order, second order and third order time dependent linear PDEs.

MS02-B-4: Sampling Methods for Inverse Scattering Problems in Locally Perturbed Periodic Media
Thi-Phong Nguyen, New Jersey Institute of Technology
Abstract: Since introduction of the Linear Sampling Method (LSM) in 1996, Sampling Methods, known as non-iterative and fast methods, have been developed quickly in recent decades as valuable tools for solving inverse scattering problems. These problems typically aim to determine the support in inhomogeneous media when measuring waves scattered by the domain (at some distance).
This talk will present some ideas for implementing and developing such methods for the inverse problem of recovering local perturbations in a periodic domain when only minimal data is needed.

MS03-A-1: UNIQUENESS FOR A STOCHASTIC IDEAL DYADIC MHD MODEL
Qirui Peng, University of Illinois at Chicago
Abstract: We study a stochastic dyadic model with both forward and backward energy cascade mechanisms for the inviscid and non-resistive magnetohydrodynamics. For a particular class of stochastic forcing, we show weak uniqueness for the stochastic system. However the solution dissipates the energy which is formally an invariant quantity for the system.

MS03-A-2: TBD
George Avalos, University of Nebraska-Lincoln
Abstract: TBD

MS03-A-3: Analysis of a Structural Acoustics Model with Competing Nonlinear Forces
Yanqiu Guo, Florida International University
Abstract: In this talk, I will discuss a structural acoustics model consisting of a semilinear wave equation defined on a 3D bounded domain, which is strongly coupled with a Berger plate equation acting on the elastic wall, specifically, a flat portion of the boundary. The system is influenced by several competing forces, including boundary and interior source and damping terms. It is worth noting that the source term acting on the wave equation is allowed to have a supercritical exponent, meaning that its associated Nemytskii operator is not locally Lipschitz. I will present several results on the energy decay rates and the blow-up of weak solutions, assuming different conditions on damping and source terms. The most significant challenge in this work arises from the coupling of the wave

and plate equations on the elastic wall. This is a joint work with Feng and Rammaha.

MS03-A-4: On ergodicity of the damped-driven stochastically forced KdV equation via a simple feedback-control mechanism

Vincent Martinez, CUNY Hunter College & Graduate Center

Abstract: One of the simplest control strategies one can implement in a dynamical system is to guide the solution towards one that is already given, even only partially. While this choice of control appears seemingly naive, it nevertheless has far-reaching consequences in mathematics and various real-world applications. One particularly powerful application of this concept is in context of verifying the ergodic hypothesis for stochastically forced systems. We discuss an application of this strategy in the case of the damped-driven stochastic Korteweg de Vries equation. Classically this equation was derived as model for shallow water waves. It has since become a canonical model for uni-dimensional wave propagation. In this talk, we show how this strategy can be used to demonstrate uniqueness of invariant probability measures as well as a streamlined approach to establishing regularity of its support.

MS03-B-1: Long-time statistics of SPDEs: mixing and numerical approximation

Cecilia Mondaini, Drexel University

Abstract: In analyzing complex systems modeled by stochastic partial differential equations (SPDEs), such as certain turbulent fluid flows, an important question concerns their long-time behavior. In particular, one is typically interested in determining how long it takes for the system to settle into statistical equilibrium, and in investigating efficient numerical schemes for approximating such long-time statistics. In this talk, I will present two general results in this direction, and illustrate them with an application to the 2D stochastic Navier-Stokes equations. Most importantly, our approach does not require gradient bounds for the underlying Markov semigroup as in previous works, and thus provides a flexible formulation for further applications. This is based on joint work with Nathan Glatt-Holtz (Tulane U).

MS03-B-2: Stabilizing phenomenon for incompressible fluids

Weinan Wang, University of Arizona

Abstract: This talk presents several examples of a remarkable stabilizing phenomenon. For the Oldroyd-B model, we show that small smooth data lead to global and stable solutions. When Navier-Stokes is coupled with the magnetic field in the magneto-hydrodynamics system, solutions near a background magnetic field are shown to be always global in time. The magnetic field stabilizes the fluid. In all these examples the systems governing the perturbations can be converted to damped wave equations, which reveal the smoothing and stabilizing effect.

MS03-B-3: Remarks on the two-dimensional magnetohydrodynamics system forced by space-time white noise

Kazuo Yamazaki, University of Nebraska-Lincoln

Abstract: We study the two-dimensional magnetohydrodynamics system forced by space-time white noise. Due to a lack of an explicit invariant measure, the approach of Da Prato and Debussche (2002, J. Funct. Anal., 196, pp. 180–210) on the Navier-Stokes equations does not seem to fit. We follow instead the approach of Hairer and Rosati (2023, arXiv:2301.11059 [math.PR]), take advantage of the structure of Maxwell's equation, such as anti-symmetry, to find an appropriate paracontrolled ansatz and many crucial cancellations, and prove the global-in-time existence and uniqueness of its solution.

MS03-B-4: Calming the Navier-Stokes Equations

Matt Enlow, University of Nebraska-Lincoln

Abstract: We propose a modification to 3D Navier-Stokes with either kinematic pressure term (NSE) or with Bernoulli pressure term

(rNSE) which "calms" the system in the sense that the algebraic degree of the nonlinearity is effectively reduced. This system, the calmed Navier-Stokes Equations, introduces a calming function applied to the nonlinear term which locally bounds high velocities. Under suitable conditions, we are able to prove the global well-posedness of strong solutions and the convergence of calmed solutions to NSE (or rNSE) solutions on the time interval of existence for the latter. Moreover, we are able to show that calmed NSE with a Bernoulli pressure term possesses both an energy identity and a compact global attractor.

MS03-C-1: The PE diagram
Xin Liu, Texas A&M University
Abstract: We introduce the asymptotic limit between the compressible Navier-Stokes equations, the incompressible Navier-Stokes equations, the compressible primitive equations, and the incompressible primitive equations. The relation is summarized as the PE diagram. Both the scaling and the rigorous proof will be presented.

MS03-C-2: Recent Results on Data Assimilation for Turbulent Flows
Adam Larios, University of Nebraska-Lincoln
Abstract: A major difficulty in accurately simulating turbulent flows is the problem of determining the initial state of the flow. For example, weather prediction models typically require the present state of the weather as input. However, the state of the weather is only measured at certain points, such as at the locations of weather stations or weather satellites. Data assimilation eliminates the need for complete knowledge of the initial state. It incorporates incoming data into the equations, driving the simulation to the correct solution. The objective of this talk is to discuss innovative computational and mathematical methods to test, improve, and extend a promising new class of algorithms for data assimilation in turbulent flows and related systems. We will look at how these techniques can be adapted to yield faster convergence and recover unknown parameters.

MS03-C-3: On the Proximity Between Solutions to the Completely Integrable Focusing Nonlinear Schrödinger Equation and its Non-Integrable Generalizations
Dionyssios Mantzavinos, University of Kansas
Abstract: The question of persistence of dynamics of completely integrable systems as one transitions to non-integrable settings is a central one in the field of nonlinear dispersive equations. In this talk, we discuss the proximity between the solutions to (i) the integrable focusing nonlinear Schrödinger (NLS) equation and (ii) a broad class of non-integrable generalized NLS counterparts of that equation, in the framework of the Cauchy (initial value) problem on the real line. We consider two main settings: the traditional scenario of zero boundary conditions at infinity, and the scenario of nonzero boundary conditions at infinity, which is less studied but very relevant in terms of physical applications, as it is directly related to the phenomenon of modulational instability. This is joint work with D. Hennig, N. Karachalios, J. Cuevas-Maraver, and I. Stratis.

MS03-C-4: Stable singularity formation of the inviscid primitive equations
Quyuan Lin, Clemson University
Abstract: Large scale dynamics of the oceans and the atmosphere are governed by the primitive equations (PEs). While the global well-posedness of viscous PEs has been well established, the smooth solutions to the inviscid PEs (also known as the hydrostatic Euler equations) can form singularity in finite time. In this talk, I will briefly introduce the inviscid PEs, and discuss the stability of a certain type of blowup for smooth solutions.

MS04-A-1: Triangle percolation on the grid
Tyrrell McAllister, University of Wyoming
Abstract: We consider a geometric percolation process motivated by recent work of Hejda and Kala in the theory of integral universal quadratic

forms. We start with an initial subset X of the lattice $\mathbb{Z}^2$, and then we iteratively check whether there exists a lattice triangle in $\mathbb{R}^2$ that contains exactly four points of $\mathbb{Z}^2$ with exactly three of these points in X. If we find such a triangle Δ, we add the missing lattice point of Δ to X, and we repeat this process until no such triangle exists. We call a subset $S \subset \mathbb{Z}^2$ *stable* if S is a limit set of this process. We determine the possible densities of stable sets in $\mathbb{Z}^2$, and we classify the stable sets that arise under various conditions on the initial set X.
This work is joint with Igor Araujo, Bryce Frederickson, Robert Krueger, Bernard Lidický, Florian Pfender, Sam Spiro, and Eric Stucky.

MS04-A-2: On quasiregular values

K. Ilmari Kangasniemi, University of Cincinati

Abstract: Quasiregular maps are an n-dimensional geometric generalization of holomorphic maps to $\mathbb{R}^n$, satisfying the distortion bound $|Df(x)|^n \leq Kdet(Df(x))$ almost everywhere. In this talk, we consider a generalization of this distortion bound of the form $|Df(x)|^n \leq Kdet(Df(x)) + \Sigma(x)|f(x) - y|^n$, where Σ is a locally L^p-integrable function for $p > 1$ and $y \in \mathbb{R}^n$ is a fixed point. It turns out that this condition yields a theory where f satisfies results similar to those of ordinary quasiregular maps at the single image point y. In particular, we discuss the generalizations that the theory of quasiregular values yields for the Liouville theorem, Reshetnyak's theorem, and Rickman's Picard theorem. Joint work with Jani Onninen.

MS04-A-3: Convergence of the Probabilistic Interpretation of Modulus

Joan Lind, University of Tennessee

Abstract: Many objects in complex analysis are approximated by discrete analogues. We consider three discrete objects on orthodiagonal maps: discrete modulus, discrete paths that are extremal for the modulus, and discrete harmonic functions. We show that these approximate their respective continuous counterparts: the continuous modulus, the extremal curves (or horizontal trajectories) for the modulus, and harmonic functions. This is joint work with Nathan Albin and Pietro Poggi-Corradini.

MS04-A-4: Homogeneous graph reinforcement

Huy Truong, Kansas State University

Abstract: The class of homogeneous graphs is a class of graphs that appears and plays an important role in the study of spanning tree modulus. A homogeneous graph satisfies a nice property where its strength is equal to its maximum denseness. In [6], Cunningham gives efficient algorithms for computing the strength and for finding a minimum cost reinforcement to achieve a desired strength. The algorithm computing the strength by Cunningham was used in [3] to give an algorithm for computing spanning tree modulus. In this paper, we are interested in the problem of finding a minimum cost reinforcement to make the resulting graph homogeneous. Moreover, we also give an algorithm for the problem of finding the maximum denseness of graphs and that gives rise to a new algorithm for computing spanning tree modulus.

MS04-B-1: Uniformization of metric surfaces

Matthew Romney, Stevens Institute of Technology

Abstract: The classical uniformization theorem states that any smooth simply connected Riemannian 2-manifold can be mapped conformally to either the disk, the sphere or the plane. We discuss our efforts to generalize this theorem to the setting of metric spaces homeomorphic to a surface under minimal assumptions. Conformal modulus methods are central to our approach. This talk represents joint work with D. Ntalampekos, P. Creutz and K. Rajala.

MS04-B-2: An Intrinsic Approach to Scalar-Curvature Estimation for Point Clouds, Networks, and Finite Metric Spaces

Abigail Hickok, Columbia University

Abstract: I will discuss recent results in which we introduce an intrinsic estimator for the scalar curvature of a data set presented as a fi-

nite metric space (e.g., a distance matrix, a point cloud, or a network with the shortest-path metric). Our estimator depends only on the metric structure of the data, and not on an embedding in Euclidean space. Our estimator is consistent in the sense that for points sampled randomly from a compact Riemannian manifold, the estimator converges to the scalar curvature as the number of points increases. Additionally, our estimator is stable with respect to perturbations of the metric (e.g., noise in the sample or error estimating the intrinsic metric), which justifies its use in applications. We validate our estimator experimentally on synthetic data that is sampled from manifolds with specified curvature.
This is joint work with Andrew J. Blumberg.

MS04-B-3: From the discrete to the continuum
Pietro Poggi-Corradini, Kansas State University
Abstract: Our first motivation for studying modulus on graphs rested on the fact that the theory of modulus of curve families in the complex plane, in Euclidean spaces, or more generally, in metric measure spaces, is a well-established and powerful tool in analysis. So it made sense to try and adapt it to the context of graph theory and networks.
However, after fully developing the theory in the discrete, it became clear that one should try and go back to the continuum, armed with this new point of view. In this talk I will give three examples of results in the continuum that were inspired by the theory in the discrete setting.

MS04-B-4: Modulus of edge covers and stars
Adriana M. Ortiz Aquino, Kansas State University
Abstract: This talk explores the modulus (discrete p-modulus) of the family of edge covers on a discrete graph. This modulus is closely related to that of the larger family of fractional edge covers; the modulus of the latter family is guaranteed to approximate the modulus of the former within a multiplicative factor of $(4/3)^p$. These bounds can be computed efficiently due to a duality result that relates the fractional edge covers to the family of stars.

MS04-C-1: ON REGULARITY OF SETS OF FINITE FRACTIONAL PERIMETER IN METRIC MEASURE SPACES
Josh Kline, University of Cincinnati
Abstract: Federer's characterization states that a set is of finite perimeter if and only if its measure theoretic boundary has finite codimension 1 Hausdorff measure. In this talk, we discuss the extent to which an analog of this result holds for sets of finite α-perimeter, with $0 < \alpha < 1$, in doubling metric measure spaces. Here the α-perimeter is defined via the Besov seminorm, and as shown by Dávila in $\mathbb{R}^n$ and Di Marino and Squassina in the metric setting, recovers the perimeter of a set as $\alpha \to 1^-$ under suitable rescaling. We also consider a nonlocal minimization problem for the α-perimeter with respect to a given domain, as introduced by Caffarelli, Roquejoffre, and Savin in $\mathbb{R}^n$, and discuss boundary regularity results for minimizers in the metric setting.

MS04-C-2: Whitney Extension in the Heisenberg Group and Beyond
Gareth Speight, University of Cincinnati
Abstract: The classical Whitney extension theorem characterizes when a mapping defined on a compact subset of R^n can be extended to a smooth mapping on the whole of R^n. In the last few decades it has become clear that a large part of mathematical analysis can be extended to more general spaces. In this talk we describe some recent versions of the Whitney extension theorem for curves in the Heisenberg group and more general spaces. The Heisenberg group arises naturally in physics and can be viewed as a Euclidean space equipped with a non-abelian group operation. This talk does not assume previous knowledge concerning Whitney extension or the Heisenberg group.

MS04-C-3: Spectral Gaps and Cubical Complexes
Eric Babson, University of California at Davis
Abstract: Garland introduced a cohomologi-

cal vanishing criterion for simplicial complexes based on the spectral gaps of the graph Laplacians of the links of faces which has turned out to be effective in a wide range of examples. In this note we extend the approach to include various posets including both simplicial and cubical face posets and to give cohomological generators rather than vanishing and elaborate further on the cubical case.

MS04-C-4: Gravitational Lensing and Dynamics of Rational Maps

Lukas Geyer, Montana State University

Abstract: Gravitational lensing is the bending of light by massive objects such as stars and galaxies. In the last 20 years, techniques from complex analysis and complex dynamics have been successful in establishing sharp bounds on the number of apparent images of a single light source for certain gravitational lenses. We will give novel applications of techniques from complex dynamics to study and classify gravitational lens configurations.

MS05-A-1: Grounded ice sheets melting as an obstacle problem

Paolo Piersanti, Indiana University

Abstract: In this talk, which is the result of a joint work of the speaker with Roger Temam (IU), we formulate a model describing the evolution of thickness of a grounded shallow ice sheet. The thickness of the ice sheet is constrained to be nonnegative, rendering the problem under consideration an obstacle problem. A rigorous analysis shows that the model is thus governed by a set of variational inequalities that involve nonlinearities in the time derivative and in the elliptic term, and that it admits solutions, whose existence is established by means of a semi-discrete scheme and the penalty method.

MS05-A-2: Fractional Voigt Regularization of the 3D Navier Stokes Equations

Isabel Safarik, University of Nebraska-Lincoln

Abstract: The Navier-Stokes (NS) equations are used to describe turbulent flows under certain conditions. While NS is applied in many areas of science and technology, well-posedness in 3D is a long-standing open problem in mathematical physics. In this talk, we consider a regularization of these equations that can be used to model large scales by filtering out small scales analytically. As opposed to the standard NS-Voigt model, the fractional Voigt model allows for dissipative effects. We will discuss existence and uniqueness, convergence, a blow-up criterion for NS, and numerical simulations.

MS05-A-3: Luenberger Compensator Theory for Heat-Structure Interaction via Boundary/Interface Feedback Controls

Xiang Wan, Loyola University Chicago

Abstract: In this talk, we will introduce some recent development of a continuous theory of the Luenberger dynamic compensator (or state estimator or state observer), with applications on a class of heat-structure interaction PDE-models, with structure subject to high Kelvin-Voigt damping, and feedback control exercised either at the interface between the two media or else at the external boundary of the physical domain in three different settings. Three different cases of controls will be discussed: (i) Neumann type at the interface; (ii) Dirichlet type at the interface; (iii) Dirichlet type at the external boundary. Our goal is to reveal how delicate PDE-energy estimates dictate how to define the interface/boundary feedback control in each of the three cases.

MS05-A-4: Local Nonuniqueness for Stochastic Transport Equations with Deterministic Drift

Andre Schenke, Courant Institute of Mathematical Sciences at New York University (NYU)

Abstract: We study well-posedness for the stochastic transport equation with transport noise, as introduced by Flandoli, Gubinelli and Priola. We consider periodic solutions in $\rho \in L_t^\infty L_x^p$ for divergence-free drifts $u \in L_t^\infty W_x^{\theta,\tilde{p}}$ for a large class of parameters. We prove local-in-time pathwise nonuniqueness and compare

them to uniqueness results by Beck, Flandoli, Gubinelli and Maurelli, addressing a conjecture made by these authors, in the case of bounded-in-time drifts for a large range of spatial parameters. To this end, we use convex integration techniques to construct velocity fields u for which several solutions ρ exist in the classes mentioned above. The main novelty lies in the ability to construct deterministic drift coefficients, which makes it necessary to consider a convex integration scheme *with a constraint*, which poses a series of technical difficulties. Joint work with Stefano Modena.

MS05-B-1: Controllability of a Cochlea Model
Scott Hansen, Iowa State University
Abstract: We consider some basic fluid-elastic systems that have been used to model cochlear dynamics of the inner ear and and corresponding control problems based on inputs that could model i) pressure from the ear drum, ii) forces locally distributed on the basilar membrane and iii) boundary control at the end of the BM. When the BM is modelled as independent oscillators the fluid is dominant and an approximate controllability result holds. If tension is included exact controllabiity is possible with appropriate controllers.

MS05-B-2: Synchronization of stochastic models in complex networks
Hakima Bessaih, Florida International University
Abstract: we consider a complex network consisting of reaction-diffusion system of equations subject to a stochastic coupling. We investigate the longtime behavior of the system resulting in synchronization. We will describe different situations where the synchronized model is either random or deterministic.

MS05-B-3: Several Robust Model Reductions for the Boundary Feedback Stabilization of Fully Magnetic Piezoelectric Smart Beams
Ahmet Kaan Aydin, University of Maryland, Baltimore County
Abstract: Piezoelectric materials exhibit electric responses to mechanical stress and mechanical responses to electric stress. The electrostatic and magnetizable PDE models, describing the longitudinal oscillations on the beam, with boundary feedback sensors/actuators are known to have exponentially stable solutions. Firstly, a thorough analysis of the maximal decay rate via the optimal choice of feedback sensor amplifiers is discussed. Next, model reductions by standard Finite Differences and Finite Elements, with the discretization parameter h, are proposed. Indeed, numerical filtering is implemented for each case to eliminate the spurious high-frequency modes. The exponential decay rate, as a function of the filtering parameter, is obtained uniformly as h goes to zero, mimicking the PDE counterpart. However, the lack of optimality of the applied filtering is one of the drawbacks of these model reductions. Finally, we propose a recently developed Finite-Difference based model reduction for the order-reduced PDE model. Without the need for any filtering, we successfully obtained the exponential decay rate uniformly as h goes to zero. This novel model reduction approach is promising for coupled PDE systems of the same sort.
Several ongoing and open problems will be also discussed.

MS05-B-4: A New Practical Framework for the Stability Analysis of Perturbed Saddle-point Problems and Applications
Qingguo Hong, Missouri University of Science and Technology
Abstract: This talk provides a new abstract stability result for perturbed saddle-point problems which is based on a proper norm fitting. We derive the stability condition according to Bauska's theory from a small inf-sup condition, similar to the famous Ladyzhenskaya-Bauska-Brezzi (LBB) condition, and the other standard assumptions in Brezzi's theory under the resulting combined norm. The proposed framework allows to split the norms into proper seminorms and not only results in simpler (shorter) proofs of many stability results but also guides the con-

struction of parameter robust norm-equivalent preconditioners. These benefits are demonstrated with several examples arising from different formulations of Biot's model of consolidation.

MS05-C-1: Babuska-Brezzi formulation for semigroup wellposedness of a coupled composite structure-fluid interaction PDE system

Pelin Guven Geredeli, Clemson University

Abstract: This talk will focus on the coupled PDE systems which have implications in the modeling of certain phenomena in biomedicine. To wit, we will consider a multilayered structure-fluid interaction PDE system which has been used in the literature to describe the blood transport process within vascular walls. Our main objective is to establish semigroup wellposedness of the coupled PDE system by way of "nonstandard" elimination of associated pressure terms via appropriate nonlocal operators and subsequent Babuska-Brezzi formulations.

MS05-C-2: NON-UNIQUE STATIONARY SOLUTIONS OF FORCED SQG

Qirui Peng, University of Illinois at Chicago

Abstract: We show the existence of non-unique stationary weak solutions for forced surface quasi-geostrophic (SQG) equations via a convex integration scheme. The scheme is implemented for the sum-difference system of two distinct solutions. Through this scheme, one observes the external forcing is naturally generated accompanying the feature of lack of uniqueness. It thus provides a transparent way to see the flexibility of the system with the presence of a forcing.

MS05-C-3: New a priori interior trace estimates on the 3D incompressible Navier-Stokes equation

Jincheng Yang, University of Chicago

Abstract: We derive several nonlinear a priori trace estimates for the 3D incompressible Navier-Stokes equation, which extend the current picture of higher derivative estimates in the mixed norm. The main ingredient is the blow-up method and a novel averaging operator. It could apply to PDEs with scaling invariance and ϵ-regularity.

MS05-C-4: Semigroup Well-Posedness and Finite Element Approximation for a Biot Model

Sara McKnight, University of Nebraska-Lincoln

Abstract: The Biot equations describe the dynamics of a semi-permeable, elastic solid filled with a viscous, compressible fluid. These equations have numerous applications, including biomedical sciences and thermoelasticity. In this talk, we will establish semigroup well-posedness for a fully dynamic Biot model. The weak formulation which arises in this process admits a finite element formulation for a static version of the problem. We will present numerical results from implementing the finite element scheme.

MS06-A-1: Stability and time-step constraints of implicit-explicit Runge–Kutta methods for the linearized Korteweg–de Vries equation

Zheng Sun, The University of Alabama

Abstract: In this talk we present a study on the stability and time-step constraints of solving the linearized Korteweg–de Vries (KdV) equation, using implicit-explicit (IMEX) Runge-Kutta (RK) time integration methods combined with either finite difference or local discontinuous Galerkin spatial discretization. We analyze the stability of the fully discrete scheme, on a uniform mesh with periodic boundary conditions, using the Fourier method. For the linearized KdV equation, the IMEX schemes are stable under the standard CFL condition $\tau \leq \hat{\lambda} h$. Here $\hat{\lambda}$ is the CFL number, τ is the time-step size, and h is the spatial mesh size. We study several IMEX schemes and characterize their CFL number as a function of $\theta = d/h^2$ with d being the dispersion coefficient, which leads to several interesting observations. We also investigate the asymptotic behaviors of the CFL number for sufficiently refined meshes and derive the necessary conditions for the asymptotic sta-

bility of the IMEX-RK methods. Some numerical experiments are provided in the paper to illustrate the performance of IMEX methods under different time-step constraints.

MS06-A-2: An immersed finite element method and error analysis for elastodynamic interface problems

Xu Zhang, Oklahoma State University

Abstract: In this talk, we present an immersed finite element (IFE) method for solving elastodynamics interface problems on interface-unfitted meshes. For spatial discretization, we use vector valued P1 and Q1 IFE spaces. We establish some important properties of these IFE spaces, such as inverse inequalities, which will be crucial in the error analysis. For temporal discretization, both the semi-discrete and the fully discrete schemes are derived. These discretized schemes are proved to be unconditionally stable and enjoy optimal rates of convergence in the energy, and L2 norms. Numerical examples are provided to confirm our theoretical analysis and to demonstrate the stability and robustness of our schemes.

MS06-A-3: A high order geometry conforming immersed finite element for elliptic interface problems

Haroun Meghaichi, Virginia Tech

Abstract: We present a high order immersed finite element method for the elliptic interface problem using interface-independent meshes. The IFE functions developed here satisfy the interface conditions strongly, have optimal approximation capabilities, and their construction is easy and robust.

This new framework allows us to use the classical symmetric interior penalty discontinuous Galerkin scheme without additional penalties on the interface. Numerical examples are included at the end that showcase the convergence properties of the method under h and p refinements.

MS06-A-4: Optimal Error Estimates of Ultra-weak Discontinuous Galerkin Methods with Generalized Numerical Fluxes for Multi-dimensional Convection-Diffusion and Biharmonic Equations

Yuan Chen, Ohio State University

Abstract: We study ultra-weak discontinuous Galerkin methods with generalized numerical fluxes for multi-dimensional high order partial differential equations on both unstructured simplex and Cartesian meshes. The equations we consider as examples are the non-linear convection-diffusion equation and the biharmonic equation. Optimal error estimates are obtained for both equations under certain conditions, and the key step is to carefully design global projections to eliminate numerical errors on the cell interface terms of ultra-weak schemes on general dimensions. The well-posedness and approximation capability of these global projections are obtained for arbitrary order polynomial space based on a wide class of generalized numerical fluxes on regular meshes. These projections can serve as general analytical tools to be naturally applied to a wide class of high order equations. Numerical experiments are conducted to demonstrate these theoretical results. This is a joint work with Dr. Yulong Xing.

MS06-B-1: High-order IPDG Method for Anisotropic Diffusion Equations

Lin Mu, University of Georgia

Abstract: In this talk, we present an interior penalty discontinuous Galerkin finite element scheme for solving diffusion problems with strong anisotropy arising in magnetized plasmas for fusion applications. In such application, the anisotropy is introduced by strong magnetic fields. The heat conduction along the parallel field direction may at the order 10^6 (boundary region) to 10^12 (core region) larger than that along perpendicular direction. Due to the high anisotropy ratio, the errors in the parallel may significantly affect the error in the perpendicular direction and thus cause numerical pollution. One possible way is to perform the simulation on the aligned mesh. However, for our

interested far scrape off layer region, the filed aligned mesh is almost impossible to use. In order to handle the high geometry fidelity and relax the burden in mesh generation, we propose the high order discontinuous Galerkin methods on the non-aligned mesh together with the efficient linear solver of auxiliary space preconditioner. We demonstrate the accuracy produced by the high-order scheme and efficiency in the preconditioning technique, which is robust to the mesh size and anisotropy of the problem. Several numerical tests are provided to validate the proposed algorithm.

MS06-B-2: Hybridizable discontinuous Galerkin methods for coupled systems of porous/poroelastic media and free flow equations

Jeonghun Lee, Baylor University

Abstract: In this work we present hybridizable discontinuous Galerkin (HDG) methods for the problems that Stokes/Navier-Stokes equations and porous/poroelastic equations are coupled with interface.

In our HDG methods the compressibilities of fluid and poroelastic matrix, and the fluid mass in poroelastic domain are strongly conservative. For time-dependent Navier-Stokes equations on free fluid domain, we derive quantatitive conditions for well-posedness of time-dependent numerical solutions and proved the a priori error estimates. This is a joint work with Aycil Cesmelioglu at Oakland University and Sander Rhebergen at University of Waterloo.

MS06-B-3: A Positivity-preserving and Robust Fast Solver for Time-fractional Convection-subdiffusion Problems

Jiangguo (James) Lin, Colorado State University

Abstract: This talk presents a fast solver for time-fractional two-dimensional convection-subdiffusion problems that maintains nonnegativity of numerical solutions. To this end, two new techniques are developed. (i) A three-part decomposition of the L1 discretization for Caputo derivatives is proposed and justified for fast evaluation while maintaining positivity; (ii) A positivity-correction technique is devised for both diffusive and convective fluxes. An upwinding technique for the bilinear finite volume approximation on general quadrilaterals is utilized for enabling the solver robustness in handling convection dominance. The solver attains optimal convergence rates when graded temporal meshes are used. These properties are theoretically justified and numerically illustrated. This is a joint work with Boyang Yu and Prof. Yonghai Li at Jilin University.

MS06-B-4: A fully decoupled iterative method with 3D anisotropic immersed finite elements of non-homogeneous flux jump for Kaufman-type discharge problems

Xiaoming He, Missouri University of Science and Technology

Abstract: In order to simulate the Kaufman-type discharge problems, a fully decoupled iterative method with anisotropic immersed finite elements on Cartesian meshes is proposed, especially for a three-dimensional (3D) non-axisymmetric anisotropic hybrid model which is more difficult than the axisymmetric or isotropic models. The classical hybrid model, which describes the important plasma distribution of the Kaufman-type discharge problems, couples several difficult equations together to form a large scale system. The 3D non-axisymmetric and anisotropic properties will further increase the complexity of this system. Hence it generally needs to be solved in the decoupled way for significantly reducing the computational cost. Based on the Particle-in-Cell Monte Carlo collision (PIC-MCC) method and the immersed finite element (IFE) method, we propose a fully decoupled iterative method for solving this complex system. The IFE method allows Cartesian meshes for general interface problems, while the traditional finite element methods require body-fitting meshes which are often unstructured. Compared with traditional finite element methods, this feature significantly improves the efficiency of the proposed 3D fully decoupled iterative method, while maintaining the optimal accuracy of the chosen finite elements. Numerical simulations of traditional Kaufman ion thruster and annular ion thruster discharge chambers are provided and compared with the corresponding lab experiment results to illustrate the features of the proposed method.

MS07-A-1: TBD
Rana Parshad, Iowa State University
Abstract: TBD

MS07-A-2: Understanding the Chemostat and reversing Competitive Exclusion
Thomas Griffin, Iowa State University
Abstract: The chemostat, short for "chemical environment station," is a powerful tool used in microbiology and bio-process engineering to study the interactions between microbial populations and their environment. With its ability to mimic real-world ecosystems and sustain continuous cultures under precise conditions, the chemostat opens a window into understanding fundamental biological processes, optimizing industrial production of biofuels, pharmaceuticals, and other valuable compounds, and even shedding light on ecological dynamics. In the well-studied classical chemostat model competitive exclusion occurs with the strongest species surviving, in this talk we will investigate a novel change in the classical chemostat model and outline the dynamics of the new system, as well as explore the impact of changing the human controlled parameters of the model to influence the stability of species inside the system.

MS07-A-3: A patch driven additional food model
Urvashi Verma, Iowa State University
Abstract: Patch models have been widely used in ecology whenever population dispersal is involved. In this paper, we observed that introducing a patchy environment helps the pest's controllability of the underlying 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. We show that this modified patch model helps to achieve locally stable pest extinction in one patch while other populations exhibit stable limit cycles. This model also demonstrates that low levels of pests can be obtained compared to classical prey-predator models. The simulations further indicate that the system can exhibit chaotic behavior for some quantity of additional food. This is a joint work with Rana Parshad and Aniket Banerjee.

MS07-A-4: Sex-biased predation and predator intraspecific competition effects in a mating system
Eric Takyi, Ursinus College
Abstract: Invasive species are nonnative species capable of causing economic and environmental harm and are very difficult and costly to eradicate. There are several control methods utilized to regulate them, one of which is biocontrol, which involves the introduction of natural enemies (predators). There is evidence that some invasive species are being predated based on sex-bias as a result of sexual dimorphism. In this talk, we will discuss the impacts of sex-biased predation in a mating system together with its ecological implications. Numerical simulations will be provided to support theoretical results.

MS07-B-1: A discrete Model for the Trojan Y Chromosome Strategy
Don "Kumudu" Mallawa Arachchi, Iowa State University
Abstract: The Trojan Y Chromosome strategy is used as a biological control of invasive species in which a genetically modified species is introduced to skew the sex ratio, thereby inducing a population decline. We propose a gender- and state-structured discrete-time model with harmonic-mean birth functions. The model gives rise to the existence of an extinction equilibrium, and we find the conditions for the existence of a positive equilibrium. Some numerical simulations are carried out to illustrate the

behavior of the population.

MS07-B-2: Dynamical Analysis of a Lotka-Volterra Competition Model with both Allee and Fear Effect

Vaibhava Srivastava, Iowa State University

Abstract: Population ecology theory is replete with density-dependent processes. However, trait-mediated or behavioral indirect interactions can both reinforce or oppose density-dependent effects. This paper presents the first two species of competitive ODE and PDE systems. The non-consumptive behavioral fear effect and the Allee effect, a density-dependent process, are present. The stability of the equilibria is discussed analytically using the qualitative theory of ordinary differential equations. It is found that the Allee effect and the fear effect change the extinction dynamics of the system and the number of positive equilibrium points, but they do not affect the stability of the positive equilibria. We also observe standard co-dimension one bifurcation in the system by varying the Allee or fear parameter. Interestingly, we find that the Allee effect, working in conjunction with the fear effect, can bring about several dynamic changes to the system with only fear. There are three parametric regimes of interest in the fear parameter. For small and intermediate amounts of fear, the Allee + fear effect opposes dynamics driven by the fear effect. However, for large amounts of fear, the Allee + fear effect reinforces the dynamics driven by the fear effect. The analysis of the corresponding spatially explicit model is also presented. To this end, the comparison principle for parabolic PDE is used. The conclusions of this paper have strong implications for conservation biology, biological control as well and the preservation of biodiversity.

MS07-B-3: Towards holistic modeling of invasive species, zoonotic diseases, and climate change

Majid Bani-Yaghoub, University of Missouri-Kansas City

Abstract: The spatiotemporal dynamics of invasive species have been historically modeled by ordinary and delayed partial differential equations. In the past two decades, the existence and stability of traveling waves have been the focus of several studies. We have previously shown that traveling wave solutions of population models can become oscillatory due to increased maturation delay. In the present work, we have developed a nonlocal hyperbolic-parabolic population model to analyze and numerically explore the destabilizing effects of dispersal delay on the stationary wave pulse of wavefronts of invasive species. These results are essential because invasive species can serve as a reservoir host for diseases that can spill over to humans or other animals. Our current modeling efforts are focused on incorporating climatic factors to study how climate change can influence the dynamics of invasive species and increase the likelihood of zoonotic spillover in certain regions of the US.

MS07-B-4: The changing dynamics of Virulent and Avirulent Aphids: Effect of plant suitability and soybean field flooding

Aniket Banerjee, Iowa State University

Abstract: The soybean Aphid is an invasive pest that causes severe yield loss to soybean in the North Central United States. A tactic to counter this pest is the use of aphid-resistant soybean varieties. However, the frequency of virulent biotypes that can survive on resistant varieties is expected to increase as more farmers use these varieties. To understand the population dynamics of soybean aphids a dynamical system is formulated to replicate the dynamics of soybean aphids on susceptible soybean plants in fields. Two soybean aphid biotypes (Avirulent and Virulent aphids) are also considered that are and are not affected by the aphid-resistant varieties. Simulations are done by data-fitting field data on different mathematical models to find the best way to describe the dynamics of the aphids. A continuous model is also formulated to mimic the change in soybean plant suitability in a sin-

gle season. Currently, flooding is a common scenario seen across different agricultural fields across the globe. Flooding can affect the yield as well as the dynamics of the pest population. So, experiments are conducted to analyze the effect of flooding for a week effect on the aphid population and formulate the model to take flooding throughout the season into account and predict the change in aphid dynamics using a mathematical model and simulations.

MS08-A-1: Robust Model Reductions for the Strongly-Coupled PDEs of Piezoelectric Multilayer Beams

Ahmet Ozkan Ozer, Western Kentucky University

Abstract: Two PDE models describing the vibrations on a multilayer smart beam with arbitrary number of piezoelectric layers are considered. The standard electrostatic approximation of Maxwell's equations is adopted. These PDE models are known to be exactly observable in appropriate Hilbert spaces with a single boundary sensor measurement. However, as the standard Finite Differences are considered, it is proved that the model reductions lack exact observability uniformly as the mesh parameter goes to zero, $h \to 0$. This is a known phenomenon in the literature, mainly caused by spurious (artificial) high-frequency eigenvalues. Moreover, these eigenvalues get extremely crammed, causing the uniform gap approach zero, as $h \to 0$. Unlike the single beam case, there may be multiple branches of eigenvalues in the spectrum of the system operator. Therefore, first, each branch must be filtered appropriately by the so-called direct Fourier filtering. Then, it is proved that the exact observability of the model uniformly as $h \to 0$, can be retained back by the implementation of the direct Fourier filtering technique. Unfortunately, the optimality of the applied filtering is ambiguous for practical implementations. For this reason, next, an alternate model reduction is investigated by cleverly reducing the order of the model together with the consideration of equidistant grid points and averaging operators. The new model reduction successfully retains the exact observability uniformly as $h \to 0$ without any need of a further numerical filtering. Our results are based on both non-harmonic Fourier series and discrete multipliers techniques. All of the presented results can be adopted for single-layer Euler Bernoulli and Rayleigh beam models. There are various open problems to be shared by the audience.

MS08-A-2: Uniform Stability in a Vectorial Full Von Karman Thermoelastic System with Solenoidal Dissipation and Free Boundary Conditions

Catherine Lebiedzik, Wayne State University

Abstract: We will consider the full von Karman thermoelastic system with free boundary conditions and dissipation imposed only on the in-plane displacement. It will be shown that the corresponding solutions are exponentially stable, though there is no mechanical dissipation on the vertical displacements. The main tools used are: (i) partial analyticity of the linearized semigroup and (ii) trace estimates which exploit the hidden regularity harvested from partial analyticity.

MS08-A-3: Multi-Scale Interface Coupling between Deformable Porous Media and Lumped Hydraulic Circuits

Sarah Strikwerda, University of Pennsylvania

Abstract: We consider an elliptic-parabolic coupled partial differential equation connected to a nonlinear ODE through an interface. The model describes fluid flowing through biological tissues with the ODE accounting for global features of blood flow that affect the tissue. We discuss a modeling choice on the interface coming from the fact that the ODE is 0D and the PDE is 3D and show existence of a solution to this problem using semigroup theory for implicit evolution and a contraction mapping.

MS08-A-4: Existence and stability of forced oscillation of a type of parabolic equations

Taige Wang University of Cincinnati

Abstract: We establish the existence of time-

periodic solutions of 1D viscous Burgers Equation and 2D incompressible Navier-Stokes Equation when a periodic force is applied in bounded domains. This is referred to as forced oscillation. Following, its stability is obtained. We would point out the results are due to the fact of smallness of forced oscillations when periodic force is small.

MS08-B-1: Global Attractors for Suspension Bridge Models Under Unstable Flow of Gas
Madhumita Roy, The University of Memphis
Abstract: In this talk we address long-term behavior of solutions to a plate model describing a suspension bridge with mixed boundary condition in presence of wind-effect and polynomial type weak damping. We prove the well-posed of the dynamical system by the traditional theory of nonlinear semigroups and monotone operators. Existence of the global attractor is shown by constructing an Absorbing set and then showing quasi-stability property of the system. Due to the presence of the term u_y, the dynamical system becomes non-Gradient; to overcome this crisis we use the Barrier's method for the construction of the Absorbing set.

MS08-B-2: The relativistic Euler equations for an ideal gas with a physical vacuum boundary
Brian Luczak, Vanderbilt University
Abstract: In this presentation, we will provide several preliminary results on the relativistic Euler equations for an ideal gas equation of state and a physical vacuum boundary. Our focus will be on choosing the correct thermodynamic variables, and then providing energy estimates for the linearized system. To conclude, we discuss next steps in connecting our analysis back to the quasilinear system.

MS08-B-3: Fluid–Plate Interaction with Kelvin-Voigt Damping and Bending Moment at the Interface: Well-posedness, Spectral Analysis, Uniform Stability
Rasika Mahawattege, University of Maryland, Baltimore County
Abstract: We consider a fluid-plate interaction model where the two dimensional plate is subject to viscoelastic (strong) damping, as it occurs in some biological systems. Coupling occurs at the interface between the two media, where each component evolves. In this paper, we apply "low" physically hinged boundary interface conditions, which involve the bending moment operator for the plate. We prove four main results: (1) analyticity, on the natural energy space, of the corresponding contraction semigroup (and of its adjoint); (2) sharp location of the spectrum of its generator (and similarly of the adjoint generator), neither of which has compact resolvent. 3) both original generator and its adjoint have the origin as a common eigenvalue with a common, explicit, 1-dimensional eigenspace; (4) The subspace of codimension 1 obtained by the original energy space by factoring out the common 1-dimensional eigenspace is invariant under the action of the (here restricted) semigroup (or of its adjoint), and on such subspace both original and adjoint semigroups are uniformly stable.

MS08-B-4: A regularity criterion for the 3-D 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.

The first result we present will be for a "general" Leray-Hopf weak solution on the so-called weak attractor, while the second will be for a weak solution with a sufficiently smooth initial condition.

MS08-C-1: Existence of solutions past collisions for viscoelastic solids
Giovanni Gravina, Arizona State University
Abstract: In this talk, we will consider the time evolution of viscoelastic solids within a framework that allows for collisions and self-contact. In the static and quasi-static regimes, corresponding existence results have been shown through variational descriptions of the problem. For the fully dynamical case, however, collisions have so far either been ignored or handled using a simplified model, e.g. repulsive terms. In contrast to this, by employing a newly developed variational technique, we are able to prove the existence of solutions for arbitrary times. Our presentation will additionally delve into the latest developments concerning solids with Lipschitz boundaries.

MS08-C-2: Time Dependent Finite Elements for a Fluid-Structure System
Dylan McKnight, University of Nebraska-Lincoln
Abstract: In this talk we will introduce a numerical scheme for the analysis of solutions to a Fluid-Structure system. The numerical scheme centers on a Ritz Galerkin spatial approximation with appropriate time stepping. Through this numerical lens we will discuss the regularity of the system (i.e. its Gevrey class) by providing solutions that exhibit smoothing of data. Time permitting, we will see how one may utilize such a numerical scheme to answer questions of null controllability.

MS08-C-3: A brief introduction to the controllability of quantum systems:Lie algebras, representations and the role of symmetries
Domenico D'Alessandro, Iowa State University
Abstract: For finite dimensional, closed, quantum systems subject to the action of an external control function, the model is typically given by the Schrodinger operator equation, that is, the time varying differential equation for the evolution operator of the system.
Driving this operator to a desired value often means to perform a desired quantum logic operation. The controllability analysis describes the set of states that can be reached with this type of systems. Since the evolution operator is a unitary matrix, it is appropriate to analyze the dynamics on the Lie group of n x n unitary matrices. Techniques of Lie theory and representation theory become important. In particular a Lie algebra rank condition tells us whether all the unitary evolutions can be achieved. The presence of a group of symmetries suggests that the dynamics take a block diagonal form and it is not controllable. The mathematical problem is then to find an appropriate change of coordinates to put the system in a block diagonal form and to study the controllability of each subsystem.
This talk will describe the Lie theoretic foundations of the study of the controllability of quantum systems and recent results on the decomposition of uncontrollable networks of quantum systems subject to symmetries. Quantum systems subject to symmetries are of great current interest due to their role in geometric quantum machine learning and in the treatment of structured quantum data.

MS08-C-4: Stability analysis on HDG method for elliptic equation
Yukun Yue, University of Wisconsin-Madison
Abstract: We delve into the stability and convergence of the hybridizable discontinuous Galerkin (HDG) finite element method for second-order elliptic equations. Central to our study is a novel Poincaré-type inequality crafted for hybridizable elements. Notably, we explore the method with a constant stabilization parameter under minimal regularity conditions. Contrasting prior works, our analysis provides a rigorous theoretical assessment of energy stability based solely on fundamental assumptions about the data within specific domains.

MS09-A-1: Full weak Galerkin FEMs for linear and nonlinear poroelasticity problems

Zhuoran Wang, University of Kansas

Abstract: In this talk, we present full weak Galerkin (WG) schemes for both linear and nonlinear poroelasticity problems. Both the Darcy pressure and the elasticity are discretized using the WG finite element method. We establish discrete weak gradient and numerical velocity in the Arbogast-Correa space. We formulate the fully-discrete system using implicit Euler time discretization and Crank-Nicolson method for higher order methods. Iterative methods to handle nonlinear cases featuring permeability dependent on dilation or stress are being discussed. Numerical experiments are presented for validating the accuracy and the locking-free property of the new solvers.
This is a joint work with Dr. James Liu, Dr. Simon Tavener, and Dr. Ruishu Wang.

MS09-A-2: Weak Galerkin Methods

Chunmei Wang, University of Florida

Abstract: The speaker will present the basics of weak Galerkin Methods.

MS09-A-3: Front Tracking Method for the Numerical Simulations of Turbulent Mixing

Tulin Kaman, University of Arkansas

Abstract: Numerical simulations of turbulent mixing induced by hydrodynamics instabilities are of great interest in a variety of scientific and engineering problems, such as astrophysical and high-energy-density applications. In this talk, we present an increasingly accurate front tracking method used to describe the evolution of turbulent mixing at the interface of two fluids and predict the state variables of flow changed sharply. The numerical simulation results have been compared with the experimental data of Rayleigh-Taylor Instability (RTI) and Richtmyer–Meshkov instability (RMI). We achieve good agreement on the evolution of the RTI/RMI turbulent mixing layers between the numerical simulations and experiments.

MS09-A-4: Pressure robust numerical scheme for incompressible flow

Lin Mu, University of Georgia

Abstract: In this talk, we shall introduce the recent development regarding the pressure robust finite element method (FEM) for solving incompressible flow. Due to the viscosity and pressure independence in the velocity approximation, our scheme is robust with small viscosity and/or large permeability, which tackles the crucial computational challenges in fluid simulation. Then this method will be applied to solve several other impressible fluid equations. We shall discuss the details in the implementation and theoretical analysis. Several numerical experiments will be tested to validate the theoretical conclusion.

MS10-A-1: Parameter estimation in nonlinear PDEs

Vincent Martinez, CUNY Hunter College & Graduate Center

Abstract: In this talk, we will describe a class of algorithms for identifying unknown parameters of nonlinear PDEs. In the absence of observational errors, the convergence of these algorithms can be rigorously established under the assumption that sufficiently many scales of the solution are observed and that certain non-degeneracy conditions hold, which ensures identifiability of the parameters. This approach to parameter estimation is robust and can be applied not only to recover damping coefficients, but also external driving forces that are unknown apriori. Moreover, it is applicable to a large class of nonlinear equations, including many of those that arise in hydrodynamics, such as the 2D Navier-Stokes equations of incompressible flow, the 2D system for Rayleigh-Benard convection, the 3D primitive equations, or even dispersive-type models such as the 1D Korteweg-de Vries equation or 1D cubic nonlinear Schrödinger equation. We describe the derivation of these algorithms, address their convergence, and showcase the results of several computational experiments.

MS10-A-2:Learning Parameters and Forcing Terms in Turbulent Flows Using Analytic Techniques

Elizabeth Carlson, California Institute of Technology

Abstract: In this talk, I will be giving a summary of recent papers proposing and proving methods for recovering parameters and forcing in equations for turbulent flows. The methods all rely on insertion of data (data assimilation) from a system with the correct parameters/forcing into a system with "knowledge" of the true state using a feedback control term. In the data assimilation world, this particular method is known as nudging, the AOT or CDA algorithm, or restoring. These papers propose analytically motivated alternatives to the more popular method of model term recovery, machine learning methods. The results presented will summarize work from multiple papers authored by me and/or my collaborators in our research group.

MS10-A-3: Operator learning and nonlinear dimension reduction by deep neural networks

Wenjing Liao, Georgia Institute of Technology

Abstract: This talk focuses on the problem of operator learning to learn an operator between function spaces from data. Dimension reduction plays a significant role, to reduce the data dimension and the problem size. We consider a neural network architecture to utilize low-dimensional nonlinear structures in dimension reduction, and prove an upper bound of the generalization error. Our theory shows that, the sample complexity depends on the intrinsic dimension of the model.

MS10-A-4: Learning a zero of the score operator: a new transport method for Bayesian inference and sampling

Nisha Chandramoorthy, Georgia Institute of Technology

Abstract: In Bayesian data assimilation, we are interested in sampling repeatedly from Bayesian posteriors that assimilate newly available data. When the underlying dynamical system is chaotic, these posteriors are singular but have an underlying structure that can be exploited for a fast and accurate estimation of their conditional scores. The score of a probability density is the gradient of its logarithm. Inspired by the setting of Bayesian data assimilation, and assuming the availability of the score of a target distribution, we develop a new method to use scores to sample from the unknown target. This general-purpose sampling and Bayesian inference technique starts by posing this problem as an infinite-dimensional score matching problem. An iterative transport construction is developed to find a solution to this score matching problem. In this talk, we will describe this construction and how this leads to an alternative to other score-based sampling and inference techniques. Joint work with Youssef Marzouk.

MS10-B-1: DATA-DRIVEN OPTIMAL CONTROL WITH NEURAL NETWORK MODELING OF GRADIENT FLOWS

Hailiang Liu, Iowa State University

Abstract: Extracting physical laws from observation data is a central challenge in many diverse areas of science and engineering. We propose Optimal Control Neural Net- works (OCN) to learn the laws of vector fields in dynamical systems, with no assumption on their analytical form, given data consisting of sampled trajectories. The OCN estimator consists of a neural network representation, trained with an optimal control solver. We provide error bounds for both the solution and the vector field, and the bounds are shown to depend on both the training error and the time gaps between neighboring data. We also demonstrate the effectiveness of OCN, as well as its generalization ability by testing on several prototypical systems, including the chaotic Lorenz system.

MS10-B-2: Neural differential equations for medical image prediction and segmentation

Hangjie Ji, North Carolina State University

Abstract: In this talk, we discuss recent progress

in incorporating ODEs and PDEs in medical image prediction and segmentation. First, we present a PDE-guided deep learning framework to learn the underlying tumor cell dynamics influenced by radiotherapy. A two-branch neural network is designed to encode a reaction-diffusion equation with an unknown operator approximated by a neural network. Starting from pre-treatment PET images and radiation dose distributions, this model shows promising results in predicting the post-treatment PET images and the influence of the imposed radiotherapy. Second, we propose a Neural-ODE based method for interpreting the behavior of neural networks in multi-parametric medical image segmentation tasks. We characterize the continuous evolution of images with multi-modality from inputs to segmentation results using Neural ODEs. We also design an accumulative contribution curve to quantify the utilization of each modality in the learned dynamics. In a multi-parametric MRI-based glioma segmentation study, the proposed method successfully identifies key MR modalities. This method offers a new tool for optimizing inputs and enhancing the interpretability of deep learning models for multimodal image segmentation.

MS10-B-3: A nonlocal gradient for black-box optimization with applications to data-driven discovery and design

Hoang Tran, Oak Ridge National Laboratory

Abstract: The problem of minimizing multi-modal loss functions with a large number of local optima frequently arises in model calibration, architecture design and machine learning problems. Since the local gradient points to the direction of the steepest slope in an infinitesimal neighborhood, an optimizer guided by the local gradient is often trapped in a local minimum. To address this issue, we develop a novel nonlocal gradient to skip small local minima by capturing major structures of the loss's landscape in black-box optimization. The nonlocal gradient is defined by a directional Gaussian smoothing (DGS) approach. The key idea of DGS is to conducts 1D long-range exploration with a large smoothing radius along d orthogonal directions in R^d, each of which defines a nonlocal directional derivative as a 1D integral. Such long-range exploration enables the nonlocal gradient to skip small local minima. The d directional derivatives are then assembled to form the nonlocal gradient. We use the Gauss-Hermite quadrature rule to approximate the d 1D integrals to obtain an accurate estimator. We provide a convergence theory of our method and demonstrate the superior performance in several benchmark tests as well as data-driven discovery and design problems.

MS10-B-4: Geometric Surface Characterization and Learning

Yingying Wu, University of Houston

Abstract: In this talk, I will present a discrete surface characterization method based on the extraction of the top smallest k eigenvalues of the Laplace-Beltrami operator, including data preparation, geometric feature extraction, and shape classification. Then I will report our recent investigation on computing geometric invariants on triangular meshes and point cloud using deep neural networks, as well as using classical computational geometry approaches.

MS11-A-1: Wind farm modeling and optimization

Stefano Leonardi, The University of Texas at Dallas

Abstract: Wind energy is a major renewable source for electricity production. Global wind power installed capacity exceeded 740 gigawatts (GW) at the end of 2020. The global penetration of wind energy in electricity markets is estimated at 5% on average; that is 5% of the electricity around the globe comes from wind. However, top electricity markets such as Denmark, Ireland, Portugal, Germany, the U.K. and Spain have penetration levels between 20% and 50%. At over 100 GW of installed capacity, wind is the largest source of renewable energy in the U.S. with 7% penetration on the electric grid and

six states supplying over 20% of their electricity from wind. The goal in the U.S. is to further increase installed wind capacity to 400 GW and reach 35% of the nation's electricity generation by 2050.

To increase the production of energy and reduce its cost, the size of the turbines has continuously increased, up to blade lengths of the order of the order of 100 m. This leads to two major challenges: (i) the flow field in a wind turbine array is inherently coupled to unsteady dynamics at the synoptic scale and (ii) the deformation of the blades, and the interaction between the fluid and the structure cannot be neglected. In addition, to increase the penetration of wind energy, turbines are installed in areas of complex topography or near the coastal region. The wind velocity profile and turbulence are site-specific and often the turbines function in off-design conditions. To address these challenges, we developed a numerical model to mimic the behavior of arrays of wind turbines and optimize power production and durability.

At the conference, we will present comparisons of our numerical predictions with measurements in real wind farms and discuss control algorithms that can potentially increase the power production up to 7-10%. We will also describe a procedure to estimate the annual energy production of a wind plant which can be used to evaluate possible upgrades of existing wind farms and mitigate the risk of investment.

MS11-A-2: Accurately predicting aerodynamic loads from synoptic and non-synoptic winds using CFD simulations

Faiaz Khaled, University of Illinois, Urbana Champaign

Abstract: Synoptic and non-synoptic windstorms are the costliest natural disasters in the United States. Between 1980 and 2011, damages caused by tropical cyclones and severe local storms amount to $512.5 Billion out of the total estimated damages worth $881.2 Billion caused by the major weather and climate events in the US. The current abstract aims to facilitate the development of wind-resilient infrastructure capable of withstanding both synoptic and non-synoptic windstorms. Computational fluid dynamics (CFD) simulation is attracting increasing attention within the structural wind engineering community to model realistic wind behavior and aerodynamic loads. However, concerns persist with CFD regarding accuracy, computational cost, and addressing newer flow problems. The current abstract will cover our contributions to modeling synoptic and non-synoptic wind characteristics with CFD. On the synoptic wind part, we demonstrate the ability to generate improved characteristics of synoptic winds including vertical profiles, and turbulence content. The modeled flow characteristics from CFD reveal good conformance with field measurements. Subsequently, improvements in the prediction of surface pressures on benchmark low-rise building models are observed at the expense of lower computational resources. On the non-synoptic part, we are proposing a technique that will enable straight-line wind generators to produce tornado-like vortices. In the first phase, the efficacy of the proposed idea is investigated computationally using computational fluid dynamics (CFD) simulations. In the second phase, the physical implementation of the computationally created flow environment and validation of the CFD findings are conducted. Promising flow features are observed computationally and experimentally that support the proposed idea. Typically, boundary layer wind tunnels or straight-line wind generators can produce wind flow better representative of synoptic winds. To date, tornado-like vortices have been experimentally recreated using specialized tornado vortex generators. The proposed approach can enhance the capabilities of straight-line wind generators by integrating the ability to produce a tornado-like vortex.

MS11-A-3: Computation of Building Corner Peak Pressure Using CFD

Panneer Selvam, University of Arkanas

Abstract: Computation of peak pressure on buildings will be very useful for safer design of buildings. Recent years, the University of Arkansas (UARK) has been validating the computed peak pressures on the Texas Tech University (TTU) building for the flow along the short side of the building. The computed peak pressures are in reasonable comparison with 1:6 scale wind tunnel (WT) measurements. As a next step, validating the CFD roof corner peak pressures is initiated. In the literature only a handful of works reported peak pressures. Due to extensive errors in generating turbulence either high spurious pressures are produced in the computational domain or energy loss at the building location is very high. So, the reliability of the reported works is questionable. Mansouri et al. (2022) investigated 11 different inflow turbulence generators and from that they concluded that synthetic eddy method (SEM) may be one of the better methods of choice in reducing the spurious pressures. In this work SEM method is used as inflow turbulence generator. Since corner vortex generation is a complex problem, high grid resolution is needed. On the other hand, using very high grid resolution all over the computational domain will take large memory and many days of computational time even using parallel computing. Finding optimum grid spacings in the computational domain is one of the major research tasks. Hence, grid resolution of various sizes is investigated. The research findings will be reported in the presentation. In addition, the computed peak pressures are compared with available WT measurements. Visualizations are used to show the development of the roof corner vortex and other details.

MS11-A-4: Examining the Effects of Synthetically Generated Inlet Turbulence on Wind Loads using Large Eddy Simulation (LES)

Irina Afanasyeva, University of Arkansas

Abstract: Precise prediction of peak wind pressures on buildings, especially for low-rise ones, is still challenging for wind engineers. For the most used experimental approach to determine wind loads like Wind Tunnel (WT) testing there is a scaling issue of reproducing highly turbulent flow accurately in the near-ground boundary layer where the low-rise buildings are immersed. Also, studies show that WT lacks energy in low-frequency regions of the wind spectrum which causes severe underestimation in peak pressures. An alternative and complementary approach to WT testing is Computational Fluid Dynamics (CFD). CFD helps to model turbulent flow reasonably accurately if the Large Eddy Simulation (LES) approach is used with proper inflow turbulence. Existing inflow turbulence generators (ITGs) are sensitive to the given input parameters to obtain desirable wind spectrum like von-Karman spectrum at the inlet. If the high frequencies greater than those which LES can resolve are present in the inflow spurious unrealistic pressures occur. Also, ITGs lose their energy while approaching the building location compared to what is generated at the input. This study concentrates on applying Synthetic Eddy Methods to enhance peak pressure predictions on building envelopes. It delves into understanding the impact of synthetically generated turbulence introduced at the inlet on wind loads. This is achieved by comparing CFD results across models with varying grid resolutions (coarse, medium, fine) under different conditions: with and without turbulent inflow, in conjunction with WT data. The outcomes reveal the influence of introduced turbulence at the inflow on mean and peak pressures, as well as on the frequency characteristics of wind loads. Finally, the study evaluates the performance of different ITGs based on criteria such as wind load magnitude, pressure frequency content, and the structure of turbulent flows.

MS12-A-1: High-order bound-preserving discontinuous Galerkin methods for multicomponent chemically reacting flows

Yang Yang, Michigan Technological University

Abstract: In this talk, we design high-order bound-preserving discontinuous Galerkin (DG) methods for multicomponent chemically react-

ing flows. In this problem, the density and pressure are positive and the mass fractions are between 0 and 1. There are three main difficulties. First of all, it is not easy to construct high-order positivity-preserving schemes for convection-diffusion equations. In this talk, we design a special penalty term to the diffusion term and construct the positivity-preserving flux for the system. The proposed idea is locally conservative, high-order accurate and easy to implement. Secondly, the positivity-preserving technique cannot preserve the upper bound 1 of the mass fractions. To bridge this gap, we apply the positivity-preserving technique to each mass fraction and develop consistent numerical fluxes in the system and conservative time integrations to preserve the summation of the mass fractions to be 1. Therefore, each mass fraction would be between 0 and 1. Finally, most previous bound-preserving DG methods are based on Euler forward time discretization. However, due to the rapid reaction rates, the target system may contain stiff sources, leading to restricted time step sizes. To fix this and preserve conservative property, we apply the conservative modified exponential Runge-Kutta method. The method is third-order accurate and keeps the summation of the mass fractions to be 1. Numerical experiments will be given to demonstrate the good performance of the proposed schemes.

MS12-A-2: A high-order well-balanced discontinuous Galerkin method for hyperbolic balance laws with non-hydrostatic equilibria

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 the preservation of nonhydrostatic equilibria of shallow water equations with non-flat bottom topography and Euler equations in gravitational fields. The well-balanced property is achieved through two essential ingredients. First, the source term is reformulated in a flux-gradient form at 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 the source term is exactly balanced by the flux at equilibrium states. Our method differs from existing well-balanced DG methods for the shallow water equations with non-hydrostatic equilibria in that it does not require the decomposition of the source term integral. The good performance of our method is demonstrated by ample numerical tests.

MS12-A-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.

MS12-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 discontinu-

ous 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.

MS13-A-1: C0 interior penalty methods for an elliptic distributed optimal control problem with general tracking and pointwise state constraints

SeongHee Jeong, Florida State University

Abstract: We consider C0 interior penalty methods for a linear-quadratic elliptic distributed optimal control problem with pointwise state constraints in two spatial dimensions, where the cost function tracks the state at points, curves and regions of the domain. Here we reformulate the optimal control problem into a problem that only involves the state, which is equivalent to a fourth-order variational inequality. We derive the Karush-Kuhn-Tucker conditions from the variational inequality and find the regularity result of the solution. The reduced minimization problem is solved by a C0 interior penalty method. The C0 interior penalty methods are very effective for fourth-order problems and much simpler than C1 finite element methods. The discrete problem is a quadratic program with simple box constraints which can be solved efficiently by the primal-dual active set algorithm. We provide a convergence analysis and demonstrate the performance of the method through several numerical experiments.

MS13-A-2: A fourth order finite difference method for solving elliptic interface problems with the FFT acceleration

Shan Zhao, University of Alabama

Abstract: In this talk, we will introduce an augmented matched interface and boundary (AMIB) method for solving elliptic interface problems. The AMIB method provides a uniform fictitious domain approach to correct the fourth order central difference near interfaces and boundaries. In treating a smoothly curved interface, zeroth and first order jump conditions are enforced repeatedly to generate fictitious values surrounding the interface. Different types of boundary conditions, including Dirichlet, Neumann, Robin and their mix combinations, can be imposed to generate fictitious values outside boundaries. Based on fictitious values at interfaces and boundaries, the AMIB method reconstructs Cartesian derivative jumps as additional unknowns and forms an enlarged linear system. In the Schur complement solution of such system, the FFT algorithm will not sense the solution discontinuities, so that the discrete Laplacian can be efficiently inverted. In our numerical tests, the FFT-AMIB not only achieves a fourth order convergence in dealing with interfaces and boundaries, but also produces an overall complexity of $O(n^2 log n)$ and $O(n^3 \log n)$, respectively, for 2D and 3D problems, where n standards for the number of grid

points in each Cartesian direction. Moreover, the AMIB method can provide fourth order accurate approximations to solution gradients and fluxes.

MS13-A-3: Reduced Mixed Finite Element Method

Rajan Bahadur Adhikari, Oklahoma State University

Abstract: The traditional mixed finite element method (FEM) approximates the flux and the primary functions simultaneously. We propose a simple, accurate, and efficient FEM to compute the flux independently of the primary function and present results to establish the convergence and accuracy of our approximation. We also propose a method to obtain an accurate approximation of the primary function by utilizing the flux approximated via our reduced mixed FEM and introduce a local post-processing scheme to increase its accuracy. We present numerical examples confirming the theoretical analysis.

MS13-A-4: Best approximation results and essential boundary conditions for novel types of weak adversarial network discretizations for PDEs

Cuiyu He, University of Georgia

Abstract: In this talk, we provide a theoretical analysis of the recently introduced weakly adversarial networks (WAN) method, used to approximate partial differential equations in high dimensions. We address the existence and stability of the solution, as well as approximation bounds. More precisely, we prove the existence of discrete solutions, intended in a suitable weak sense, for which we prove a quasi-best approximation estimate similar to Cea's lemma, a result commonly found in finite element methods. We also propose two new stabilized WAN-based formulas that avoid the need for direct normalization. Furthermore, we analyze the method's effectiveness for the Dirichlet boundary problem that employs the implicit representation of the geometry. The key requirement for achieving the best approximation outcome is to ensure that the space for the test network satisfies a specific condition, known as the inf-sup condition, essentially requiring that the test network set is sufficiently large when compared to the trial space. The method's accuracy, however, is only determined by the space of the trial network. We also devise a pseudo-time XNODE neural network class for static PDE problems, yielding significantly faster convergence results than the classical DNN network.

MS13-B-1: Adaptive least-squares finite element methods: guaranteed upper bounds and Convergence in L_2 norm of the dual variables

JaEun Ku, Oklahoma State University

Abstract: Adaptive least-squares finite element methods are considered. Guaranteed upper bounds for the dual error in L_2 norm are developed, and these can be used as a stopping criterion for the adaptive procedures. Also, based on the a posteriori error estimates for the dual variables, we develop an error indicator that identify the local area to refine, and establish the convergence of the adaptive procedures based on the Dörfler's marking strategy. Our convergence analysis is valid for all range of the bulk parameter $0 < \Theta \leq 1$ and it shows the effect of bulk parameter and reduction factor of elements on the convergence rate.

MS13-B-2: A uniform and pressure-robust enriched Galerkin method for the Brinkman equations

Seulip Lee, University of Georgia

Abstract: This paper presents a pressure-robust enriched Galerkin (EG) method for the Brinkman equations with minimal degrees of freedom based on EG velocity and pressure spaces. 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. We derive, analyze, and compare two EG methods in this paper: standard and robust methods. The standard method requires a mesh size to be less than a viscous parameter to produce stable and accurate velocity solutions, which is impractical in the Darcy regime. Therefore, we propose the pressure-robust method by utilizing a velocity reconstruction operator and replacing EG velocity functions with a reconstructed velocity. The robust method yields error estimates independent of a pressure term and shows uniform performance from the Stokes to Darcy regimes, preserving minimal degrees of freedom. We prove well-posedness and error estimates for both the standard and robust EG methods. We finally confirm theoretical results through numerical experiments with two- and three-dimensional examples and compare the methods' performance to support the need for the robust method.

MS13-B-3: Regularized Reduced Order Modeling for Turbulent Flow

Jorge Reyes, Virginia Tech

Abstract: This talk focuses on the development and motivations behind regularized reduced order models (ROMs) for turbulent flow. Direct numerical simulations have long been understood to be computationally infeasible for day-to-day simulations of turbulent flows. ROMs have been shown to provide an efficient alternative. In the case of under-resolved flows, which is generally the case for high Reynolds numbers i.e. turbulent flows, standard ROM accuracy tends to suffer. Regularization, which is based on spatial filtering, increases the ROM stability and accuracy at a negligible overhead. In this talk, I will outline several regularized ROMs that have been proven effective in the numerical simulation of under-resolved turbulent flows.

MS13-B-4: Radial basis function methods for integral fractional Laplacian using arbitrary radial functions

Qiao Zhuang, Worcester Polytechnic Institute

Abstract: We consider radial basis function methods for fractional PDEs on general bounded domains. Efficient computation of such problems with high accuracy on bounded domains is challenging, due to the intrinsic singularity and nonlocal nature of the fractional Laplacian. We develop a numerical method that can accurately compute the fractional Laplacian of any radial basis function. We present several examples to compare our method with some existing methods and illustrate the efficiency in two dimensions.

MS14-A-1: An efficient and provable sequential quadratic programming method for American and swing option pricing

Weizhang Huang, University of Kansas

Abstract: In this talk I will present a sequential quadratic programming method for American and swing option pricing based on the variational inequality formulation. The variational inequality is discretized using the theta-method in time and the finite element method in space. The resulting system of algebraic inequalities at each time step is solved through a sequence of box-constrained quadratic programming problems, with the latter being solved by a globally and quadratically convergent, large-scale suitable reflective Newton method. It is proved that the sequence of quadratic programming problems converges with a constant rate under a mild condition on the time step size. The method is general in solving the variational inequalities for the option pricing with many styles of optimal stopping and complex underlying asset models. In particular, swing options and stochastic volatility and jump diffusion models are studied. Numerical examples are presented to confirm the effectiveness of the method.

MS14-A-2: Recent results in inverse gravimetry and inverse conductivity problems

Tianshi Lu, Wichita State University

Abstract: In the three-dimensional inverse gravimetry problem we proved that the minimal data to recover an ellipsoidal or rectangular cavity consist of nine parameters, and these parameters can be uniquely determined from the measurement of the gravitational acceleration on the boundary encircling the cavity at nine or more distinct points. A system of algebraic equations for the parameters of an ellipsoid or a rectangular prism was derived and used in a robust numerical solver. For the linearized inverse conductivity problem an efficient solver was developed combining the Fourier transform of the conductivity and the three-dimensional Yee scheme on the staggered grid for the Maxwell equations.

MS14-A-3: A direct parallel-in-time quasi-boundary value method for inverse space-dependent source problems

Yi Jiang, Southern Illinois University Edwardsville

Abstract: Many efficient parallelizable numerical algorithms have been developed in the last few decades for solving direct (or forward) PDE problems. However, such fast solvers to ill-posed inverse problems were rarely investigated. In this talk, we will introduce a modified quasi-boundary value method solving inverse source problems that leads to a fast diagonalization-based parallel-in-time direct solver. The proposed algorithm can achieve a dramatic speedup in CPU times when compared with MATLAB's sparse direct solver. The high efficiency of the proposed algorithms is illustrated by 1D and 2D numerical examples.

MS14-A-4: A dynamic mass transport method for Poisson-Nernst-Planck equations

Hailiang Liu, Iowa State University

Abstract: A dynamic mass-transport method is proposed for approximately solving the Poisson– Nernst–Planck (PNP) equations. The semi-discrete scheme based on the JKO type variational formulation naturally enforces solution positivity and the energy law as for the continuous PNP system. The fully discrete scheme is further formulated as a constrained minimization problem, shown to be solvable, and satisfy all three solution properties (mass conservation, positivity and energy dissipation) independent of time step size or the spatial mesh size. Numerical experiments are conducted to validate convergence of the computed solutions and verify the structure preserving property of the proposed scheme.

MS14-B-1: Learning Free Space Green's Function For Elliptic Partial Differential Equations

Shuwang Li, Illinois Institute of Technology

Abstract: Green's function (GF) of an elliptical partial differential equation (PDE) plays an important role in mathematical analysis and many numerical meth- ods. They have an ability to seamlessly map solutions of the PDE in the entire domain by an integration operation on the boundary. However, an explicit form of the Green's function is non-trivial to evaluate. In this talk, we propose a radial basis function (RBF) kernel based neural network to learn GF for given PDE for an infinite domain. By leveraging the radial symmetry of the GF and controlling the refinement (of the RBF kernel) near the singularity of the Dirac delta, our method enables fast training and accurate evaluation of the GF. The learned GF is reusable across different domain shapes, forcing function and boundary condition. We demonstrate the applicability of the present method by solving Laplace equation, helmholtz equation and variable coefficient elliptic PDEs with different domain shape, forcing function and boundary conditions.

MS14-B-2: Discontinuous Galerkin methods for network patterning phase-field models

Yuan Liu, Wichita State University

Abstract: In this talk, we discuss a class of discontinuous Galerkin methods under the scalar auxiliary variable framework (SAV-DG) to solve a biological patterning model in the form of parabolic-elliptic partial differential equation system. In particular, mixed-type discontinuous Galerkin approximations are used for the spatial discretization, aiming to achieve a balance between the high resolution and computational cost. Second and third order backward differentiation formulas are considered under

SAV framework for discrete energy stability. Numerical experiments are provided to show the effectiveness of the fully discrete schemes and the governing factors of patterning formation.

MS14-B-3: Adaptive gradient methods with energy and momentum

Xuping Tian, Iowa State University

Abstract: We introduce AEGD, a first-order gradient-based algorithm for solving general optimization problems, based on a dynamically updated 'energy' variable, and its variants with both energy and momentum. Such energy-adaptive gradient algorithms are shown to be unconditionally energy stable, irrespective of the base step size. An energy-dependent convergence rate in the general nonconvex stochastic setting and a regret bound in the online convex setting are provided. We also study the dynamic behavior of the proposed algorithms through analysis of a high-resolution ODE system. Experimental results demonstrate that the energy-adaptive gradient algorithms show better generalization performance than SGD with momentum in training some deep neural networks.

MS14-B-4: Maximum-Taylor discontinuous Galerkin (MTDG) schemes for solving linear hyperbolic systems

James Rossmanith, Iowa State University

Abstract: In this work we develop the maximum Taylor discontinuous Galerkin (MTDG) method for solving linear systems of hyperbolic partial differential equations (PDEs). The proposed method is a hybrid of the Lax-Wendroff DG (LxW-DG) and the semi-Lagrangian DG (SLDG) methods from the literature. The key innovation in the newly proposed method is that we replace the single integration-by-parts step in LxW-DG by an approach that moves all spatial derivatives onto the test function. This approach is developed in one, two, and three spatial dimensions. The regions of stability of MTDG are compared to the LxW-DG and we show that MTDG has both a larger stability region and improved accuracy. The resulting scheme is applied to several numerical test cases.

MS15-A-1: Sampling type method combined with deep learning for inverse scattering with one incident wave

Thu Thi Anh Le, Kansas State University

Abstract: We consider the inhomogeneous acoustic inverse problem of determining the geometry of penetrable objects from scattering data generated by one incident wave at a fixed frequency. We first study an Orthogonality Sampling-type method which is fast, simple to implement, regularization-free, and robust against noise in the data. This sampling method has a new imaging functional that is applicable to data measured in near-field or far-field regions. The resolution analysis of the imaging functional is analyzed where the explicit decay rate of the functional is established. The sampling method is then combined with a Deep Neural Network to solve the inverse scattering problem. This combined method can be understood as a network using the image computed by the sampling method for the first layer, followed by the U-net Xception architecture for the rest of the layers. The fast computation and the knowledge from the results of the sampling method help speed up the training of the network. The combination leads to a significant improvement in the reconstruction results initially obtained by the sampling method. The combined method is also able to invert some limited aperture experimental data without any additional transfer training. Numerical results testing against simulated data and experimental data will be presented. This talk is based on joint work with Dinh-Liem Nguyen, Vu Nguyen, and Trung Truong.

MS15-A-2: On nonscattering media and their connections in inverse problems

Jingni Xiao, Drexel University

Abstract: In this talk I will present some recent results on the regularity of anisotropic nonscattering media. The application in inverse prob-

lem of shape determination by one single measurement will also be discussed.

MS15-A-3: Inverse scattering for higher waves
Paul Sacks, Iowa State University
Abstract: Let V be a radially symmetric potential on $\mathbb{R}^3$ appearing in the Schrödinger equation

$$\Delta\Psi + V(x)\Psi = k^2\Psi$$

For $\ell = 0, 1, \ldots$ and for a suitable class of V, there is a function S_ℓ, the associated S-matrix, defined in terms of the corresponding Jost solution of

$$\psi'' + \left(k^2 - V(r) - \frac{\ell(\ell+1)}{r^2}\right)\psi = 0 \qquad r > 0$$

The inverse scattering problem of interest is that of determining V from knowledge of S_ℓ for some fixed ℓ. The nonsingular case $\ell = 0$ has been very well studied, and to some extent a parallel theory is known for the higher wave case $\ell > 0$. We'll discuss how some known techniques for $\ell = 0$ can be exploited for more efficient numerical solution in the higher ℓ case, making use of some older results of Marchenko.

MS15-A-4: Fast imaging of point-like electromagnetic sources using single-frequency data
Dinh-Liem Nguyen, Kansas State University
Abstract: This talk addresses the numerical reconstruction of small electromagnetic sources using boundary Cauchy data at a single frequency. We study a sampling-type method to efficiently and robustly determine the locations of these small sources. Moreover, the method can also compute the intensity of point sources, provided that the sources are well-separated. The implementation of the method is non-iterative, computationally inexpensive, rapid, and straightforward.

MS15-B-1: A Spectral Target Signature for Thin Surfaces with Higher Order Jump Conditions
Heejin Lee, Purdue University
Abstract: In this talk, we consider the inverse problem of determining the structural properties of a thin anisotropic and dissipative inhomogeneity from scattering data. In the asymptotic limit, as the thickness goes to zero, the thin inhomogeneity is modeled by an open m-1 manifold(here referred to as screen), and the field inside is replaced by jump conditions on the total field involving a second-order surface differential operator. We show that all the surface coefficients are uniquely determined from far-field patterns of the scattered fields due to infinitely many incident plane waves at a fixed frequency. Then we introduce a target signature characterized by a novel eigenvalue problem such that the eigenvalues can be determined from measured scattering data. Changes in the measured eigenvalues are used to identify changes in the coefficients without making use of the governing equations that model the healthy screen. In our investigation, the shape of the screen is known since it represents the object being evaluated. We present some preliminary numerical results indicating the validity of our inversion approach. This is joint work with Fioralba Cakoni, Peter Monk, and Yangwen Zhang.

MS15-B-2: Coupling physics-deep learning inversion
Lu Zhang, Rice University
Abstract: In recent years, there has been increasing interest in applying deep learning to geophysical/medical data inversion. However, the direct application of end-to-end data-driven approaches to inversion has quickly shown limitations in practical implementation. Indeed, due to the lack of prior knowledge about the objects of interest, the trained deep learning neural networks very often have limited generalization. This talk presents a new methodology for coupling model-based inverse algorithms with deep learning for full waveform inversion. In particular, we present an offline-online computational strategy that couples classical least-squares-based computational inversion with modern deep learning-based approaches for full waveform inversion to achieve benefits that cannot be achieved by either component alone.

MS15-B-3: A variational quasi-reversibility

model for a time-reversed nonlinear parabolic problem
Anh Khoa Vo, Florida A&M University
Abstract: This talk is about a modified quasi-reversibility method for computing the exponentially unstable solution of a terminal-boundary value parabolic problem with noisy data. As a PDE-based approach, this variant relies on adding a suitable perturbing operator to the original PDE and consequently, on gaining the corresponding fine stabilized operator. The designated approximate problem is a forward-like one. This new approximation is analyzed in a variational framework, where the finite element method can be applied. With respect to each noise level, the Faedo–Galerkin method is benefited to study the weak solvability of the approximate problem. Relying on the energy-like analysis coupled with a suitable Carleman weight, convergence rates in L^2–H^1 of the proposed method are obtained when the true solution is sufficiently smooth.

MS15-B-4: A new sampling indicator function for stable imaging of periodic scattering media
Trung Truong, Marshall University
Abstract: Inverse scattering problems for periodic media arise from many real-life applications, especially non-destructive testing for photonic crystals. Photonic crystals are an important type of material in optics. Therefore, studying them is of interest to not only mathematicians, but also physicists and engineers. The inverse problem that we consider in the presented work is severely ill-posed. Thus, a lot of numerical methods fail to give reasonable results when there is a high level of noise in the data. In this talk, we present a sampling method with a new indicator function. This method is capable of reconstructing periodic media from highly noisy data, is very simple to implement and does not require any regularization. The theoretical justification of the method is proved using an integral representation that involves the Green's function along with a series expansion of the scattered waves. This is joint work is Dinh-Liem Nguyen and Kale Stahl.

MS15-C-1: Conditional sampling via block-triangular transport maps
Ricardo Baptista, Caltech
Abstract: We present an optimal transport framework for conditional sampling of probability measures. Conditional sampling is a fundamental task of solving Bayesian inverse problems and generative modeling. Optimal transport provides a flexible methodology to sample target distributions appearing in these problems by constructing a deterministic coupling that maps samples from a reference distribution (e.g., a standard Gaussian) to the desired target. To extend these tools for conditional sampling, we first develop the theoretical foundations of block triangular transport in a Banach space setting by drawing connections between monotone triangular maps and optimal transport. To learn these block triangular maps, we will then present a computational approach, called monotone generative adversarial networks (MGANs). Our algorithm uses only samples from the underlying joint probability measure and is hence likelihood-free, making it applicable to inverse problems where likelihood evaluations are inaccessible or computationally prohibitive. We will demonstrate the accuracy of MGAN for sampling the posterior distribution in Bayesian inverse problems involving ordinary and partial differential equations, and probabilistic image in-painting.

MS15-C-2: Noise-robust Deep Direct Sampling via Transformers
Shuhao Cao, University of Missouri-Kansas City
Abstract: In this talk, we shall present a study on a Transformer-based deep direct sampling method proposed for electrical impedance tomography, a well-known severely ill-posed nonlinear boundary value inverse problem. By evaluating the learned inverse operator using an end-to-end pipeline, a real-time reconstruction of the construction can be achieved. However, the robustness to noises in this approach re-

lies on including specifically designed training data with clean output (conductivity) with noisy input (harmonic extensions of noisy boundary data). In this study, we shall propose an algorithm, based on the famous Denoising Diffusion Probabilistic Models (DDPM), to learn how the nonlinear inverse operator's outputs are affected by the noise. Under moderate assumptions on the priors, the evaluation will achieve equally good reconstruction with input samples with 20% noise and those with 0% noise.

MS15-C-3: On a new interior transmission eigenvalue problem in locally perturbed periodic media

Thi-Phong Nguyen, New Jersey Institute of Technology

Abstract: Transmission eigenvalue problems play an essential role in scattering theory, for example, to study the parameters of the scattering problem in the case of the scattered wave being suppressed. The study of numerical methods, such as Sampling Methods, for solving an inverse scattering problem also led to studying transmission eigenvalues problems.
This talk will introduce and discuss the discreteness property of eigenvalues of interior transmission eigenvalue problems associated with the inverse scattering problem of recovering defects in locally perturbed periodic media.

MS16-A-1: Regularity of solutions to boundary nonlocal equations

Pablo Raúl Stinga, Iowa State University

Abstract: We introduce the fractional normal derivative of a function on the boundary of a bounded domain as the fractional power of the Dirichlet-to-Neumann map for its corresponding harmonic extension to the interior. We prove Hölder regularity estimates of solutions to the boundary nonlocal problem depending on the regularity of the boundary manifold. This is joint work with Luis A. Caffarelli (UT Austin) and Mitchell Haeuser (Iowa State University).

MS16-A-2: Monotone meshfree methods for linear elliptic equations in non-divergence form via nonlocal relaxation

Qihao Ye, University of California, San Diego

Abstract: We design a monotone meshfree finite difference method for linear elliptic PDEs in non-divergence form on point clouds via a nonlocal relaxation method. The key idea is a combination of a nonlocal integral relaxation of the PDE problem with a robust meshfree discretization on point clouds. Minimal positive stencils are obtained through a linear optimization procedure that automatically guarantees the stability and, therefore, the convergence of the meshfree discretization. A major theoretical contribution is the existence of consistent and positive stencils for a given point cloud geometry. We provide sufficient conditions for the existence of positive stencils by finding neighbors within an ellipse (2d) or ellipsoid (3d) surrounding each interior point, generalizing the study for Poisson's equation by Seibold in 2008. It is well-known that wide stencils are in general needed for constructing consistent and monotone finite difference schemes for linear elliptic equations. Our result represents a significant improvement in the stencil width estimate for positive-type finite difference methods for linear elliptic equations in the near-degenerate regime (when the ellipticity constant becomes small), compared to previously known works in this area. Numerical algorithms and practical guidance are provided with an eye on the case of small ellipticity constant. Numerical results will be presented in both 2d and 3d, examining a range of ellipticity constants including the near-degenerate regime.

MS16-A-3: Extension equation for fractional power of operator defined on Banach spaces

Animesh Biswas, University of Nebraska-Lincoln

Abstract: In this talk, we show the extension (in spirit of Caffarelli-Silvestre) of fractional power of operators defined on Banach spaces. Starting with the Balakrishnan definition, we use semigroup method to prove the extension. This is a joint work with Pablo Raul Stinga.

MS16-A-4: A novel and simple spectral method for nonlocal PDEs with the fractional Laplacian

Shiping Zhou, Missouri University of Science and Technology

Abstract: For the existing numerical methods for the fractional Laplacian, finite difference methods are famous for easy implementation but have low accuracy and spectral methods have high accuracy but need periodic boundary conditions. In this talk, we will propose an easy-implementing spectral method with no periodic boundary condition restrictions for the general dimensional fractional Laplacian operator. We provide the local truncation error analysis result for the operator approximation and the stability and convergence analysis results, all those analytical results are verified by our numerical experiments. Furthermore, we study the solution behaviors of the coexistence of anomalous-anomalous diffusion problems.

MS16-B-1: Analytical and applied aspects for nonlocal frameworks and operators

Petronela Radu, University of Nebraska-Lincoln

Abstract: The emergence of nonlocal theories as promising models in different areas of science (continuum mechanics, biology, image processing) has led the mathematical community to conduct varied investigations of systems of integro-differential equations and the underlying operators. In this talk I will discuss properties of nonlocal operators, counterparts of local versions, and present some recent results on Helmholtz-Hodge type decompositions of nonlocal operators. Applications of these results will be discussed, as well as connections with other theories.

MS16-B-2: A grid-overlay finite difference method for the fractional Laplacian on arbitrary bounded domains

Weizhang Huang, University of Kansas

Abstract: In this talk I will represent a grid-overlay finite difference method for the numerical approximation of the fractional Laplacian on arbitrary bounded domains. The method uses an unstructured simplicial mesh and an overlay uniform grid for the underlying domain and constructs the approximation based on a uniform-grid finite difference approximation and a data transfer from the unstructured mesh to the uniform grid. The method takes full advantages of both uniform-grid finite difference approximation in efficient matrix-vector multiplication via the fast Fourier transform and unstructured meshes for complex geometries and mesh adaptation. It is shown that its stiffness matrix is similar to a symmetric and positive definite matrix and thus invertible if the data transfer has full column rank and positive column sums. Piecewise linear interpolation is studied as a special example for the data transfer. It is proved that the full column rank and positive column sums of linear interpolation is guaranteed if the spacing of the uniform grid is smaller than or equal to a positive bound proportional to the minimum element height of the unstructured mesh. Moreover, a sparse preconditioner is proposed for the iterative solution of the resulting linear system for the homogeneous Dirichlet problem of the fractional Laplacian. I will present numerical examples to demonstrate that the new method has similar convergence behavior as existing finite difference and finite element methods and that the sparse preconditioning is effective. Furthermore, the new method can readily be incorporated with existing mesh adaptation strategies. Numerical results obtained by combining with the so-called MMPDE moving mesh method are also presented.

MS16-B-3: Fourier Multipliers for Linear Peridynamic Operators

Nathan Albin, Kansas State University

Abstract: I will discuss the derivation of formulas for the Fourier multipliers of linear peridynamic operators, using the multipliers of related scalar peridynamic operators as a guide. These formulas provide an accurate and efficient way to study properties of linear peridynamic equa-

tions and to implement numerical methods for these equations. This is joint work with Bacim Alali.

MS16-B-4: Solving A Non-local Fokker-Planck Equation by Deep Learning
Xiaofan Li, Illinois Institute of Technology
Abstract: TBD

MS17-A-1: Mathematical studies of nonlocal half-ball vector operators and their applications to peridynamics correspondence material models
Xiaochuan Tian, University of California, San Diego
Abstract: Nonlocal gradient operators are basic elements of nonlocal vector calculus that play a key role in peridynamics correspondence material modeling. It is found, however, that choosing the interaction kernels for nonlocal gradient operators is a subtle issue, and instability of the peridynamics correspondence models may be observed without a conscious design of appropriate kernel functions. In previous studies, strongly singular kernels were proposed to replace continuous or weakly singular kernels for stabilizing the peridynamics correspondence models. This work proposes a different approach to stabilization by modifying the nonlocal interaction neighborhoods. In particular, we show mathematically that the instability of the correspondence models can be resurrected by using the nonlocal half-ball vector operators.
More technically speaking, we define the nonlocal half-ball gradient, divergence and curl operators with a general class of kernel functions and apply them to the study of nonlocal models on bounded domains with Dirichlet boundary conditions. The key result is a nonlocal Poincare-Korn inequality for the peridynamics correspondence models which leads to the well-posedness of the models. Other applications of our study include nonlocal convection-diffusion equations and nonlocal Helmholtz decomposition on bounded domains.

MS17-A-2: Analysis and Discretization of Optimal Control Problems in Peridynamics
Joshua Siktar, University of Tennessee-Knoxville
Abstract: In this talk, we investigate a nonlocal optimal control problem in solid mechanics involving a linear, bond-based peridynamics model; this model depends on the horizon parameter, which is the degree of non-locality. In addition to establishing the well-posedness of our problem, we study the behavior as the horizon parameter approaches zero. We then analyze a finite element-based discretization of this problem, its convergence, and the so-called asymptotic compatibility as the discretization parameter and the horizon parameter tend to zero simultaneously.

MS17-A-3: Asymptotically compatible schemes for saddle point problems and applications to nonlocal models
Zhaolong Han, University of California, San Diego
Abstract: In this work, we propose an abstract asymptotically compatible scheme for saddle point problems. Then we apply this framework to several nonlocal problems, including nonlocal Poisson's problem with Dirichlet boundary condition, nonlocal convection diffusion equations, as well as nonlocal biharmonic problems.

MS17-A-4: Nonlocal Boundary Value Problems with Local Boundary Conditions
James Scott, Columbia University
Abstract: We state and analyze nonlocal problems with classically-defined, local boundary conditions. The model takes its horizon parameter to be spatially dependent, vanishing near the boundary of the domain. We establish a Green's identity for the nonlocal operator that recovers the classical boundary integral, which permits the use of variational techniques. We show the existence of solutions, as well as their variational convergence to classical counterparts as the horizon uniformly converges to zero. In certain circumstances, global regularity

of solutions can be establishing, resulting in improved modes of variational convergence.

MS17-B-1: The extension problem characterization for higher fractional power operators in Banach spaces

Pablo Raúl Stinga, Iowa State University

Abstract: We prove an extension problem characterization for all fractional powers L^s, $s > 0$, of generators L of uniformly bounded C_0-semigroups on Banach spaces in the spirit of Caffarelli–Silvestre, Stinga–Torrea and Galé–Miana–Stinga. We prove existence and uniqueness of the Banach-valued initial value extension problem and obtain new formulas for the solution that allow us to characterize L^s as a Dirichlet-to-Neumann map. This is joint work with Animesh Biswas (U. of Nebraska-Lincoln).

MS17-B-2:A Spectral Method for Fractional Wave Equations in Heterogeneous Media

Yanzhi Zhang, Missouri University of Science and Technology

Abstract: Recently, variable-order nonlocal models have gained a lot of attention in the study of heterogeneous media. However, their numerical studies still remain scant, and the main challenges are from their nonlocality and heterogeneity. In this talk, I will present a Fourier pseudospectral method for solving the variable-order fractional wave equation. For constant-order wave equations, the fast Fourier transforms can be used for their efficient implementation. In contrast to it, the spatial heterogeneity of the variable-order wave equations makes the fast Fourier transform fail, which leads to huge computational and storage costs, especially in high dimensions. To deal with this, a fast algorithm is proposed. The accuracy and efficiency of our method will be studied. Our method can achieve a spectral order of accuracy in space and a second-order of accuracy in time.

MS17-B-3: Analytical Solutions for Peridynamic Models for Transient Diffusion and Elastodynamics

Florin Bobaru, University of Nebraska-Lincoln

Abstract: Peridynamic models are described by integro-differential equations (IDEs) with associated initial and nonlocal boundary conditions. I will present some recent results on obtaining analytical solutions to transient diffusion (heat and mass transfer, etc.) and elastodynamics problems using the idea of separation of variables employed in the classical partial differential equations (PDEs) problems. We show that, formally, the solutions to the initial and boundary values problems for IDEs are identical to those of the corresponding PDEs-based problems with the exception of the presence of a “nonlocal factor" which becomes equal to one in the PDE case. The discussion covers both 1D and 2D cases, and extensions to 3D problems are immediate. For a number of examples we prove uniform convergence of the series solutions. If time permits, I will also discuss some interesting connections between analytical classical solutions and approximate nonlocal solutions. This work is in collaboration with Prof. Z. Chen (Huazhong University of Science and Technology, China) and Dr. S. Jafarzadeh (Lehigh University, USA), and is detailed in https://doi.org/10.1007/s42102-022-00080-7 (for transient diffusion) and https://doi.org/10.1016/j.ijengsci.2023.103866 for elastodynamics.

MS17-B-4: Results on Nonlocal Volume Constraint Problems with Finite Horizon

Scott Hootman-Ng, University of Nebraska-Lincoln

Abstract: In this talk we will look at some recent work regarding the nonlocal Neumann operator with a kernel of finite horizon to analyze the nonlocal analog of boundary value problems in PDE called volume constraint problems. Because nonlocal domains introduce collars which are not measure zero, like most boundaries in classical problems, some technical and qualitative care must be made in posing these problems to make sure the model we choose is appropriate. Things that we will investigate is

the well-posedness of the associated Robin and Neumann volume constraint problems, convergence of solutions and convergence of operators to their classical counterpart as the horizon goes to 0. If time permits we may mention some future directions regarding trace spaces of nonlocal operators.

MS18-A-1: Harmonic measure distribution functions in various geometries

Christopher Green, Wichita State University

Abstract: Consider releasing a Brownian particle from a basepoint z_0 in a planar domain $\Omega \cup \mathbb{C}$. What is the chance, denoted $h_{\Omega,z_0}(r)$, that the particle's first exit from Ω occurs within a fixed distance $r > 0$ of z_0? The function $h_{\Omega,z_0}(r) : [0,\infty) \to [0,1]$ is called the harmonic measure distribution function, or h-function, of Ω with respect to z_0. 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. Special function theory and conformal mapping are judiciously combined to this end.

MS18-A-2: Fast computation of analytic capacity

Mohamed Nasser, Wichita State University

Abstract: In this talk, a boundary integral equation method is presented for fast computation of the analytic capacities of compact sets in the complex plane. The proposed method can be used for domains with smooth and piecewise smooth boundaries. When combined with conformal mappings, the method can be used for compact slit sets. Several numerical examples are presented to demonstrate the efficiency of the proposed method.

MS18-A-3: Vortex shedding from bluff bodies: A conformal mapping approach

Vijay Matheswaran, Wichita State University

Abstract: A method to calculate flow around bluff bodies of various geometries is presented. Using a hybrid potential flow solution for a circular cylinder, and a combination of Karman-Trefftz transformations and Fornberg's method, a conformal map between the plane of the bluff body and the plane of a unit circular cylinder is established. Flow in the circle plane is calculated and mapped back to the shape plane. By joining this calculated near-body flow with von Karman's model for a vortex wake, forces due to vortex shedding and shedding frequencies can be quickly calculated. In this manner, a complete solution for the flow around bluff bodies of various geometries is established.

MS18-A-4: Computation of plane potential flow in multiply connected domains

Thomas K DeLillo, Wichita State University

Abstract: We will give an overview of recent progress computing plane potential flow in multiply connected domains in the complex plane using numerical conformal mapping.

SC-A-1: Asymptotic-Preserving Scheme for the Kinetic Boltzmann-BGK Equation

Preeti Sar, Iowa State University

Abstract: The kinetic Boltzmann equation with the Bhatnagar-Gross-Krook (BGK) collision operator describes the motion of a fluid for the simulation of gas dynamics over a wide range of Knudsen numbers with a simplified collision operator. The small scales in kinetic and hyperbolic equations lead to different asymptotic regimes which are expensive to solve numerically. Asymptotic preserving schemes are efficient in these regimes, which preserve at the discrete level, the asymptotic limit which drives the microscopic equation to its macroscopic

equation. Such schemes allow the numerical method to be stable at fixed mesh parameters for any value of the Knudsen number, including in the fluid (very small Knudsen numbers), slip flow (small Knudsen numbers), transition (moderate Knudsen numbers), and free molecular flow (large Knudsen numbers) regimes. In this work, we develop a wave propagation finite volume method to solve both the Boltzmann-BGK and Boltzmann-ES-BGK systems. The proposed method is applied to the lid driven cavity problem and then parallelized using MPI on the supercomputer.

SC-A-2: Functional equivariance and modified vector fields

Sanah Suri, Washington University in St. Louis

Abstract: Certain numerical integrators preserve geometric properties of the flow of differential equations. In particular, the preservation of linear and quadratic first integrals has been studied extensively. McLachlan and Stern introduced the idea of F-functional equivariance providing a new framework to talk about the preservation of first integrals as well as other notable observables of a dynamical system. This talk will extend the idea of functional equivariance to backward error analysis and modified vector fields. We generalize results on invariant preservation and describe the numerical evolution of non-invariant observables.

SC-A-3: Decoupled Finite Element Method for a phase field model of two-phase ferro-fluid flows

Youxin Yuan, Missouri University of Science and Technology

Abstract: Ferrofluid is a liquid that is attracted to the poles of a magnet and usually does not retain magnetization in the absence of an externally applied magnetic field. In this talk, the decoupled finite element method for the two-dimensional ferrohydrodynamics model and the numerical validation of the method, which consists of the Navier-Stokes equation, the Cahn-Hilliard equation, and the magnetic field equation, will be discussed.

SC-A-4: Spacetime Discontinuous Galerkin Methods for the Vlasov-Maxwell System

Yifan Hu, Iowa State University

Abstract: The Vlasov-Maxwell system is a kinetic description of collisionless plasma. Numerical methods for this system face many challenges, such as high dimensionality, conservation of physical quantities, and long-range interactions through the Coulomb force. To tackle these issues, we develop a high-order spacetime discontinuous Galerkin (DG) method formulated in a prediction-correction fashion, where the prediction step is a regionally implicit spacetime reconstruction, and the correction step is an explicit update based on those reconstructed solutions. The prediction step is made efficient through a hierarchical solution procedure, which significantly reduces the computational complexity for multidimensional problems. Additional computational efficiencies are achieved by using nodal basis functions in both the prediction and correction steps.

In this talk, we first consider the proposed method on the multidimensional linear advection equations. We demonstrate improved linear stability for these equations compared to other spacetime DG methods. We then validate the resulting scheme on common benchmark problems such as the two-stream instability, Landau damping, and Weibel instability problems.

SC-B-1: Role of Network Geometry and Human Mobility in the Metapopulation Model

Haridas Das, Oklahoma State University

Abstract: We investigate epidemic thresholds for metapopulation network models over a more extensive set of networks. By analyzing the SIR-network model in large classes of networks, we establish the concept of flux-driven epidemic control, where human movement between nodes can control outbreaks of an infectious disease in the network. We find a family of networks with the same kind of epidemic control inspired by the star-shaped networks, providing analytical estimates in both general and particular cases. In contrast, we also analyze cycle-shaped networks, where each node is only connected to its immediate neighbors. Remarkably, cycle-shaped networks exhibit flux-driven epidemic control but with different epidemic thresholds compared to fully connected networks.

SC-B-2: Simulation of turbulent mixing due to Richtmyer-Meshkov Instability using high order Weighted Essentially Non-Oscillatory Scheme

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 hydro-dynamically unstable interfaces between fluids. In our present simulations, higher order weighted essentially non-oscillatory (WENO) methods are used. We first introduce the WENO methods in solving hyperbolic partial differential equations. WENO schemes are high order accurate upwind finite difference schemes designed for problems with piecewise smooth solutions containing discontinuities. The convex combinations of candidate stencils are chosen to approximate the flux at cell boundaries to a high order of accuracy and avoid oscillations near shocks. We investigate higher order WENO schemes with and without Monotonicity preserving bounds. Lastly, the use of higher order WENO methods is investigated in the simulation of turbulent mixing due to Richtmyer-Meshkov Instability.

SC-B-3: Block-structured, adaptive mesh refinement in the front-tracking method for numerical simulation of fluid instabilities

James Burton, University of Arkansas

Abstract: Front-tracking is an adaptive numerical approach that explicitly tracks the interface between distinct mediums as a hypersurface moving through a rectangular grid, providing sharp resolution of the wavefront and preventing unwanted mixing between neighboring cells of different materials. The increased accuracy of front-tracking comes at a computational cost, which can be mitigated through adaptive mesh refinement by refining in areas of complex structures and vorticities, and coarsening in smoother areas. The front-tracking based software library FronTier has been used in validation and verification of turbulence mixing due to hydrodynamic instabilities. The Richtmyer-Meshkov instability of an air/SF6 interface simulation is used as a test-case in implementing the block-structured, adaptive mesh refinement library AMReX to reduce computational costs and increase accuracy in regions with complex mixing structure.

SC-B-4: Performance analysis of U-Net over the different number of initial channels

Nailah Rawnaq, Pritom Roy, University of Arkansas **Abstract**: Medical image segmentation is the process of identifying the objects of interest accurately within an image for diagnostic and treatment planning purposes. One of the well-known image segmentation algorithms is the Convolutional Neural Networks (CNNs)-based segmentation algorithm U-Net that consists of encoder-decoder architecture with four different stages in the network. We study the effect of the number of input channels on the performance of U-Net architecture with the goal of finding the most efficient way of analyzing the electron microscopy dataset for mitochondria separation in the region of the brain.

CT1-A-1: Learning Collective Behaviors from Observation

Ming Zhong, Illinois Institute of Technology

Abstract: Collective behavior (clustering, flocking, milling, swarming and synchronization, etc), also known as self organization, is the emergence of global patterns from local interactions of agents in complex systems. It can be observed in physics (super conductivity), chemistry (liquid crystals), biology (folding of proteins), sociology (herd behavior, groupthink), etc. It is challenging to understand such behaviors using rigorous mathematical formulas. We present a series of machine learning methods to construct dynamical systems to explain these behaviors from observation data. We demonstrate the efficiency and effectiveness of our methods not only through extensive numerical testings, but also via thorough theoretical analysis. Future directions of enhancements and extensions are also discussed.

CT1-A-2: Monolithic and local time-stepping decoupled algorithms for transport problems in fractured porous media

Toan Huynh, Auburn University

Abstract: The objective of this paper is to develop efficient numerical algorithms for the linear advection-diffusion equation in fractured porous media. A reduced fracture model is considered where the fractures are treated as interfaces between subdomains and the interactions between the fractures and the surrounding porous medium are taken into account. The model is discretized by a backward Euler upwind-mixed hybrid finite element method in which the flux variable represents both the advective and diffusive fluxes. The existence, uniqueness, as well as optimal error estimates in both space and time for the fully discrete coupled problem are established. Moreover, to facilitate different time steps in the fracture-interface and the subdomains, global-in-time, non-overlapping domain decomposition is utilized to derive two implicit iterative solvers for the discrete problem. The first method is based on the time-dependent Steklov-Poincare operator, while the second one employs the optimized Schwarz waveform relaxation (OSWR) approach with Ventcel-Robin transmission conditions. A discrete space-time interface system is formulated for each method and is solved iteratively with possibly variable time step sizes. The convergence of the OSWR-based method with conforming time grids is also proved. Finally, numerical results in two dimensions are presented to verify the optimal order of convergence of the monolithic solver and to illustrate the performance of the two decoupled schemes with local time-stepping on problems of high Peclet numbers.

CT1-A-3: Low regularity integrators for the conservative Allen-Cahn equation with maximum bound principle

Cao Kha Doan, Auburn University

Abstract: In contrast to the classical Allen-Cahn equation, the conservative Allen-Cahn equation with a nonlocal Lagrange multiplier not only satisfies the maximum bound principle (MBP) and energy dissipation law but also ensures mass conservation. Many existing schemes often fail to preserve all these properties at the discrete level or require high regularity in time on the exact solution for the convergence analysis. In this work, we construct a new class of low regularity integrators (LRIs) for the time discretization of the conservative Allen-Cahn equation by repeatedly using Duhamel's formula. The proposed first- and second-order LRI schemes are shown to conserve mass unconditionally and satisfy the MBP under some time step size constraints. Temporal error estimates for these schemes are derived under a low regularity requirement that the exact solution is Lipschitz continuous in time, followed by a rigorous proof for energy stability of the corresponding time-discrete solutions. Various numerical experiments in both two and three dimensions are presented to verify the theoretical results and illustrate the outperformance of the LRI schemes compared to the exponential time differencing schemes, especially when the interfacial parameter approaches zero.

CT1-A-4: Learning Temporal Evolution of Parametrized PDEs with Convolutional Neural Networks

Yumeng Wang, Missouri University of Science and Technology

Abstract: The traditional mathematical strate-

gies pose two primary challenges in solving parameterized high-dimensional PDEs, particularly those involving nonlocal fractional terms: substantial computational cost for high dimension and repeated computation according to parameters changes. To tackle these problems, we propose a convolutional neural network to compress high-dimensional data and perform time evolution. This framework can not only save huge computational cost in high dimensions, but also predict solutions recurrently with unseen parameters. The numerical experiments are exhibited by 1D and 2D parametric PDEs. Our results show that the proposed method can achieve computational efficiency with high accuracy.

CT2-A-1: The Exponential Stabilization of a Heat and Piezoelectric Beam Interaction with Static and Dynamic Feedback Controllers

Sk Md Ibrahim Khalilullah, Western Kentucky University

Abstract: The PDE model of a magnetizable piezoelectric beam, describing the longitudinal vibrations and the total charge accumulation at the electrodes of the beam, is coupled to the heat equation in the transmission line setting. Electromagnetic and mechanical waves on the piezoelectric beam are able to interact strongly despite a huge difference in wave velocities. With the thermal effects only, the coupled system is not exponentially stable. Therefore, two boundary state feedback controllers are designed. (i) For the first case, the electrical (voltage) controller is chosen for which the feedback controller is static. (ii) For the second case, the electrical (charge or current) controller is chosen for which the feedback controller is naturally a dynamic feedback controller. The PDE model for each case is shown to have exponentially stable solutions by cleverly constructed Lyapunov functions. Our methodology provides a solid foundation for the corresponding model reductions. The ongoing research problems and several open problems will be discussed.

CT2-A-2: Applying LES-C Turbulence Models for Turbulent Fluid-Fluid Interaction Problems

Kyle James Schwiebert, Michigan Technological University

Abstract: The large eddy simulation (LES) models for incompressible flow have found wide application in computational fluid dynamics (CFD), including areas relevant to aeronautics such as computing drag and lift coefficients and fluid-structure interaction problems. LES models have also found application in climate science through modeling fluid-fluid (atmosphere-ocean) problems. Large eddy simulation with correction (LES-C) turbulence models, introduced in 2020, are a new class of turbulence models which rely on defect correction to build a high-accuracy turbulence model on top of any existing LES model. LES-C models have two additional benefits worth serious consideration. First, LES-C models are easy to run in parallel: One processor can compute the defect (LES) solution, while the other processor computes the LES-C solution. Thus, if one has access to a machine with more than one computational core (essentially ubiquitous in modern architectures), the improved solution comes at nearly no cost in terms of the "wall time" it takes a simulation to complete. Second, LES-C models readily lend themselves to coupling with other defect correction approaches including the several options in numerical ordinary differential equations.

We will build upon a prior result in which the LES model Navier-Stokes omega was adapted to fluid-fluid interaction problems, representing the first unconditionally stable and optimal order turbulence model for such problems. It will be shown that expanding this model into its corresponding LES-C model produces a yet more accurate solution, improving accuracy in time as well as in the LES model parameter. The numerical results are backed by a full numerical analysis, showing that, like its LES-C counterpart, Navier-Stokes omega with correction is unconditionally stable and of optimal order accu-

racy.

CT2-A-3:

Md Asfar Ali, Kansas Wesleyan University

Abstract: Background
As COVID-19 vaccination coverage increases, public health and industries are contemplating re-opening measures of public spaces, including theme parks. To re-open, theme parks must provide public health mitigation plans. Questions on the implementation of public health mitigation strategies such as park cleaning, COVID-19 testing, and enforcement of social distancing and the wearing of personal protective equipment (PPE) in the park remain.
Methods
We have developed a mathematical model of infectious disease transmission in public spaces, including theme parks that considers direct human-human and indirect environment-human transmission of the virus. The model thus tracks the changing infection/disease landscape of all visitors, workers, and environmental reservoirs in a theme park setting. We have tested the model for four viruses, such as Covid-19, Norovirus, Measles, and Influenza.
Findings
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 virus transmission in the park. Thus, cleaning rates and mitigation of human-environment contact increase in importance. Comparisons on the results of four viruses are made.
Conclusion
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 public spaces, including theme parks in developing public health mitigation strategies for a safe re-opening.

CT3-A-1: Semi Discrete Models of Radiation Therapy

Abigail D'Ovidio Long, University of Nebraska-Lincoln

Abstract: During radiation therapy, cancer growth is well modeled by the logistic equation for times off of treatment. However, due to the instantaneous nature of radiation, continuous time representations do not suit times in treatment. We thus employ a semi discrete, impulsive treatment model and establish fixed points and periodic solutions. We then discuss stability and attractivity of each of the solutions, along with applications and other dynamics which will be incorporated in the future.

CT3-A-2: On the kinetic description of the objective molecular dynamics

Kunlun Qi, University of Minnesota-Twin Cities

Abstract: We develop a multiscale hierarchy framework for objective molecular dynamics (OMD), a reduced order molecular dynamics with a certain symmetry, that connects it to the statistical kinetic equation, and the macroscopic hydrodynamic model. In the mesoscopic regime, we exploit two interaction scalings that lead, respectively, to either a mean-field type or to a Boltzmann-type equation. It turns out that, under the special symmetry of OMD, the mean-field scaling results in vastly simplified dynamics that extinguish the underlying molecular interaction rule, whereas the Boltzmann scaling yields a meaningful reduced model called the homo-energetic Boltzmann equation. At the macroscopic level, we derive the corresponding Euler and Navier-Stokes systems by conducting a detailed asymptotic analysis. The symmetry again significantly reduces the complexity of the resulting hydrodynamic systems. This talk is based on the joint work with Richard D. James and Li Wang.

CT3-A-3: Swarm-Based Gradient Method for Non-Convex Optimization

Jingcheng Lu, University of Minnesota

Abstract: We introduce a new swarm-based gradient descent (SBGD) method for non-convex optimization. When solving global optimization problems, the classical gradient-based optimization algorithms often suffer from getting trapped at local minima due to the limited local information. To enhance the perception of global landscape, the SBGD dynamics employs a swarm of agents to explore the domain, each is identified with a position, x, and a mass, m. The key to the algorithm is communication: masses are being transferred from agents at high ground to low(-est) ground. At the same time, agents change positions with step size, h=h(x,m), which is dependent their relative mass: heavier agents proceed with small time-steps in the direction of local gradient, while lighter agents take larger time-steps based on a backtracking protocol.

The interplay between positions and masses lead to dynamical distinction between 'heavier' leaders, expected to approach local minima, and 'lighter' explorers. With large-step protocol, light explorers are expected to encounter improved minimizing region away from their current positions; if they do, then they take over the role of 'heavy' swarm leaders. Convergence analysis and numerical simulations in one- and multi-dimensional benchmarks demonstrate the effectiveness of SBGD as a global optimizer.

CT3-A-4: Piecewise Smooth Solutions to Scalar Balance Laws with Singular Source Terms

Evangelia Ftaka, North Carolina State University

Abstract: We will present a local well-posed result for piecewise regular solutions with a single shock of scalar balance laws, with singular integral of convolution type kernels. In a neighborhood of the shock curve, a description of the solution is provided for a general class of initial data.

CT4-A-1: Boundary Output Feedback Stabilization for a Magnetizable Piezoelectric Beam Model with non-collocated Controllers and Observers

Uthman Rasaq Adeniran, Western Kentucky University

Abstract: In this talk, a magnetizable piezoelectric beam model free at both ends is considered. The PDE model describes the longitudinal vibrations and the total charge accumulated at the electrodes of the beam. The same model with two collocated state feedback controllers in one end of the beam is known to have exponentially stable solutions. However, the collocation of controllers is not always feasible since not only this badly affects the performance of the overall closed-loop system but also small increments of feedback controller gains can easily make the system unstable. Therefore, a non-collocated controller and observer design is considered for the PDE model. In particular, two state feedback controllers are designed at the right end to recover the states so that the boundary output feedback controllers can be designed as a replacement of the states with the estimate from the observers on the left end. By a carefully constructed Lyapunov function, it is proved that the both the observer and the observer error dynamics have the uniformly exponential stable solutions. This framework offers a good foundation for the model reductions of the PDE model by Finite Differences. The ongoing research and open problems will be discussed.

CT4-A-2: An Agent-Based modeling approach to Investigate Pandemic Preparedness of Nursing Homes

Kiel Daniel Corkran, University of Missouri-Kansas City

Abstract: The pandemic preparedness of nursing homes has been a major concern for decades. The COVID-19 pandemic proved that the concerns were valid, as it caused devasting death tolls in nursing home facilities. This study presents an agent-based modeling framework to better understand the dynamics of pandemics within and between nursing homes. This is sharply distinct from many agent-based modeling works that resemble the spread of the infection within a single nursing home. We first calibrate the model of multiple nursing homes using the available COVID-19 data. Then we in-

vestigate the effects of shared staff on the efficacy of Covid-19 preventive policies through extensive simulations. It is shown that shared staffing can significantly diminish the efficacy of preventive policies. In conclusion, the nursing workforce is a determining factor for pandemic preparedness.

CT4-A-3: Mathematical analysis of singularities in the diffusion model under the submanifold assumption

Yubin Lu, Illinois Institute of Technology

Abstract: This talk presents several mathematical analyses of the diffusion model in machine learning. The drift term of the backwards sampling process is represented as a conditional expectation involving the data distribution and the forward diffusion. The training process aims to find such a drift function by minimizing the mean-squared residue related to the conditional expectation. Using small-time approximations of the Green's function of the forward diffusion, we show that the analytical mean drift function in DDPM and the score function in SGM asymptotically blow up in the final stages of the sampling process for singular data distributions such as those concentrated on lower-dimensional manifolds, and is therefore difficult to approximate by a network. To overcome this difficulty, we derive a new target function and associated loss, which remains bounded even for singular data distributions. We illustrate the theoretical findings with several numerical examples.

CT4-A-4: 3D Generative Adversarial Network to Achieve Realistic Synthesis of Pancreatic Cancer CT Image Data

Yu Shi, University of Nebraska-Lincoln

Abstract: Pancreatic ductal adenocarcinoma (PDAC) presents a critical global health challenge, and early detection is crucial for improving the 5-year survival rate. Recent advances in medical imaging and computational algorithms offer potential solutions for early diagnosis. Deep learning, particularly in the form of convolutional neural networks (CNNs), has demonstrated success in medical image analysis tasks, including classification and segmentation. However, the limited availability of clinical data for training purposes continues to provide a significant obstacle. Data augmentation, generative adversarial networks (GANs), and cross-validation are potential techniques to address this limitation and improve model performance. In this study, we developed a GAN-based tool for generating realistic 3D CT images of PDAC tumors and pancreatic tissue, which can generate the interslice connection data that the existing 2D CT image synthesis models lack. The transition to 3D models has allowed the preservation of contextual information from adjacent slices, improving efficiency. PDAC's challenging characteristics, such as iso-attenuating or hypodense appearance and lack of well-defined margins, make tumor shape and texture learning challenging. To overcome these challenges and make this 3D GAN model have a better performance, 3D UNet was implemented for the Generator. Thorough examination and validation across many datasets were conducted on the developed 3D GAN model to ascertain the efficacy and applicability of the model in clinical contexts. Ultimately, this approach represents a promising avenue to address the pressing need for innovative and synergistic approaches to combat PDAC. The development of this GAN-based model holds the potential for improving the accuracy and early detection of PDAC tumors, which could have a profound impact on patient outcomes. Furthermore, this model has the potential to be adapted to other types of solid tumors, hence making significant contributions to the field of medical imaging in terms of image processing models.